Credit Valley Conservation

Terrestrial Ecosystem Enhancement Model

Towards a Natural Heritage System for the Credit River Watershed

Phases 1 & 2: Watershed characterization and Landscape Scale Analysis

Final Technical Report, February 2011

CVC
CREDIT VALLEY CONSERVATION

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Executive Summary

Conservation authorities (CAs) derive their authority from the *Conservation Authorities Act* (CAA) and regulate development and interference with wetlands, shorelines and watercourses pursuant to Section 28 of the Act. Section 20 of the CAA outlines the object of a CA to "*establish and undertake, in the area over which it has jurisdiction, a program designed to further the conservation, restoration, development and management of natural resources other than gas, oil, coal and minerals."* Through service agreements, many CAs also provide planning and technical advice to municipal planning authorities to assist them in fulfilling their responsibilities regarding hazardous land and natural heritage management pursuant to the *Planning Act*. In this regard, the Ontario government in its updated *Provincial Policy Statement* (OMMAH 2005a) and the *Natural Heritage Reference Manual* (OMNR 2010) recognizes the importance of a natural heritage systems approach to the protection of water and natural resources using the watershed as the meaningful scale for planning. A number of municipalities within CVC boundaries have also completed or are in the process of completing Official Plan updates relating to natural heritage.

Credit Valley Conservation (CVC) is building upon its considerable natural heritage expertise and data to identify a science based, integrated, Natural Heritage System for the Credit River Watershed. The primary goals for the Natural Heritage System are: to protect, restore, or enhance the ecological integrity of the Credit River Watershed's natural features, functions and systems; and to protect or enhance the quantity and quality of surface and ground water for environmental and human uses. A watershed is recognized by the province of Ontario as the "*ecologically meaningful scale for planning"* to protect, improve, or restore the quality and quantify of water; hence the CVC focus on the watershed as the scale for Natural Heritage System planning.

A The Natural Heritage System can be used as a watershed planning tool and for watershed securement, stewardship and restoration programs. The System can also be used to identify natural heritage data gaps and to guide species or community inventories. The system can also be used by municipal planning authorities to review existing natural heritage systems policies and strategies at the municipal scale to enhance the protection of natural heritage features and functions within their area of jurisdiction over the long term.

The Terrestrial Ecosystem Enhancement Model (TEEM) program was launched in 2006 to develop a Natural Heritage System for the Credit River Watershed. The term 'Credit River Watershed' is used in this document as a convenient term to refer to the entire CVC jurisdiction which encompasses the watershed of the Credit River and also the watersheds of several smaller creeks that flow directly into Lake Ontario. The project Phases are as follows:

Phase 1: Characterize and assess existing conditions for the watershed in GIS, based on existing terrestrial and hydrologic data;

Phase 2: Plan integration of water and terrestrial functions within model, gathering data as needed; consult with stakeholders

Phase 3: Develop integrated model of terrestrial and aquatic functioning on watershed lands and develop approach to identifying a watershed Natural Heritage System; consult with stakeholders;
Phase 4: Develop a Natural Heritage System, identifying lands for stewardship, protection or restoration following assessments of impacts of increased development or other land uses and climate change, using pre-settlement vegetation and potential vegetation models for Credit River Watershed for guidance as needed. Identify key natural areas providing connectivity across watershed boundaries. Develop model recommended policies following stakeholder consultation. Engage municipal planning authorities to emphasize the effectiveness of existing natural heritage related policies and provide information in updating existing natural heritage system protection strategies within the context of watershed health.

This technical report documents Phases 1 and 2 of TEEM. Existing conditions were characterized and assessed in a Landscape Scale Analysis (LSA) as follows:

- Background information on the Credit River Watershed's existing biophysical condition, key natural heritage features, and natural and semi-natural areas is provided. Information on ecosystem functions provided by natural and semi-natural areas is provided along with the connection between ecosystem functions and ecosystem services critical for human survival. These data on land cover and land use and the size and configuration of natural areas in the watershed inform the Landscape Scale Analysis that assesses the importance of specific natural features and functions.
- A Landscape Scale Analysis using GIS (Geographic Information System) mapping was the tool used to assess the functional contribution of natural and cultural (or semi-natural) features within the watershed.
- Natural and semi-natural features of the Credit watershed were assessed using the Landscape Scale Analysis in terms of their relative importance in contributing to ecosystem functions using a science based, systems approach. Natural and semi-natural features were clustered into habitat patches, which were defined as any contiguous natural or semi-natural area separated from another natural or semi-natural area by a road or by another land use type. The habitat patch was selected as the unit of analysis because most species use multiple community types – such as forests, wetlands, or successional communities - for nesting, feeding, reproduction, and movement. Communities that are connected within the same habitat patch permit species to complete their life cycles more easily relative to communities that are separated by gaps such as roads, urbanized areas, or agriculture.
- Landscape Scale Analysis methodology was as follows:
    - Habitat patches were scored with respect to their relative importance in contributing to ecosystem function within the watershed. Features fulfilling nine key criteria contributing to ecological functioning of the Credit River Watershed were identified. These features included **woodlands**, **wetlands**, **successional habitats** such as meadows, and **valleylands or riparian areas**; habitat patches containing **high habitat diversity** or **uncommon vegetation communities** at watershed scale; and

habitat patches contributing to **ecological proximity**, **regional linkages**, or **provincial linkages**.
    - Habitat patches were given a score of zero or one, based on whether they satisfied the above criteria and thresholds. Thresholds for the criteria were based on well established scientific principles, federal or provincial guidelines, best practices, professional judgment of technical committee or external peer reviewers, and CVC data. Habitat patches were defined as high functioning if they received a score of one for any criterion.
    - Scores for individual habitat patches were then added across criteria. Habitat patches received scores ranging from 0 (relatively small contribution to watershed ecosystem functioning) to 9 (extremely high contribution to watershed functioning).
- Habitat patches that scored 7, 8 or 9 based on the assessment criteria were termed 'Core ecofunction habitats' of the Credit watershed because they were of very high importance in terms of ecosystem function within the watershed; habitats receiving scores of 4, 5, or 6 were termed 'Highly Supporting ecofunction habitats'; those scoring 1, 2, or 3 were termed 'Supporting ecofunction habitats', and those receiving a score of 0 were termed 'Contributing ecofunction habitats'.
- Aquatic features contributing strongly to ecosystem function at the watershed scale were also identified. These included permanent and intermittent streams, lakes, and online ponds.

The Landscape Scale Analysis represents the first step in developing a Natural Heritage System for the Credit River Watershed by first identifying existing natural and semi-natural features on the landscape, and next by analyzing their relative importance for ecosystem function and the provision of ecosystem services such as clean air, climate regulation, a pure and abundant supply of water, and flood control.

Future work will focus on developing a Natural Heritage System for the Credit River Watershed that will improve the healthy functioning of the watershed's ecosystems particularly through improving functional linkages among natural areas. The Natural Heritage System will identify opportunities for stewardship, restoration, protection, or securement that will maintain, restore, and enhance biodiversity and ecosystem function in the Credit River Watershed.

The Credit River Watershed Natural Heritage System will include lands that are in a natural or semi-natural state as well as areas under compatible uses or "*lands with the potential to be restored to a natural state"*, as defined by the *Provincial Policy Statement*, and aquatic features. Areas under compatible uses include agricultural lands, and areas with potential to be restored to a natural state could include successional lands such as cultural meadows to create tableland linkages. The Natural Heritage System is not intended to limit existing uses on lands within the system, and recommended model policies will reflect this intention.

The development of the Credit River Watershed Natural Heritage System does not limit the ability of planning authorities within CVC jurisdiction to consider other systems based approaches but provides an alternative based on maintaining water quality and quantity and healthy ecological functioning of the Credit River Watershed. In this regard, CVC continues to be committed to further working with planning authorities to develop 'municipal level' natural heritage system models that best fit their needs.

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1. Credit Valley Conservation's Terrestrial Ecosystem Enhancement Model (TEEM)

With the development of the Natural Heritage Project in 1995, Credit Valley Conservation Authority (CVC) recognized the need to build on existing Natural Heritage Systems to further recognize the importance of linkages between terrestrial and hydrologic resources within the watershed context. A watershed is defined as a region draining into a river, river system, or body of water. Water quality and quantity in a watershed are strongly dependent upon the amount and quality of terrestrial cover in the watershed. Terrestrial natural cover and biodiversity in a watershed are strongly dependent on available water resources. Recognizing the importance of these linkages and the need to protect, restore and enhance them, the CVC Board of Directors approved the Terms of Reference for developing a watershed scale Natural Heritage System on 10 February 2006. The goal of TEEM is to establish a Natural Heritage System for the Credit River Watershed that will protect biodiversity and ecosystem functions of the watershed in perpetuity (CVC 2006b). Within the context of this study, the term 'watershed' shall be used for convenience to indicate the area of jurisdiction of Credit Valley Conservation and includes the area drained by creeks that flow directly into Lake Ontario, as well as the Lake Ontario Shoreline and the area extending 6km into Lake Ontario.

As defined under the *Provincial Policy Statement* (PPS), a Natural Heritage System means *"a system made up of natural heritage features and areas, linked by natural corridors which are necessary to maintain biological and geological diversity, natural functions, viable populations of indigenous species and ecosystems. These systems can include lands that have been restored and areas with the potential to be restored to a natural state"* (OMMAH 2005a). Lands *"with the potential to be restored to a natural state"* means lands that currently do not hold natural or cultural cover but have the capacity to be restored or rehabilitated to a natural state. These may include agricultural lands as well as semi-natural or cultural lands such as cultural meadows, cultural thickets and cultural savannahs. Agricultural lands within a Natural Heritage System that have no or limited natural cover can still perform natural functions such as infiltration, groundwater recharge, and habitat for species movement, feeding, or migration.

In heavily human-modified environments such as the Credit River Watershed, remaining natural features are often not large enough or diverse enough, or lack sufficient connectivity to meet the daily, seasonal and long term life cycle requirements of species. When species survival is compromised, ecosystems lose the ability to function well. Land use change from rural to urban and the impacts of climate change result in significant impacts to natural areas and increased human dependence on dwindling natural features and functions. A Natural Heritage System that improves the functioning of natural features through improvements to their size, connectivity, and hydrological functioning will help mitigate to some extent the impacts of land uses and climate change within the watershed. A watershed approach can help ensure that the hydrologic functioning of the system is maintained, restored or enhanced.

The Natural Heritage System for the Credit River Watershed is not intended to prevent existing uses from continuing, and recommended model policies for the system will reflect this intention. The goal of TEEM is to identify a system which has a greater likelihood of sustaining and improving biodiversity and ecosystem function for the watershed over the long term through a combination of stewardship, restoration, securement and policy.

1.1 Planning and policy context for TEEM

The purpose of TEEM is to develop a Natural Heritage System for the Credit River Watershed that will result in a high probability that biodiversity and ecosystem function will be maintained or enhanced over the long term. The PPS states that '*the diversity and connectivity of natural features in an area, and the long-term ecological function and biodiversity of natural heritage systems, should be maintained, restored or, where possible, improved, recognizing linkages between and among natural heritage features and areas, surface water features and ground water features*'(Section 2.1.2, OMMAH 2005a). In this regard, the Natural Heritage System for the Credit River Watershed will be a system composed of cores linked by corridors to maintain or enhance biodiversity, ecological functions, and viable populations of indigenous species and ecosystems over the short and long term.

Section 2.2.1 of the PPS refers to the responsibility of planning authorities to protect, improve or restore the quality and quantity of water by:

a) using the watershed as the ecologically meaningful scale for planning;
b) minimizing potential negative impacts, including cross-jurisdictional and cross-watershed impacts;
c) identifying surface water features, ground water features, hydrologic functions and natural heritage features and areas which are necessary for the ecological and hydrological integrity of the watershed; … and
e) maintaining linkages and related functions among surface water features, groundwater features, hydrologic functions and natural heritage features and areas.

The TEEM program will be used to support CVC watershed management programs such as the Greenlands Securement Strategy, the Credit River Fisheries Management Plan, the Credit River Water Management Strategy, the Lake Ontario Integrated Shoreline Study, the Natural Areas Inventory (NAI), and current and future programs, including subwatershed studies. In addition, the program will help inform restoration and stewardship, plan review and plan input, and monitoring activities within CVC. The program may also be used by planning authorities and other agencies to emphasize the effectiveness of existing natural heritage related policies and provide information in updating existing natural heritage system protection strategies within the context of watershed health. The Credit River Watershed Natural Heritage System may be considered by planning authorities as one approach to further implement systems based planning objectives at a watershed scale. For example, Halton Region has updated its Official Plan and developed a Natural Heritage System for the Region. The Region of Peel has updated its Greenlands system through an Official Plan update. The development of the Credit River Watershed Natural Heritage System does not limit the ability of planning authorities within CVC jurisdiction to consider other systems based approaches but provides an alternative based on ecological considerations within the Credit River Watershed context. In this regard, CVC continues to be committed to further working with planning authorities to develop 'municipal level' natural heritage system models that best fit their needs.

1.2 Project phases and timelines

The project is divided into four phases (see Terms of Reference CVC 2006a):

Phase 1

Review literature and relevant natural heritage models; establish Technical and Municipal Advisory Committees; provide background information related to the watershed; characterize existing conditions in the watershed and assess existing natural and semi-natural features in the watershed with regards to their relative importance in sustaining ecosystem function.

Phase 2

Identify data gaps; plan integration of water and land functions within model; complete analysis of natural and semi-natural features and functions within watershed; communicate analysis of existing features and functions to stakeholders and invite stakeholder input.

Phase 3

Develop integrated model of terrestrial and aquatic functioning on watershed lands; finalize variables in model; consult with stakeholders on approach to developing the watershed Natural Heritage System. Proposed timeline: Summer 2010.

Phase 4

Develop a Natural Heritage System for the Credit River Watershed, identifying lands for stewardship or restoration and ensuring accordance with existing provincial, municipal and watershed policies, strategies, and guidelines; use pre-settlement vegetation and potential vegetation models for Credit River Watershed as guidance for restoration or rehabilitation. Consider climate change adaptation; assess impacts of increased development and other land uses, and climate change. Identify key natural areas providing connectivity across watershed boundaries. Consult with stakeholders and the public on the Natural Heritage System methodology through stakeholder workshops. Proposed timeline: Summer 2010-Summer 2011.

Develop recommended model policies and strategies for the Credit River Watershed Natural Heritage System. Hold stakeholder workshops on recommended model policies and strategies and provide opportunities for public input on model policies and strategies. Proposed timeline: Spring-Summer 2012.

Ongoing following phase 4
Engage municipalities in discussions to best determine how a healthy watershed can be maintained (for example through policy review and/or strategy development) under municipal mandates for ensuring sustainable social, economic, and environmental systems. Monitor and refine the Natural Heritage System at appropriate time intervals, and update as required to integrate with provincial policies, Official Plans, and new science.

Documentation of the biophysical conditions of the watershed and an assessment of its natural features with respect to their ability to support biodiversity and contribute to watershed function is an essential prerequisite to developing a Credit River Watershed Natural Heritage System. This document reports on Phases 1 and 2 of TEEM development, namely, background information on the watershed and an assessment of existing features and functions in the watershed. Phases 1 and 2 were combined because much of the hydrologic integration was initiated during Phase 1 of the project.

Table 1 lists the key deliverables from the TEEM project.

Table 1: Key deliverables of the Terrestrial Ecosystem Enhancement Model (TEEM).

No.	Deliverable	Estimated timeline
1.	**Background information** on natural heritage features and biophysical characteristics of the Credit River Watershed; **assessment of existing natural and semi-natural features through a Landscape Scale Analysis** to determine their relative importance in contributing to ecosystem function based on a systems approach and established scientific principles. Deliverables include: A final report documenting and analyzing existing conditions and related GIS shapefiles.	**2008-2010**
2.	Development of a Credit River Watershed **Natural Heritage System methodology** that builds upon the systems approach to provide a criterion-based system for improving biodiversity and ecosystem function in the Credit River Watershed. Development of a **Natural Heritage Strategy** that encompasses the Natural Heritage System for the Credit River Watershed and recommended strategies related to restoration, stewardship, and securement. Deliverables include: recommended criteria for identifying a watershed scale Natural Heritage System; a draft report identifying the Credit River Watershed Natural Heritage System and mapping for consultation; a final report and mapping following consultation; recommended model policies and strategies related to the watershed's Natural Heritage System; maps and shapefiles showing system and component attributes for the use of municipalities.	**2010-2012**

2. Systems approach to natural heritage planning in Ontario

Environmental planning in Ontario in the 1970s included the identification of landscape features of high biodiversity or species habitat value, hydrological value, or aesthetic or distinctive landform characteristics. These features were identified as Environmentally Significant (or Sensitive) Areas (ESAs). Provincially significant features identified under similar criteria, including contribution to ecosystem function, were identified by the Ontario Ministry of Natural Resources as Life Science Areas of Natural and Scientific Interest (ANSIs). These natural heritage features and areas lacked overall connectivity, although the position of some of these features and areas within valleyland systems permitted some flow of genes and species among them. Recognition of the importance of these features and functions is reflected within municipal Official Plans and policies.

As the science of landscape ecology and conservation biology progressed, studies showed that landscape level planning is necessary to maintain biodiversity and ecosystem functions over the long term, because the spatial configuration of natural features can have important effects on biodiversity and the health of ecosystems (Forman and Godron 1986, Forman 1995, Hargis et al. 1998, Leitao and Ahern 2002, McGarigal and Marks 1995, McGarigal and McComb 1995, Riitters et al. 1995). For example, it is now understood that the health of a wetland is maintained not by protecting just the wetland area, but through protection of the wetland's hydrology as well.

This systems approach, recognizing that the health of individual natural heritage features depends upon their placement within a functioning system, gained rapid acceptance. In 1991, OMNR released a framework for protection of natural heritage (OMNR 1991), outlining key principles for natural heritage protection that emphasized the protection of natural heritage systems. In 1996 (OMMAH 1996, amended in 1997), the *Provincial Policy Statement* was released to provide direction on matters of provincial interest related to land use planning and development. This document contained natural heritage policies that provided protection for key natural heritage features while stressing that the functions of natural features be maintained and that natural connections between features should be "…*maintained and improved where possible*." The 1999 *Natural Heritage Reference Manual* (OMNR 1999) and updated in 2010 (OMNR 2010), intended for use in policy development, provided guidance on developing natural heritage systems, while reinforcing the importance of a systems approach in protection of individual features: "*A natural heritage system approach is a useful method for the protection of specific natural heritage features and areas because it reinforces an understanding that individual areas and features have strong ecological ties to other physical features and areas in the overall landscape*"**.**

While the 2005 PPS requires the protection of significant natural features and areas, it also emphasizes the importance of recognizing linkages between and among natural features to maintain, restore or, where possible improve diversity, connectivity, long term ecological function and biodiversity of the natural heritage system.

The policy direction provided by the provincial government has resulted in the development of several natural heritage systems in Ontario that utilize a systems approach, based on sound, scientifically defensible landscape ecology and conservation biology principles – examples are the *Niagara Escarpment Plan* (NEC 2010), *Oak Ridges Moraine Conservation Plan* (OMMAH 2002), Middlesex Natural Heritage Study (UTCA 2003), *Greenbelt Plan* (OMMAH 2005b), Seaton Lands/Duffins-Rouge Agricultural Preserve Natural Heritage System, City of Pickering (OMNR 2005b), Oxford County Natural Heritage Study (UTRCA and County of Oxford 2006), Toronto and Region Terrestrial Natural Heritage System Strategy (TRCA 2007), and the Lake Simcoe Region Natural Heritage System (Beacon Environmental and LSRCA 2007). These Natural Heritage Systems frequently identify cores and corridors, where cores represent large tracts of forests, wetlands, and semi-natural or rural areas, and linkages or corridors represent smaller natural, semi-natural, or rural areas that knit the cores into a larger, functioning system (OMNR 2004).

3. Rationale for developing a Natural Heritage System for the Credit River Watershed

3.1 Planning and policy context for watershed scale planning and systems approaches

Like all other CAs, CVC derives its authority from the Conservation Authorities Act and regulates development and interference with wetlands, shorelines and watercourses pursuant to Section 28 of the Act. Credit Valley Conservation also provides planning and technical advice to planning authorities to assist them in fulfilling their responsibilities regarding hazardous land, natural heritage and water management pursuant to the Planning Act. The following is a brief review of CVC's mandate, roles and responsibilities.

3.1.1 Conservation Authorities Act

The *Conservation Authorities Act* is the enabling legislation that provides the legal basis for the creation of Conservation Authorities (CAs) in Ontario. Generally, the Conservation Authorities Act directs CAs to perform a number of functions regarding watershed planning and management including the prevention, elimination, or reduction of loss of life and property from flooding and erosion, as well as the protection and restoration of natural resources. Section 20 of the Conservation Authorities Act outlines the objects of the CAs which is to *"establish and undertake, in the area over which it has jurisdiction, a program designed to further the conservation, restoration, development and management of natural resources other than gas, oil, coal and minerals."*

For the purpose of accomplishing this object, Section 21 of the Conservation Authorities Act establishes the powers of a CA. A few key powers most applicable to watershed planning include:

- *To study and investigate the watershed and to determine a program whereby the natural resources of the watershed may be conserved, restored, developed and managed;*
- *To collaborate and enter into agreements with ministries and agencies of government, municipal councils and local boards and other organizations;*
- *To cause research to be done; and*
- *Generally to do all such acts as are necessary for the due carrying out of any project.*

Whereas Sections 20 and 21 govern the objects and powers of Conservation Authorities, Section 28 of the *Conservation Authorities Act* empowers CAs to make regulations in the area under its jurisdiction. In 2006, Conservation Authorities updated their regulations through provincial approval of the Development, Interference and Alteration Regulations for all Conservation Authorities. Through these updated regulations CAs are to regulate interference with wetlands and watercourses as well as development in or adjacent to natural heritage features such as river or stream valleys, Great Lakes and large inlandlakes shorelines, watercourses, hazardous lands and wetlands. In support of managing natural heritage systems on a watershed wide basis, the regulatory responsibilities of CAs help in managing risks to public health and safety including the protection of the natural hydrologic cycle and ecological functions associated with flooding, erosion, dynamic beaches, pollution and the conservation of land.

3.1.2 Planning Act

The *Planning Act* is the primary piece of legislation governing land use planning activities in Ontario, and outlines the means by which planning authorities make land use planning decisions. Section 3 of the *Planning Act* enables the Province to develop and implement detailed policies (e.g., *Provincial Policy Statement*) for those matters considered to be of provincial interest. Municipalities are the land use approval authority or planning authority, and are responsible for ensuring the long term protection of regional or local Natural Heritage Systems. Under the Planning Act, CAs provide input and technical advice from several viewpoints including as a planning and technical advisor (e.g., service agreements), a watershed based management agency, a regulatory body and a proponent or landowner.

3.1.3 Provincial Policy Statement

Section 3 of the *Planning Act* enables the Province to issue policy statements on matters related to municipal planning that are of provincial interest. Decisions affecting planning matters 'shall be consistent with' these policy statements which are contained in the *Provincial Policy Statement* (PPS). Of particular relevance to CVC are Sections 2.1 (Natural Heritage), 2.2 (Water) and 3.1 (Natural Hazards) of the PPS. However, because of the linkages among policy areas, the policies contained in the sections referred to above are not read in isolation from other relevant policies in the PPS. Planning decisions are also required to be in conformity with provincial plans, including the Niagara Escarpment Plan (2005), Oak Ridges Moraine Conservation Plan (2002), Greenbelt Plan (2005) and the Growth Plan for the Greater Golden Horseshoe (2006). Any recommended model policies for the Credit River Watershed Natural Heritage System will take into account the policies related to these Plans.

The watershed is an integrated system of human and natural resources that needs to be managed in a holistic and balanced way to achieve a healthy and sustainable environment. In this regard, Section 2.1.2, states: *"The diversity and connectivity of natural features in an area, and the long-term ecological function and biodiversity of natural heritage systems, should be maintained, restored or, where possible, improved, recognizing linkages between and among natural heritage features and areas, surface water features and ground water features."*

Natural heritage protection is also mentioned in section 2.2 of the *PPS* on Water, particularly policies 2.2.1a, 2.2.1c and 2.2.1e:

"Planning authorities shall protect, improve or restore the quality and quantity of water by:a) using the watershed as the ecologically meaningful scale for planning;

c) *identifying surface water features, ground water features, hydrologic functions and natural heritage features and areas which are necessary for the ecological and hydrological integrity of the watershed;*

e) *maintaining linkages and related functions among surface water features, ground water features, hydrologic functions and natural heritage features and areas;"*

3.1.4 Greenbelt Plan

Within the Province of Ontario, the *Greenbelt Plan 2005* refers to a Natural Heritage System of core areas and connecting corridors (OMMAH 2005b). The Greenbelt Plan includes land within, and builds upon the Niagara Escarpment Plan and the Oak Ridges Moraine Conservation Plan, complimenting other provincial level initiatives such as the Parkway Belt West Plan and Rouge North Management Plan. The Credit watershed contains lands that fall within the *Niagara Escarpment Plan area*, *Oak Ridges Moraine Conservation Plan* area, Parkway Belt West Plan area and Protected Countryside area of the Greenbelt Plan.

3.1.5 Places to Grow Act

The *Places to Grow – Growth Plan for the Greater Golden Horseshoe* is implemented through the *Places to Grow Act 2005* (Government of Ontario). The *Plan* sets out the framework to provide guidance for planning authorities as it relates to growth planning within their communities. In this respect, the *Plan* provides guidance in four major areas which include where and how to grow, infrastructure to support growth, protecting what is valuable, and implementation and interpretation. *Places to Grow Act* guiding principles include the direction to *"protect, conserve, enhance and wisely use the valuable natural resources of land, air and water for current and future generations"*. *The Places to Grow - Growth Plan for the Greater Golden Horseshoe* (MPIR 2006) also states that "*Planning authorities are encouraged to identify natural heritage features and areas that complement, link or enhance natural systems*" and that "*a balanced approach to wise management of all resources, including natural heritage…will be implemented*".

Policies provided in the 'Protecting What is Valuable' section of the *Growth Plan* complement and enhance those of the *Provincial Policy Statement*. However, it is important to note that where there is a conflict between policies within Provincial planning documents relating to natural environment or human health, the direction that provides more protection to the natural environment or human health prevails. The policies also recognize *"the role of municipal policy in providing leadership and innovation in developing a culture of conservation"* related to water and energy conservation, air quality protection, and integrated waste management.

The *Growth Plan* also sets out specific targets related to population density and jobs for greenfields and built areas of municipalities within the Greater Golden Horseshoe. These growth scenarios create challenges for municipalities in establishing sustainable NaturalHeritage Systems but also provide opportunities for integrating municipal approaches with watershed scale planning for protection and management of watershed natural resources.

3.1.6 Ontario Biodiversity Strategy

A commitment to the conservation of biodiversity has been identified as a key focus for the Ontario Ministry of Natural Resources (OMNR). Ontario's *Biodiversity Strategy* (OMNR 2005a) notes that *"A broad vision of the landscape is needed to provide a context for biodiversity conservation. Biodiversity conservation must be built into all aspects of land use planning."*

The Ontario Biodiversity Strategy has identified the following goals to define its strategy: *"1) Protect the genetic, species, and ecosystem diversity of Ontario and 2) Use and develop the biological assets of Ontario sustainably, and capture benefits from such use for Ontarians."*

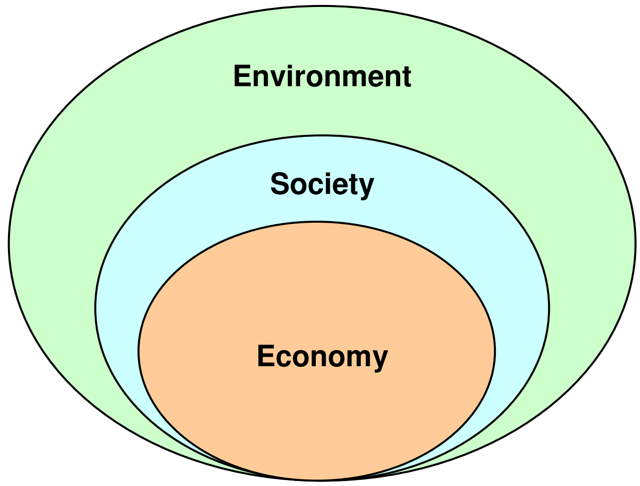
3.1.7 Other legislation relating to protection of natural resources

Other Acts additionally protect species, features, or functions that would form part of a natural heritage system. The *Federal Fisheries Act* protects all fish habitat, including that of threatened and endangered fish species. Fisheries and Oceans Canada (DFO) has signed agreements with the majority of the 36 Conservation Authorities in Ontario to review proposed projects under section 35 of the *Fisheries Act*, which deals with the management and protection of fish habitat. Lakes, rivers, streams, ponds, and many wetlands provide fish habitat, while intermittent streams and seasonally flooded areas may provide temporary habitat for some fish species. The Federal *Species at Risk Act (SARA;* Government of Canada) provides protection on federal lands for species that are Endangered or Threatened. The *Endangered Species Act* in Ontario provides protection for species that are Endangered or Threatened, and their habitat (Government of Ontario). These species are identified in the *Species at Risk in Ontario (SARO)* list. Ontario's *Clean Water Act* (Government of Ontario) relates to protection or regulation of lands within watersheds that provide drinking water.

3.2 The importance of watershed scale Natural Heritage Systems for human survival, health, and well-being

An ecosystem consists of a dynamic set of living organisms (plants, animals, and microorganisms) together with the non-living components of their environment, related ecological processes, and humans (OMNR 1999). Ecosystem functioning is a broad term that encompasses ecosystem properties and processes, ecosystem goods, and ecosystem services. Ecosystem processes involve the flows of energy and materials through ecosystems (Hooper et al. 2005). Examples of ecosystem properties and processes, also known as ecosystem functions, are biogeochemical cycling and storage, hydrologic flux and storage, nutrient and sediment cycling and transport, regulation of gases, water, and disturbances, and maintenance of biological diversity (Christensen et al. 1996). These ecosystem functions support life at all levels.

Ecosystem goods and services refer specifically to those components of the ecosystem that are recognized as being of direct or indirect benefit to human populations occupying ecosystems (Costanza et al. 1997, Daily 1997). Ecosystem goods have direct market value, such as food, fuel, construction materials, medicinal plants, wild genes for plant and animal breeding, models for engineering design, tourism and recreation (Christensen et al. 1996, Hooper et al 2005). Ecosystem services refer to ecosystem processes benefitting humans such as flood control, groundwater recharge, climate moderation, production of oxygen, generation and maintenance of biodiversity, pollination, seed dispersal, waste management, erosion and sedimentation control, natural pest control, decomposition, recreation, and aesthetic, spiritual, or scientific services (Table 2; Costanza et al. 1997, Daily 1997, Daily et al. 2000, de Groot et al. 2002, Hooper et al. 2005, Kareiva 1994).



A representation of 'strong' sustainability demonstrating the view that economy and society are constrained by environmental limits

It is now generally accepted that it would be highly unlikely that humans could replace all critical ecosystem goods and services by technological means, and that a minimum stock of natural capital is required for human social and economic well-being (Ott 2003).

Biodiversity has a positive effect on ecosystem functioning and on the provision of ecosystem goods and services (Hooper et al. 2005, Kareiva 1994, Duffy 2009, Haddad et al. 2009, Hargrave 2009, Srivastava and Bell 2009). Ecosystems are said to be "self-regulating" or "self-sustaining" because they contain feedback mechanisms that allow them to function in one or more stable states. Ecosystems have the capacity to exist in multiple equilibrium or stable states under conditions of moderate natural disturbances to which they have adapted (such as fires or flooding) but excessive disturbance can 'flip' a system from one state into another state (Holling 1973, Gunderson 1999, 2000). If a disturbance pushes a system beyond its capacity to adapt or self-regulate, it enters a chaotic state wherein its components are reorganized into a new equilibrium state. The flip from one state into another is at times precipitated by human activity, for example, massive tree dieback due to water stress (Breshears et al. 2007 in CCSP 2009), the conversion of woodlands into grasslands through grazing and fire and the eutrophication of lakes (Scheffer et al. 2001). Because of the complexity of ecosystems and their processes and our incomplete knowledge of howecosystems work, it is difficult to predict the characteristics or the functioning of new ecosystem states.

Ecological resilience is defined as the capacity of an ecosystem to absorb stress yet retain essentially the same structure and functions and avoid 'flipping' permanently to another state (Holling 1973, Gunderson 1999, 2000). In other words, it is the capacity of an ecosystem to continue functioning without moving to another ecosystem condition that does not function in the same way. Biodiversity provides for both stability (resistance) to and recovery (resilience) from disturbances that disrupt ecosystem functions and services (Christensen et al. 1996).

Planning for Natural Heritage Systems facilitates not only the long term maintenance of biological diversity and ecological functioning, but also the restoration and improvement of these through stewardship (OMNR 2010). Maintaining a self-sustaining, resilient and diverse Natural Heritage System is a precautionary approach that reduces risk to humans and is more cost-effective than addressing problems after development has occurred and ecosystem services are lost (OMNR 2010).

Ecosystem goods and services have been valued at $33 trillion globally (Costanza et al. 1997), although technological fixes for most ecosystem services do not exist, making pricing for these services moot. Technological replacements for the provision of clean, safe drinking water in one watershed (Catskill watershed, New York) were estimated at US$6-8 billion, leading municipalities to purchase the entire watershed to perform this ecosystem service for the considerably lower price of US$1-1.5 billion (Chichilnisky and Heal 1998). Agriculture and Agri-Food Canada has estimated that the value of honeybee pollination in Canada is more than $1-billion a year (Agriculture and Agri-Food Canada 2003). Research has shown that forest habitat within 1-2km of a farm can strongly stabilize and enhance pollination services, thus serving as insurance for farmers in the region (Kremen 2005). Demand for products from natural areas such as forests, wetlands, or lakes frequently exceed supply, resulting in unsustainable or illegal harvesting. Annual expenditure by Canadians on nature related activities has been estimated at $11 billion (Federal Provincial Task Force on the Importance of Nature to Canadians 1999).

Southern Ontario's terrestrial and hydrologic resources provide multiple ecosystem services. In Ontario, combined expenditures of Parks and visitors supported a gross total output of $705.4 million (Ontario Parks 2002 cited in Canadian Urban Institute 2006). The economic value of outdoor activities in Ontario was also estimated to be $807.1 million annually, that is, the value Ontarians place on recreation above and beyond the actual costs paid to engage in the activity (DuWors et al. 1999). In the Kawartha Highlands Signature Site near Peterborough, Ontario, spending by canoeists, anglers and hunters resulted in a value-added total of $1.5 million (Ontario Parks 2001 cited in Canadian Urban Institute 2006). Lands in permanent vegetative cover have been estimated to reduce the cost of filtering sediment in municipal drinking water by $5.60 per hectare per year, and phosphorus reduction costs by $23.30 per hectare per year (Olewiler 2004). A study of Ontario's Greenbelt shows that the value of ecosystemservices provided by the greenbelt surrounding the Greater Toronto Area (roughly 60% of the Credit River Watershed is covered by the Greenbelt) was $2.6 billion annually (Wilson 2008).

Over 750 000 people are estimated to live in the Credit River Watershed (based on 2001 census data; CVC 2007a). A study of the Credit River Watershed has shown that the watershed provides a minimum of $371 million in ecological services annually to area residents (Kennedy and Wilson 2009). The same study showed that the watershed's natural capital saves watershed taxpayers $100 million in water supply costs every year. A contingent valuation analysis of the Credit River Watershed's wetlands showed that households in the watershed were willing to pay a significant amount for the programs considered in the study, programs that included water quality improvement, flood, drought and erosion control, provision of wildlife habitat, and carbon storage (Lantz et al. 2010). When growth, pollution or other impacts compromise the valuable ecosystem services provided by the watershed, the lost value must ultimately be borne by taxpayers. Sound natural heritage planning helps reduce the costs of lost ecosystem services from development (OMNR 2010). The benefits of green space in the Credit River Watershed for recreation and well being are significant. A CVC study has shown that the total annual value of the Credit River fishery is estimated to be in the order of $1.2 million, which converts to a cumulative net present value of around $48 million (DSS Management Consultants Inc. 2008). Another study has shown that natural features increase property values in south Mississauga by a total of $127,636,079 and in north Mississauga by a total of $127,810,876 (DSS Management Consultants Inc. 2009).

Because ecosystems and the flows of water tend to transcend municipal boundaries, it is important to use or to consider the watershed scale as the unit of planning in designing a Natural Heritage System. This approach is consistent with provincial directives to use the watershed scale as the unit of planning to protect biodiversity, natural resources, and their functions for the long term. A Natural Heritage System that incorporates a watershed approach is likely to be more resilient to human and natural disturbances, and more robust in providing ecosystem services that meet human needs. Because healthy, functioning ecosystems also transcend watershed boundaries, it is important to connect watershed based systems with regional systems for long term resilience.

Table 2: Goods and services provided by ecosystems (from de Groot et al. 2002).

No.	Ecosystem goods and services	Examples
	Regulation functions	
1.	Climate regulation	Mitigation of urban heat island effect; cooling through evapotranspiration
2.	Gas regulation (e.g., oxygen /carbon dioxide balance, ozone layer)	Provision of oxygen, removal of carbon dioxide Maintenance of good air quality UVB protection by ozone, preventing disease
3.	Water regulation	Maintenance of water cycle (evapotranspiration and rainfall); moderation of flooding intensity
4.	Disturbance regulation	Storm protection (e.g., coastal marshes) Flood moderation (wetlands, stream sides, and forests)
5.	Nutrient regulation	Maintenance of healthy soils and productive ecosystems
6.	Soil retention	Prevention of erosion and siltation Maintenance of arable land
7.	Soil formation (e.g., leaf litter decomposition)	Maintenance of woodland and wetland productivity and species that support agriculture and natural systems
8.	Waste treatment	Pollution control/detoxification Noise abatement Filtering of dust and other particulates
9.	Pollination	Pollination of wild plants Pollination of crops
10.	Biological control	Control of pests and invasive species (e.g., mosquitoes) Control of diseases and pests (e.g., spruce budworm)
	Habitat functions	
11.	Refugium function	Living space for wild plants and animals
12.	Nursery function	Habitat for reproduction of species (e.g., for fisheries)
13.	Movement function	Movement corridors for migratory or resident species
	Production functions	
14.	Fresh water (filtering and storage)	Provision of water for consumption and irrigation
15.	Food	Provision of existing and novel food items (e.g., fish, mushrooms, nuts, berries)
16.	Raw materials	Provision of materials for building or manufacturing, biofuels and energy, fertilizer
17.	Genetic resources	Genetic resources for research and development of novel foods, textiles, fuels, medicines, raw materials
18.	Medicinal resources	Resources for pharmaceuticals, health care products
19.	Ornamental resources	Resources for crafts, art, gardening, worship, or souvenirs
	Information/Social functions	
20.	Science and education	Use of natural areas for school or public education Scientific knowledge
21.	Human health and well being	Livable neighborhoods and cities Sense of place Aesthetics Recreation
22.	Recreation	Walking, biking, canoeing, fishing, bird watching
23.	Cultural, artistic, religious, historic	Use of nature in art, books, painting, etc. (inspiration) Religious significance Historic significance (e.g., heritage forests)

4. Guiding principles, goals and objectives for the Credit River Watershed Natural Heritage System

4.1 Guiding principles in developing the Credit River Watershed Natural Heritage System

The following are CVC's governing principles as outlined in its Strategic Plan (CVC 2006b). These principles will guide development of the Natural Heritage System and provide a context for the development of the vision, goals and objectives for the Natural Heritage System.

- Recognize the inextricable link between human health and the natural environment;
- Maintain a watershed scale perspective and consider the implications of cumulative actions on the watershed as a whole;
- Recognize that protection of existing natural heritage is preferable to restoration;
- Recognize that healthy communities require a sustainable balance between economic, social and environmental uses in the watershed;
- Take a preventative, proactive and integrative approach and apply the Precautionary Principle to watershed management based on adaptive environmental management. The Precautionary Principle recognizes that the absence of full scientific certainty shall not be used as a reason to postpone decisions where there is a risk of serious or irreversible harm;
- Make decisions and take actions based on our accumulated knowledge, skills and experience. We work to continually improve our understanding of the watershed and how it functions;
- Subscribe to the belief that protection and restoration of watershed health is a broadly shared responsibility. We implement watershed management by working with partners and engage clients around shared interests and objectives. We strive for excellence in those relationships;
- Pursue practical approaches to the management of water, other natural resources and natural heritage based on the application of sound science, creativity and innovation;
- Promote ecologically sustainable development and practices within urban and rural communities;

- Ensure that CVC's conservation areas are primarily managed for natural heritage protection, secondarily for appreciation, and thirdly for recreation opportunities; and

- Fulfill our important role in climate change mitigation and adaptation in the Credit River Watershed.

4.2 Goals and Objectives for the Credit River Watershed Natural Heritage System

The goals and objectives for the Credit River Watershed Natural Heritage System arise from an overarching CVC vision of "*An environmentally healthy watershed supporting native biodiversity and self-sustaining natural features and functions for present and future generations*". Goals and objectives from CVC's Strategic Plan (CVC 2006b) related specifically to the maintenance of biodiversity and healthy ecosystem functioning were adopted for the development of a watershed Natural Heritage System:

4.2.1 Goals for the Credit River Watershed Natural Heritage System

Primary goals
Terrestrial and aquatic species, communities and ecosystems:
To protect, restore, or enhance the ecological integrity of the Credit River Watershed's natural features, functions and systems.

Water quality and quantity
To protect or enhance the quantity and quality of surface and ground water for environmental and human uses;

Secondary goals
Natural Hazards:
To protect public safety and minimize property damage from natural hazards including flooding, drought, erosion, sedimentation, wetlands and dynamic beach processes; and

Social and Economic:
To promote the health and sustainability of watershed communities through effective watershed management.

4.2.2 Objectives for the Credit River Watershed Natural Heritage System

Primary Objectives for the watershed Natural Heritage System
Terrestrial and aquatic species, communities and ecosystems:

a. Protect, restore or enhance integrity of watershed ecosystems, through an integrated network of core areas, connections, and linkages;
b. Protect, restore or enhance native terrestrial and aquatic plant and animal species, community diversity and productivity;
c. Ensure that the complete range of representative and significant natural features and functions distributed within the watershed are protected in perpetuityProtect, restore or enhance natural ecosystems to sustain watershed functions, human uses, and build resilience to stresses such as climate change; and

d. Promote sustainable resource management of aquatic and terrestrial systems and areas within the watershed for plant, animal and human needs.

Water Quality and Quantity:

a. Preserve, maintain or re-establish the natural hydrological cycle;
b. Maintain, enhance or restore natural stream processes to achieve a balance of flow and sediment transport;
c. Maintain and restore groundwater levels and baseflows (groundwater discharge to streams) to sustain watershed functions and human uses and build resilience to stresses such as climate change;
d. Minimize risk to human life and property due to flooding and erosion;
e. Maintain or enhance water and sediment quality to achieve ecological integrity;
f. Protect drinking water sources;
g. Protect and restore surface water quality with respect to conventional and toxic pollutants to ensure protection of ecosystem functions and water supply;
h. Protect, restore and enhance groundwater quality to support watershed functions;
i. Improve water quality in streams, the Credit River, and Lake Ontario to meet standards for body contact recreation and provide for sustainable fishing opportunities and the safe consumption of fish; and
j. Improve water aesthetics including odour, turbidity and clarity.

Secondary objectives
Natural Hazards:

a. Protect potentially hazardous river or stream valleys, flood plains and Lake Ontario shoreline; and
b. Protect watercourses (including their meander belt) and wetlands.

Social and Economic:

a. Promote the community benefits of the watershed's natural areas and system (recreational, educational, cultural, psychological, tourism, economic);
b. Recognize the contribution of agricultural lands and the urban forest to the health of the watershed's natural areas and to the well being of watershed communities; and
c. Provide appreciation and compatible recreational opportunities on protected land.

Development of the Natural Heritage System for the Credit River Watershed will include consideration or development of indicators and targets related to these goals and objectives.

5. Credit River Watershed overview

The following subsections describe the biophysical condition of the Credit River Watershed along with some socioeconomic information relevant to development of a watershed Natural Heritage System.

The physical characteristics of the Credit River Watershed are important in identifying or designing a Natural Heritage System because the combination of surficial geology, glacial history, soils, hydrology, and climate strongly influence the types and distribution of natural vegetation and wildlife that can be found or restored within the watershed.

5.1 Physiographic Regions and Physiographic Zones

Chapman and Putnam in 1951 described eight major and two minor physiographic regions within the Credit River Watershed. Mapping for these physiographic regions has been recently updated by the Ontario Geological Survey (Chapman and Putnam 2007). Physiographic regions are created when characteristic differences in glacial deposits create distinct regions with unique combinations of soils, elevation, and drainage. The major physiographic regions are listed in Table 3 and further described in the *Credit River Water Management Strategy Update* (CVC 2007b).

The physiographic regions are grouped into three broad physiographic zones of approximately equal area based on a combination of subwatershed boundaries and physiographic regions. These physiographic zones are termed the Upper Watershed (above the Niagara Escarpment), the Middle Watershed (Niagara Escarpment and Oak Ridges Moraine areas), and the Lower Watershed (below the Escarpment). Physiographic regions and physiographic zones are shown in Figure A1 in Appendix A (Figures with the prefix ‘A’ refer to maps; these are all found within Appendix A at the end of this document).

Table 3: Physiographic Regions of the Credit River Watershed (from *Credit River Water Management Strategy Update,* CVC 2007b).

Physiographic Region	Physiographic Zone	Geological Characterization
Lake Iroquois Plain	Lower	Gentle slope toward Lake Ontario; thin veneer of glaciolacustrine sand and silty sand; extends 3 to 5km inland from current Lake Ontario shoreline.
South Slope	Lower/ Middle	Lies at the base of the Escarpment, and encompasses portions of Palgrave and Cheltenham Moraines and part of the Trafalgar Moraine between Peel Plain and Lake Iroquois Plain. Consists of low-lying fine-grained ground moraine and knolls.
Peel Plain	Lower	Flat to undulating topography consisting of clay soils deposited when glacial melt water ponded on top of the low permeability Halton Till plain.
Niagara Escarpment	Middle/ Upper	Most distinctive physiographic feature in the Watershed. North-south trending bedrock scarp that separates the Horseshoe Moraines to the west and the South Slope and Peel Plain to the east. It forms a major topographic break in the bedrock, and was formed as a result of differential erosion of softer underlying shale and harder dolostone. Vertical cliffs exist from Acton to the Forks of the Credit. North of the Forks of the Credit glacial overburden deposits generally mask the steep surficial expression.
Oak Ridges Moraine (ORM)	Middle	Eastern portions of the watershed in Subwatershed 13 (Caledon area). The ORM is an extensive interlobate moraine that extends from the Credit River Watershed eastwards towards the Trent River. Topography is hilly with up to 50 m of local relief. In the CVC Watershed, the ORM is characterized by hummocky hills of fine-grained sand.
Horseshoe Moraines (Paris and Singhampton)	Middle/ Upper	Broad belt of north-south trending moraines lying west of the Escarpment from Acton to Orangeville. Moraines are comprised of sand and silt tills. The Paris Moraine is a moderate relief till ridge underlain by bedrock.
Guelph Drumlin Field	Upper	Low rolling streamlined drumlins located between the Singhampton Moraine and the Orangeville Moraine. Drumlins are separated from one other by interconnected meltwater channels.
Hillsburgh Sandhills (Orangeville Moraine)	Upper	Orangeville moraine lies in the northwestern portion of the watershed and consists of coarse-grained sediments. It is an area of high relief with thick deposits of glacial outwash overlying glacial tills and bedrock.
Dundalk Till Plain, Flamborough Plain	Upper/ Middle	Shallow overburden; occupy only small portions of the watershed.

5.1.1 The Upper Watershed

The Upper Watershed includes the portion of the watershed that lies above the Niagara Escarpment and has a total area of 32,858ha. This zone is entirely within the Greenbelt Plan area (Niagara Escarpment and Protected Countryside) and contains the headwaters of the Credit River. It is generally comprised of till plains, moraines, and glacial spillways. The soils in this area are moderately to highly permeable and permit significant infiltration to the support regional groundwater, cold water streams, and drinking water supplies. The surface topography is undulating and the region is generally well drained. Baseflow to rivers and streams is maintained predominantly from springs and groundwater discharge, and water quality is generally good. Dominant vegetation associations include deciduous forest and white cedar swamps. The main land use in the area has traditionally been agriculture, although in recent years this has declined somewhat, being replaced by small hobby farms.

The major urban centres in the Upper Watershed include Orangeville, Erin, Alton, Caledon Village, and Hillsburgh. These towns are experiencing growth pressures due to their location within (Alton and Caledon Village) or near the Greater Toronto Area (CVC 2006b).

5.1.2 The Middle Watershed

The Middle Watershed is almost entirely within the Greenbelt Plan area, mostly the Niagara Escarpment and Protected Countryside. It consists of the Niagara Escarpment area between Inglewood in the north and Georgetown and Norval to the south, with steep slopes, significant rock outcrops, and thin overburden. This zone with an area of 30,988ha also contains the western edge of the Oak Ridges Moraine. Average slopes exceed 0.5m/km and in some areas the Escarpment has sharply defined cliff faces. The topography of this area causes relatively high runoff volumes and velocities; however, the high forest cover in this zone helps to slow runoff and increase infiltration. The Escarpment is heavily forested with mixed deciduous forest in upland areas and white cedar swamps in lowland areas. Many tributaries of the Credit River in this zone develop in massive headwater complexes that cover approximately 40% of the Escarpment plateau. East of the Escarpment, the Credit River cuts through clay till plains and is characterized by steep-walled valleys with floodplains of varying widths.

Townships in the Middle watershed include Inglewood, Cheltenham, Terra Cotta, Ballinafad, Acton, Georgetown and Norval, all of which lie within the Greater Toronto Area (GTA) except for Ballinafad which lies near the GTA. Consequently these towns, like those in the Upper Watershed, are experiencing growth pressures (CVC 2006b).

5.1.3 The Lower Watershed

The Lower Watershed contains a small portion of the Greenbelt Protected Countryside and covers an area of 31,045ha. The ground surface topography of this zone is relatively flat with a gentle slope south towards Lake Ontario. Surficial soils in this zone have low infiltration rates compared to the rest of the watershed, although the Lake Iroquois Plain area within this zone has areas of higher permeability due to sandy soils. In general, runoff is greater in this zone and infiltration significantly lower than in other parts of the watershed. This zone is highly urbanized, with 87% of the watershed's 750,000 inhabitants living there, and natural cover is low, with few woodlands and wetlands remaining. This zone contains most of the City of Mississauga, the western portion of the City of Brampton and the eastern part of the City of Oakville.

Several creeks originate in this zone and empty directly into Lake Ontario. Many of these creeks, and tributaries of the Credit River, have been channelized and have lost significant riparian area, and water quality in the main stem of the Credit River and its tributaries is generally low (CVC 2006b). The Lower Watershed, bordering Lake Ontario, contains an important provincial corridor, the Lake Ontario Shoreline. It also contains unique natural features such as shoreline bluffs, coastal wetlands, and nearshore aquatic habitats.

5.2 Soils

Much of the Upper Watershed is characterized as having sandy loam soils, associated with the Guelph Drumlin Field and Hillsburgh Sandhills (Figure A2, Appendix A). These soils have high permeability and support the high recharge rates of the Upper Watershed. Much of the Lower Watershed is comprised of lower permeability clay loam soils associated with the Peel Plain and South Slope, with some sandier soils in the Iroquois Plain area. Soils in the Middle Watershed are variable as a result of the changing physiography between the Upper and Lower Watershed zones.

5.3 Climate

The Credit River Watershed is located within four climatic regions - the Huron Slopes, South Slopes, Simcoe and Kawartha Lakes, and Lake Ontario Shore - and is characterized by warm summers, mild winters, a long growing season, and usually reliable precipitation (Brown et al. 1974). According to Environment Canada’s Shand Dam and Toronto Pearson climate stations, the mean annual precipitation in the Credit River Watershed is 850mm, of which 15% is snowfall. The greatest precipitation amounts occur in the northern watershed south of Erin, partly due to the influence of the Niagara Escarpment on ‘lake effect’ storms originating over Lake Ontario. The watershed has a frost-free period of 148 days per year, with a growing period of about 202 days per year. The mean annual air temperature is 6C, with mean daily temperature about -6.4C in January and 20.3C in July (CVC et al. 2002). Further details on the watershed’s climate can be found in other CVC documents (CVC 2007a, b).

5.4 Hydrology

5.4.1 Surface Water Hydrology

The Credit River Watershed encompasses approximately 1000 square kilometres (or about 100,000ha) of southern Ontario landscape. The Credit River itself is nearly 90km long and passes through nine municipalities from its headwaters in Orangeville to its entry into Lake Ontario at Port Credit, Mississauga. Nearly 1500km of streams and creeks empty into the Credit River, including Black Creek, Silver Creek, West CreditRiver, East Credit River, Shaw’s Creek, Fletcher’s Creek, Caledon Creek, and others (CVC 2007b). About twenty subwatersheds have been identified within the Credit River Watershed, each of which represents a major drainage area of the Credit River (Figure A3, Appendix A). These subwatersheds are drained by the tributaries of the Credit River.

Stream order is a measure of the position of a stream or river (see Glossary). Zero-order streams are also termed headwater drainage features. These features, which can provide permanent, seasonal or contributing fish habitat, are important features within a watershed. The spatial extent of these features can account for 70-80% of the total catchment area within a watershed (TRCA and CVC 2009). First-order streams are generally small headwater streams that do not have any tributaries. Second-order streams have first-order streams as tributaries; third-order streams represent the confluence of second-order streams, and so on. First to third order streams are also termed headwater streams, and along with headwater drainage features, these contribute large amounts of organic and inorganic matter that contribute to the health of the aquatic system. The Credit River itself is a sixth- and seventh-order stream; in general, a seventh-order stream is considered a river (Figure A3, Appendix A). In general, stream orders one, two and three are considered headwater streams which are susceptible to erosion if their riparian (streamside) cover is removed. Higher order streams generally have a lower gradient, are deeper, and have slower-moving water (Environment Canada 2004). Urban streams are sometimes modified through urban development and as a result their stream orders may differ from the pre-urbanization condition.

Stream order is an important part of the River Continuum Concept (Vannote et al. 1980) that is used to predict the types of species and communities in streams based on the stream order and its related physical characteristics and energy inputs. Headwater streams are directly reliant on terrestrial inputs or organic matter that later transition into other energy inputs and solar radiation (Vannote et al. 1980).

In addition to the Credit River and its tributaries, there are approximately 15 creeks located within the City of Mississauga that drain directly into Lake Ontario – for example Birchwood Creek, Cawthra Creek, Cooksville Creek, and Sheridan Creek.

5.4.2 Groundwater recharge

Average annual groundwater recharge rates for the Credit River Watershed are estimated using CVC's calibrated HSP-F model, which predicts recharge rates for unique HRUs (Hydrologic Response Units) that share common values of land use, slope, and soil type. The greatest amount of recharge occurs in the Upper watershed above the Niagara Escarpment, where coarse-grained moraine sediments lie at ground surface. Below the Escarpment there is limited recharge to the overall groundwater system due to the lower permeability of the Halton Till, although the area of the Lake Iroquois Plain has somewhat higher permeability. There is also little topographic relief to 'drive' the groundwater flow system.

As part of Ontario's Source Protection Program, significant recharge areas have been delineated across watershed regions, these areas being considered vulnerable from a water quality and quantity perspective. According to the Ministry's Water Budget Guidance Module (MOE 2006), significant groundwater recharge areas should be delineated and mapped to identify and subsequently protect drinking water across the broader landscape. The module suggests that high volume recharge areas should be delineated in areas where the recharge rate is 115% of the average annual recharge rate for the watershed (CVC 2007a).

Figure A4 (Appendix A) illustrates areas within the Credit River Watershed that are classified as having High Recharge according to Ministry of Environment guidelines. Within the watershed, High Recharge Areas are those with estimated recharge rates greater than 300mm/year; these areas are heavily concentrated in the Upper Watershed zone.

5.5 Population

According to the 2001 census (Statistics Canada 2003), the watershed had a population of approximately 600,000 people. The population has grown by a rate of approximately 16% between 1991 and 2001, with the majority of the growth concentrated in large urban centers such as Mississauga and Brampton. Brampton and Orangeville have the fastest growing population and rates of urban development of all municipalities within the watershed. Mississauga contains the majority of the watershed's population at about 68% (CVC 2006b, 2007a).

According to the Ministry of Energy and Infrastructure (MEI) *Places to Grow - Growth Plan for the Greater Golden Horseshoe* (MPIR 2006), the Region of Peel (containing over half the Credit watershed) is predicted to grow by almost 60% by 2031 (over its 2001 population), while the Region of Halton is anticipated to grow by 100% over the same period. The greatest share of available lands for development in the Credit River Watershed lies within the municipal boundaries of the City of Brampton. There is planned growth in all urban centres in the watershed; however, growth is limited in some communities which are dependent on groundwater and sewage treatment plants (which outlet to the Credit River) due to constraints in groundwater availability and assimilative capacity respectively. Rapid population growth in the watershed is straining its infrastructure and natural resources. By 2020, it is expected that 40% of the watershed's area will be developed (CVC 2007a, 2007b).

5.6 Municipalities

Fifteen municipalities lie entirely or partially within the boundary of the Credit River Watershed (Figure A5, Appendix A). Upper tier municipalities include the Regional Municipalities of Peel and Halton, and the Counties of Dufferin and Wellington. More than half of the Credit River Watershed lies within the Regional Municipality of Peel. Lower tier municipalities include the Cities of Brampton and Mississauga, the Towns of Caledon, Erin, Halton Hills, Milton, Mono, Oakville and Orangeville, and the Townships of Amaranth and East Garafraxa.

5.7 Federally, provincially and regionally designated natural heritage features and areas of the Credit River Watershed

5.7.1 Watercourses, lakes and ponds

Watercourses, lakes and ponds within the watershed form part of the aquatic system of the Credit River Watershed (CVC 1998). These features perform important ecosystem functions such as habitat for aquatic species, conveyance, storage and release of water, groundwater recharge, and evapotranspiration.

Much of the aquatic system of the watershed (and some wetlands) receives protection under the federal *Fisheries Act* (http://lois.justice.gc.ca/en/F-14/). The fish habitat provisions of this *Act* include the directive that *"No person shall carry on any work or undertaking that results in the harmful alteration, disruption or destruction of fish habitat."* Fish habitat is defined by the *Fisheries Act* and the *Provincial Policy Statement* as the *"spawning grounds and nursery, rearing, food supply and migration areas on which fish depend directly or indirectly in order to carry out their life processes"*. The great majority of permanent and intermittent streams in the watershed are direct habitat for fish.

Hedgerows and riparian areas near streams may be considered tertiary animal movement corridors for the watershed (North-South Environmental Inc. et al. 2009). Riparian areas may also be considered indirect fish habitat. They permit the movement of wildlife and genetic material among localized natural features within the watershed.

5.7.2 Provincial protected features and areas

Much of the area of the Middle and Upper Watershed falls under the *Greenbelt Plan*. The *Greenbelt Plan* Area includes the Niagara Escarpment Plan Area, the Oak Ridges Moraine Plan Area, and the Protected Countryside – in particular the Natural Heritage System for the *Greenbelt Plan* Area (Greenbelt 2005; Figure A6, Appendix A). The plan was designed to protect "key natural heritage and hydrological features that sustain ecological and human health" (*Greenbelt Plan* 2005, OMMAH 2005b). The natural heritage features within the Greenbelt Plan areas provide regional connections beyond the watershed boundaries. A total of 61,148ha or 64% of the Credit River Watershed is covered under the Greenbelt Plan. Table 4 shows the area protected through various means in the Niagara Escarpment Plan, Oak Ridges Moraine Conservation Plan, and the Natural Heritage System of the Protected Countryside Area of the Greenbelt.

The Niagara Escarpment and Oak Ridges Moraine form natural physiographic linkages across the broader landscape of southern Ontario. These may be considered primary animal movement corridors, or inter-regional movement corridors that follow major physiographic features (North-South Environmental Inc. et al. 2009). The Greenbelt Plan enhances these natural physiographic corridors through lands identified as the Natural Heritage System of the Protected Countryside Area. The Lake Ontario shoreline is also considered a primary plant and animal movement corridor, as it permits east-west movement beyond the watershed's boundaries and links southern Ontario to the north-eastern United States. The Lake Ontario shoreline serves an important role in providing staging or resting areas for bird or insect species that migrate in a north-south direction or along the shoreline. Primary corridors allow gene flow of animal or plant species over long distances and over long time periods and gain importance as facilitators of species and genetic movement in adaption to climate change.

Table 4: Area of the Credit River Watershed protected through under the Niagara Escarpment Plan, Oak Ridges Moraine Conservation Plan, and the Natural Heritage System of the Protected Countryside Area of the Greenbelt.

Protected area	Area (ha)	Percent of watershed area
Areas designated as *Escarpment Natural Area* and *Escarpment Protected Area* under the Niagara Escarpment Plan	8,325	8.8%
Areas designated as *Natural Core* and *Natural Linkage* Areas under the Oak Ridges Moraine Plan	1,477	1.6%
Greenbelt Natural Heritage System for the Protected Countryside under the Greenbelt Plan (includes agricultural and successional lands)	21,070	22.2%

5.7.3 Areas of Natural and Scientific Interest (ANSIs)

Areas of Natural and Scientific Interest (ANSIs) are areas of land and water containing natural landscapes or features which have been identified as having values relating to protection, natural heritage, scientific study, or education. The Ontario Ministry of Natural Resources is the lead agency in identifying these areas. Two kinds of ANSI are recognized by the province of Ontario: 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 (OMNR 1999). Earth Science ANSIs consist of some of the most significant representative examples of bedrock, fossil and landform records of Ontario, including some examples of ongoing geological processes (OMNR 1999).

Provincial Policy Statement (OMMAH 2005a) policies state that development and site alteration shall not be permitted in Provincial Life Science Areas of Natural and Scientific Interest, unless it has been demonstrated that there will be no negative impacts on their natural features or their ecological functions.

Several criteria are used to evaluate the significance of natural areas in order to select "viable units which appeared to represent the habitat and vegetation patterns characteristic of the planning area" (Riley et al. 1996). These areas are known as Life Science ANSIs, and the criteria used to designate them are (OMNR 2008a):

1. *Representation* - of geological themes or landform-vegetation features of an Ecodistrict;
2. *Condition* - existing and past land uses are used to assess the degree of human induced disturbances;
3. *Diversity* – the number of high quality, representative features that exist within a site are assessed;
4. *Other ecological considerations* – ecological and hydrological functions, connectivity, size, shape, proximity to other important areas, etc.

5. *Special features* - such as populations of species at risk, special habitats, unusual geological or life science features and educational or scientific value.

There are a total of 23 provincial Life Science ANSIs in CVC's jurisdiction, but only 21 of these fall entirely or partially within the Credit River Watershed itself. These ANSIs are listed in Table 5 and shown in Figure A7 (Appendix A). Summaries of these communities can be found at http://nhic.mnr.gov.on.ca/MNR/nhic/areas.cfm.

Provincial Life Science ANSIs receive protection under the *Planning Act* through the *Provincial Policy Statement* (OMMAH 2005a). Regional Life Science ANSIs receive protection through other legislation such as the Niagara Escarpment Plan, the Oak Ridges Moraine Conservation Plan, and the Greenbelt Plan.

Table 5: Provincially Significant Life Science Areas of Natural and Scientific Interest in the Upper, Middle and Lower Regions of the Credit River Watershed.

Watershed Zone	Subwatershed name (and number)	Name of ANSI
Upper Watershed	Headwaters (19)	None
	Shaws Creek (17)	Caledon Lake Forests
		Alton Branch Swamp
	West Credit River (15)	Eramosa River Valley
		Credit Forks
		Brisbane Woods
	Credit River - Melville to Forks (18)	Dufferin Lake
	Caledon Creek (16)	None
Middle Watershed	East Credit River (13)	Little Credit Headwaters
		Part of Credit Forks Lowland
	Credit River – Forks of the Credit to Cheltenham (20)	Part of Credit Forks Lowland
		Credit Forks
		Inglewood Forest
	Silver Creek (11)	Silver Creek Valley
		Part of Brisbane Woods
	Black Creek (10)	Part of Brisbane Woods
		Speyside Forest
	Credit River – Glen Williams to Norval (14)	Georgetown Credit River Valley
Lower Watershed	Huttonville Creek (7)	Part of Huttonville Valley
	Norval to Port Credit (9)	Part of Huttonville Valley
		Part of Credit River at Erindale
		Stavebank Oakwoods and Credit River Marshes
	Fletcher's Creek (5)	Meadowvale Station Woods
	Sawmill Creek (3)	Roy Ivor's Woodlot
		Part of Credit River at Erindale
	Loyalist Creek and Mullet Creek	Part of Credit River at Erindale
	Carolyn Creek, Levi Creek, Springbrook Tributary and Churchville Tributary (2, 6, 8a, 8b)	None
Lower Watershed; Not part of Credit River Watershed, but within CVC's jurisdiction (watersheds draining directly into Lake Ontario)	Lake Ontario Shoreline West Tributaries (21)	Lorne Park Prairie
		Rattray Marsh
	Lake Ontario Shoreline East Tributaries (22)	Cawthra Woods

5.7.4 Provincially Significant Wetlands (PSWs)

The Ontario Ministry of Natural Resources is responsible for determining which wetlands and wetland complexes (groups of individual wetlands which are functionally related in an important manner) are provincially significant, based on evaluation procedures developed by the Province and amended from time to time. Wetlands can also be identified and evaluated by other qualified individuals or agencies that have been trained by the province in wetland evaluation. Credit Valley Conservation has conducted and continues to conduct evaluations on many of the wetlands in the Credit River Watershed. Evaluated wetlands are classified under a standard methodology developed by the OMNR and Environment Canada (OMNR 1993, *Wetland Evaluation System for Ontario – South of the Precambrian Shield*). Credit Valley Conservation forwards the wetland evaluations to OMNR, which is then responsible for reviewing and approving the evaluations. A number of Provincially Significant Wetlands are found in the Credit River Watershed (Figure A8, Appendix A) and several others are under evaluation. Provincial Policy Statement (OMMAH 2005a) policies state that development and site alteration shall not be permitted in Provincially Significant Wetlands. Table 6 shows the area of the watershed that contains Provincially Significant Wetlands as evaluated by MNR, although additional Provincially Significant Wetlands may yet be designated by MNR through the evaluation process. Provincially Significant Wetlands are entered into the CVC ELC community series data layer on a regular basis following MNR designation.

Wetlands not identified as Provincially Significant still often play important regional roles in terms of hydrology and ecology and contribute to healthy watershed function. These wetlands can be protected as “Locally or Regionally Significant Wetlands” by a municipality. Wetlands of all types cover 6% of the watershed’s area.

5.7.5 Environmentally Significant (or Sensitive) Areas (ESAs)

During the late 1970s and 1980s, Conservation Authorities or municipalities in southern Ontario have identified Environmentally Significant (or Sensitive) Areas (ESAs) as areas that are: 1) of importance to ecological structure and function, and/or 2) of value to society by virtue of their geological features, or the presence of native plants or animals (Ecologistics Ltd. 1979). Environmentally Significant (or Sensitive) Areas are identified as part of the Greenlands systems of Credit River Watershed municipalities of Peel, Halton and Wellington which include policies for protection of their features and functions.

Within the Credit River Watershed, CVC has been responsible for designating ESAs based primarily on ecological principles. Features designated as Environmentally Significant Areas by CVC must meet one or more of the following criteria:

- Distinctive or unusual landform;
- Areas serving a significant hydrological function;
- Critical wildlife habitat;
- Areas containing provincially or regionally rare, or endangered plant species;
- Areas that are considered to be rare communities or remnant ecosystems;

- Areas with particularly high species diversity, though individual species themselves may not be considered rare and/or unusual;
- Areas containing undisturbed, self-sustaining ecosystems; and
- Areas of high aesthetic value in the context of the surrounding landscape.

The original 1979 ESA study has been reviewed and updated over time. There are currently 66 Environmentally Significant Areas (ESAs) within Credit Valley Conservation's jurisdiction. These ESAs cover a total of 9,661ha or approximately 10% of the watershed's total area. Many of these areas have also been designated as Areas of Natural Scientific Interest (ANSI) by the Ontario Ministry of Natural Resources, indicating their importance at a provincial level (MNR 1983, 1987).

Four types of ESAs have been designated by CVC: river valleys, wetlands, Escarpment recharge areas and significant features. Thirty-three of the designated ESAs are river valley related and distributed throughout the watershed. Twenty-four of the ESAs within the watershed jurisdiction are wetlands. Together, these account for approximately 82% of the total area designated by the Authority as "environmentally significant" within the Credit River Watershed. ESAs designated as Escarpment recharge areas are located in the Niagara Escarpment. These ESAs provide significant infiltration and recharge for the regional groundwater system and serve as source areas for a number of tributaries of the Credit River. A relatively small number of ESAs contain noteworthy features related to characteristics such as unusual flora or fauna species. Included in this category are four ESAs which contain either nationally, provincially or regionally rare species as well as communities which are considered unusual for their size or representation within either their subwatershed or within the Credit River Watershed. ESAs within the watershed are shown in Figure A7 (Appendix A) and the area covered by these is shown in Table 6.

Table 6: Area values for Provincial and Regional Life Science ANSIs, ESAs, and Provincially Significant Wetlands within the Credit River Watershed rounded to the nearest hectare[1].

Feature	Area (ha)	Percent of watershed area
Provincial Life Science ANSI	3255	3.4%
Regional Life Science ANSI	1747	1.8%
Provincially Significant Wetlands (PSWs)	5142	5.4%
Environmentally Significant Areas (ESAs)	9661	10.1%

[1]As ANSIs, ESAs, and PSWs sometimes overlap, numbers cannot be added to determine total area of these features within the watershed.

5.7.6 Valleylands

Valleyland is defined under the *Provincial Policy Statement* as "*a natural area that occurs in a valley or other landform depression that has water flowing through or standing for some period of the year*" (OMMAH 2005a). Valleylands form a key natural feature of watersheds and as such play an important habitat and linkage role for a watershed Natural Heritage System. Valleylands may be considered secondary animal movement corridors and permit regional movement of both plant and animal species and genes (North-South Environmental Inc. et al. 2009). Valleylands including the Credit River and its main branches are important corridors at the watershed scale and receive protection under several municipal Official Plans (e.g., Regional Municipality of Peel 2005).

5.7.7 Species at Risk, rare vegetation communities

Species at Risk within the Credit River Watershed are protected by legislation: at the federal level by the *Species at Risk Act* or *SARA* which came into effect in 2003 and at the provincial level by the *Endangered Species Act* which came into effect in 2007.

A species is considered to be "At Risk" when numbers, sizes, or locations of populations fall below nationally or provincially determined thresholds. The Credit River Watershed is known or expected to provide habitat for a number of federally and/or provincially listed species. To date, approximately 30 species have been identified as Threatened, Endangered, or Special Concern within the Credit River Watershed under the Endangered Species Act (2007), nineteen of these classified as Threatened or Endangered at the federal and provincial level. A number of the watershed's amphibian and reptile species are at risk due to habitat loss, predation, road mortality, pollution and human activity. Due to sensitivity of the data, the specific locations of these species cannot be mapped. Rather, their approximate or generalized location is indicated by 1km by 1km squares that contain the location of the species at some point within the square. Examples of terrestrial Species at Risk within the Credit River Watershed are the Acadian Flycatcher (*Empidonax virescens* classified as Endangered), Jefferson Salamander (*Ambystoma jeffersonianum* classified as Threatened), and American Ginseng (*Panax quinquefolius* classified as Endangered). The aquatic species at risk within the watershed with the highest profile is the redside dace (*Clinostomus elongatus* classified as Endangered).

All species require habitat in which to survive and reproduce. Various pieces of legislation ensure the protection of Species at Risk. Once species are listed as endangered or threatened under the *Species at Risk Act* or the *Endangered Species Act*, they are protected by legislation and recovery strategies must be created to recover species and their habitats to prevent further decline of their populations. The *Provincial Policy Statement* also provides for protection of the significant habitat of endangered or threatened species (OMMAH 2005a). Recovery strategies are prepared by recovery teams made up of technical experts from universities, conservation groups, industry and government. These strategies include information about the species' habitat needs, the types of threats to the species or ecosystem, recommendations on how to protect and recover species and their habitats, and the area that should be considered habitat.

Certain specific rare vegetation communities are also protected by the province of Ontario. The Natural Heritage Information Centre (NHIC) compiles, maintains, and distributes information on natural species, plant communities, and species of conservation concern in Ontario (http://nhic.mnr.gov.on.ca/). The OMNR Significant Wildlife Habitat Technical Guide (OMNR 2000) provides guidance for identifying rare vegetation communities as Significant Wildlife Habitat which can then be protected by policies within the *Provincial Policy Statement*.

Credit Valley Conservation is in the process of collecting data on the abundance and geographic distribution of the flora and fauna in the Credit River Watershed. The purpose of this project is to determine population trends and identify species that are at risk of decline. The identification of species of conservation concern will support CVC and its municipal partners in the implementation of policies intended to protect species at risk, significant wildlife habitat, and the biodiversity and ecological integrity of the Credit River watershed.

5.8 Land cover and land use past and present

An examination of the Credit River Watershed land cover in the past provides a historical perspective on current-day vegetation communities. Based on detailed surveyor records dating from 1806, around the time of European settlement, the region was composed primarily of deciduous forest (CVC and University of Guelph 2003). Other communities included marsh, swamp, and a few pockets of savannah. Twenty-nine different tree species were recorded, the most frequently mentioned being maple, beech, basswood, elm, pine, and hemlock. The pre-settlement vegetation of the Credit River Watershed consisted approximately of 65% upland forest, 21.7% lowland forest and swamp, 7% non-forest wetland and aquatic (watercourse and water bodies) and 1% early successional habitats (CVC 2006b). Species specific data should be viewed with some caution because species identification skills may have differed among surveyors while the community type information is likely to be somewhat more reliable.

Wetland loss in southern Ontario has been significant (Snell 1987, Ducks Unlimited Canada 2010). A study of wetland extent and loss has shown that at least 76% of south Ontario wetland area has been lost following European settlement, primarily through early conversion of land for agriculture (Ducks Unlimited Canada 2010), and that wetland losses continue to occur. Remaining wetlands in the watershed therefore gain in importance as they represent communities that have become relatively rare. In terms of forest cover, another study estimated that about 90% of southern Ontario's land base was forested prior to European settlement (Larson et al. 1999).

Credit Valley Conservation is a partner with the Ontario Ministry of Natural Resources in a project to model the pre-settlement vegetation of southern Ontario. This model utilizes inputs based on surveyor reports at the time of European settlement. Results from this study will provide more detailed information on the species and communities present before the region was cleared for agriculture.
With increasing urbanization into the present, humans are becoming more heavily dependent on remaining natural areas in the watershed for provision of ecosystem goods and services.

5.9 Ecological Land Classification

The Canada Committee on Ecological Land Classification was established in 1976 to delineate, classify, and describe ecologically distinct areas of the earth's surface. Between

1976 and the 1980s, a standardized, hierarchical classification framework was developed that remains in use today. The hierarchy of Ecological Land Classification units allows for planning at multiple scales (Lee et al. 1998, Jalava et al. 2001).

Ecozones represent very large and generalized units approximately 10,000-1,000,000km^2 in area, characterized by biotic and abiotic factors. The Credit River Watershed lies within the Mixedwood Plains Ecozone that encompasses all of southern Ontario. This area was once dominated by deciduous forest. Deposits from ancient glaciers, particularly in the southern part of the region, make the soil extremely productive and this along with the gently rolling or flat topography of the region resulted in extensive clearing for agriculture, followed by urbanization. Ecoregions are subdivisions of the Ecozone characterized by distinct large order landforms and are on the order of 1000-10,000km^2 in area. The Credit River Watershed lies within Ecoregions (also termed Site Regions) 6E and 7E. Site Region 6E occupies the northern portion of southern Ontario in what Rowe (1972) called the Great Lakes – St. Lawrence Forest Region, characterized by a mix of deciduous and some coniferous tree species (Lee et al. 1998). Site Region 7E occupies the southernmost part of southern Ontario in what Rowe (1972) termed the Deciduous Forest Region. This region is dominated by deciduous tree species (Lee et al. 1998). Ecodistricts, on the order of 100-1000km^2 in area, are subdivisions of Ecoregions and are characterized by distinctive assemblages of landform, relief, surficial geologic material, soil, water bodies, vegetation, and land uses. The Deciduous Forest Region contains a unique and diverse flora, including a number of broad-leaved species more common to the south in the eastern United States, likely due to the favourable climatic conditions created by the moderating effects of the Great Lakes, and the rich soils found in this part of the province. Due to the presence of southern species, the Deciduous Forest Region, containing a unique and diverse has also been termed the Carolinian Zone. The Credit River Watershed contains parts of three Ecodistricts, namely, 6E1, 6E7, and 7E4 (Figure A9, Appendix A). Brief descriptions of these Ecodistricts, including those within the Credit River Watershed, may be found in documents prepared by the Nature Conservancy of Canada (Henson et al. 2005a, b).

An Ecological Land Classification (ELC) has been developed specifically for southern Ontario to incorporate its mix of natural and human-modified habitats and to identify natural and cultural communities at finer scales of ecological organization (Lee et al. 1998). The southern Ontario classification represents a standardized hierarchal classification system used for the description, inventory, and interpretation of ecological units at a local scale in southern Ontario and is nested within the Ecological Land Classification System. It provides resource managers with a "uniform and consistent way to identify, describe, name, map, manage and conserve important landscape patterns and communities" at more local scales (Lee et al. 1998). The ELC for southern Ontario identifies six nested levels below the Ecoregion level. From the largest to the smallest scale, they are: Site region (or Ecoregion) → System (Terrestrial, Wetland, or Aquatic) → Community Class → Community Series → Ecosite → Vegetation Type (Lee et al. 1998).

The ELC classification for southern Ontario (Lee et al. 1998) is the current accepted standard for this region and is used within the region by most Conservation Authorities, municipalities, and OMNR.

Land cover within the Credit River Watershed was mapped to approximately the community series scale following Ecological Land Classification for Southern Ontario (Lee et al. 1998) and the Credit Watershed Natural Heritage Project Detailed Methodology (CVC 1998). Examples of ELC community series are mixed forest, coniferous plantation, or thicket swamp. Mapping of these communities was originally completed using 1996-spring aerial photography. The polygon boundaries drawn on the air photos were then transferred to 1:10,000 Ontario Base Mapping (OBM) and were digitized. Mapping of the watershed's terrestrial communities has since been updated based on fieldwork as well as digital ortho-rectified aerial photography from various years, the latest being 2007. Mapping and analysis of wetland communities (i.e., swamp, marsh, fen and bog) is kept up to date using the Natural Resources and Values Information Systems (NRVIS) mapping layer (last update spring, 2006) and through regular updates from the Ministry of Natural Resources.

The community series scale is the finest scale that can be determined through air-photo interpretation. Credit Valley Conservation also has data that classify watershed communities at finer scales of the ELC hierarchy, from the Community class level (e.g., forest, swamp, marsh) through the Community Series level (e.g., deciduous forest, mixed swamp, marsh) down to the Vegetation Type level (e.g., Fresh-Moist Sugar Maple – Hardwood Deciduous Forest Type). However, community classifications below the ELC community series level are not available for the entire watershed because they are based on site level investigation.

The comprehensive and complete Ecological Land Classification mapping for the entire watershed represents a rich and detailed data source that, combined with biophysical data for the watershed, provides a strong and scientific foundation for Natural Heritage System planning.

Approximately one-third of the Credit River Watershed remains under natural and semi-natural cover - that is, under woodland, wetland, aquatic, or successional communities, the remaining major land cover types being agriculture and urban (Figure A10, Appendix A; see Glossary and Appendix B for definitions). Land cover values as a percentage of total watershed cover are as follows: Natural 34%, Agriculture 37%; and Urban 29%.

The detailed Ecological Land Classification for the three physiographic zones in the watershed is shown in Figures A11-A13, Appendix A.

5.10 Existing cross-watershed connections

Natural areas that lie on or near the border of the Credit River Watershed boundary provide linkages to other natural systems within neighbouring Conservation Authorities and municipalities in the broader southern Ontario landscape. These linkages allow for species movement and gene flow across jurisdictional boundaries, thereby contributing to the resilience of regional natural areas systems. To the north, the Credit River Watershed is linked to the Nottawasaga Valley Conservation Authority and the Lake Simcoe Region primarily through Island Lake via the Orangeville Wetland Complex and surrounding natural areas. To the west, areas such as Mud Lake, the Speed, Lutteral and Swan Creek Provincially Significant Wetland complex and Eramosa River Blue Springs Creek Wetland Complex provide natural connections to the Grand River Conservation Authority and Dufferin and Wellington Counties. The northwest portion of CVC is rich in wetland complexes that cross the boundary of the CVC jurisdiction and provide multiple links to natural areas in Wellington and Dufferin Counties. Also to the west, the Halton Escarpment Provincially Significant Wetland Complex provides links CVC natural areas to the Halton Region Conservation Authority and Halton Region. This complex includes Speyside ANSI. Farther south, the Joshua's Creek Valley ESA and Wildflower Woods ESA also provide linkages between natural areas between CVC and Halton Region Conservation Authority and Halton Region. To the east, natural areas in the upper reaches of the Humber River provide natural linkages to the Toronto Region Conservation Authority (TRCA) within the Region of Peel. The Albion Hills Forest ANSI, Speersville Wetland Complex, and Little Credit River Wetland Complex provide additional links that cross the CVC boundary into TRCA. In the urbanizing part of the watershed, agricultural lands with some remnant natural areas provide some connectivity across the CVC boundary to Etobicoke Creek.

The Greenbelt Natural Heritage System, Niagara Escarpment, Oak Ridges Moraine and Lake Ontario Shoreline are provincial level linkages that connect the Credit River Watershed not only to adjoining natural systems but to other natural areas and systems at an even broader landscape scale. While natural cover along the Lake Ontario Shoreline is sparse due to urbanization, this area contributes to Lake Ontario shoreline connectivity, is particularly important for migratory and shoreline utilizing species and may become an important corridor for species adapting to climate change.

During development of the Credit River Watershed Natural Heritage System, it will be important to identify these and any other key linkages so that natural systems in the area surrounding the Credit River Watershed are ecologically connected and integrated.

6. Stresses affecting the Credit River Watershed's ecosystems and implications for a watershed Natural Heritage System

There are a number of stresses that affect the watershed's ecosystems, the natural areas that provide ecosystem goods and services to its inhabitants. Observed stresses on the Credit River Watershed include climate change, habitat loss and degradation, development, aggregate extraction, water taking, pollution, fragmentation and barriers to species movement, disease, pests, and invasive species, and agriculture. Stresses are often interlinked – for example, urbanization is associated with increased levels of water taking, pollution, fragmentation, and disease, pests, and invasive species. Brief descriptions of the major stresses (in no specific order) are provided below from CVC's *Strategic Plan* (CVC 2006b).

While developing a Natural Heritage System can help lessen the impacts of these stresses on the watershed's ecosystems, the area of the system is likely to be constrained by competing land uses and socioeconomic imperatives. A more holistic approach that includes managing the matrix (urban, agricultural) in which the system is embedded will be necessary to maintain long term watershed health.

6.1 Climate change

Climate change has the potential to dramatically alter Ontario's terrestrial and aquatic ecosystems (Varrin et al. 2007). Climate projections for southern Ontario include warmer winter temperatures and mean annual temperatures with potential increases in insect outbreaks, fire, and tree mortality; more extreme heat days causing stress on species and habitats such as wetlands and competition for water resources; an increase in extreme weather-related events such as ice storms, flooding, or fire; a drop in Great Lakes water levels by as much as one metre by 2050, affecting aquatic habitat and water quality (Colombo et al. 1998, 2007).

Changes in climate are already occurring and are likely to occur faster than some species can adapt; consequently certain species, particularly those with narrow ranges of tolerance, may experience severe declines (Halpin 1997, Hansen et al. 2001, Honnay et al. 2002, Varrin et al. 2007). The maintenance of healthy, connected, and genetically diverse populations has been suggested as one important method to enable species to adapt to climate change (Halpin 1997, Hansen et al. 2001, 2DegreesC 2007, Varrin et al. 2007), along with protection of climate refugia, diversity at the landscape scale, and conservation of water resources. Because climate change exacerbates existing impacts to ecosystems, any measures that reduce existing pressures on species and ecosystems are likely to assist species and ecosystems as they adapt to climate change. Protection of transition zones between ecosystems – e.g., between the Carolinian and the Great Lakes - St. Lawrence ecosystems – is also important because it enables species to move across ecosystems in response to climate change (Halpin 1997, Hansen et al. 2001, Varrin et al. 2007). However, it is possible that a Natural Heritage System designed under current conditions may not be adequate to maintain watershed health under more severe climate change conditions due to inherent uncertainty in climate models. It will be necessary to remain apprised of current science on climate and protected areas management and to practise adaptive environmental management to enhance ecosystem resilience to climate change.

6.2 Loss and degradation of habitat and biodiversity

Habitat loss and degradation constitutes a major threat to the watershed's ecosystems. The loss of natural areas, to agriculture at the turn of the century and then to development has resulted in 12% of upland forest and 6% of wetlands currently remaining in the Credit watershed. A study of wetland extent and loss in southern Ontario has shown that 76% of large (>10ha) southern Ontario wetlands have been lost following European settlement, primarily through early conversion of land for agriculture; this number is likely greater when the loss of smaller wetlands is accounted for (Ducks Unlimited Canada 2010). An older study estimated that about 90% of southern Ontario's land base was forested prior to European settlement (Larson et al. 1999).

As a consequence of habitat loss and other factors, a number of species are at risk. Within the Carolinian and Great Lakes-St. Lawrence forest regions of which the watershed is a part, at least 9 species are considered Extinct, 10 species Extirpated, 88 Endangered, 64 Threatened, and 62 of Special Concern (CVC 2006b). Increasing biodiversity losses can lead to declines in ecosystem services (Hooper et al. 2005; Srivastava and Vellend 2005). In general, greater biodiversity ensures a stable supply of ecosystem goods and services over the long term (Cardinale et al. 2002, Hooper et al. 2005, and references therein). A few subwatersheds in the Middle and Upper portions of the CVC jurisdiction have healthy levels of forest, wetland and riparian cover and may be considered among the relatively healthier subwatersheds in the CVC jurisdiction. For example, Silver Creek, Black Creek, Shaw's Creek and West Credit are among those subwatersheds with levels of wetland cover meeting or exceeding Environment Canada guidelines of 6% (Environment Canada 2004). Credit River-Forks of the Credit subwatershed has a relatively high degree of forest cover that exceeds Environment Canada guidelines of 30%, and the East and West Credit subwatersheds have stream riparian areas that meet or exceed Environment Canada guidelines of 75% natural vegetation.

Habitat degradation through drainage alteration, encroachment, unsanctioned trails, off-road motorized vehicle use, over-harvesting of fish, forests, plants and wildlife, domestic predators (such as cats) and garbage dumping can have significant impacts on the quality of natural areas within the watershed.

6.3 Fragmentation and barriers to species movement

Land clearing for agriculture on a large scale in southern Ontario the in the late 1800s and early 1900s severely fragmented the continuous forest, swamp and marsh habitat that existed up to that time. Urbanization following agricultural expansion increased habitat fragmentation. Roads and dams constitute significant barriers to the movement of some species within fragmented habitat (Forman et al. 2003). Roads – particularly multi-lane highways such as Highways 401, 403, 407 and the QEW within the Credit River Watershed – can result in fragmented and isolated populations of reptiles and amphibians, many of which are species at risk. Natural areas that are fragmented by non-natural land uses (such as urbanization or agriculture) are less resilient because species and genetic diversity are harder to maintain over time than in connected natural areas (Forman 1995). Dams created in the 1900s for agricultural or hydroelectric power purposes prevent or reduce movement of fish and other aquatic life, affect the hydrology of streams and riparian zones, enrich nutrient or sediment status of waterways, and raise stream temperatures, impacting coldwater fisheries. About 500 dams have been documented on the Credit River; of these, approximately 35 are major dams, with minor dams concentrated in headwater areas (CVC unpublished data). Online ponds create thermal and physical barriers for certain aquatic species.

Developing a connected Natural Heritage System would improve the ability of natural areas to recover from local disturbances or loss of species but the impacts of fragmentation and barriers cannot be fully mitigated. Creation of wildlife crossings and improving the ability of species to move through ecological management of non-natural habitats (such as the agricultural or urban matrix) will be required to improve the health of the system over the long term.

6.4 Urbanization

Urbanization can cause severe loss and degradation of natural habitat if not sustainably planned. Impacts of unsustainable urban development practices on species can include inadequate habitat for reproduction, alteration of habitat hydrology, alteration of ecosystem processes and food supply, impacts from road mortality, light, noise, contaminants, trails, direct disturbance, and predation (Faulkner 2004, Gibbs and Shriver 2005, CWP 2006, Environment Canada 2007). Urban sprawl and speculation have also contributed to the loss of thousands of acres of productive agricultural land in Ontario each year. Between 1976 and 1996 more than 150,000 acres of farmland in the GTA (or 18% of Ontario's best agricultural or Class 1 farm lands) were lost from food production (CVC 2006b). The loss of agricultural land to urbanization affects not only food security but also the ability of species to move through the landscape. Development in urban areas can lead to altered water tables and dewatering, drying, and degradation of nearby wetlands and woodlands.

Another consequence of unsustainable urban development practices is an increase in impervious cover or hardened surface cover. The total amount of impervious cover in a watershed is an important measure of watershed health and is particularly related to surface water quality and stream health. Urbanization creates hardened surfaces such as roads, driveways, parking lots, and sidewalk. Along with roofs, these surfaces constitute impervious cover. Other surface types (such as woodlands, agriculture, parks, etc.) are classified as pervious cover, although agriculture is considered less pervious than natural cover. Manicured grass (turf cover) is also fairly impervious and can contribute to the impairment of water quality in urban watersheds (CWP 2003). Hardened or impervious surfaces increase the amount of rainfall that flows over land, and reduce the amount that percolates into the soil. Increased overland flow volumes are associated with a number of impacts to stream form and function (CWP 2003, Roy et al. 2005). Impervious cover has been recognized as a good indicator of stream health in smaller watersheds (CWP 2003) and linked to changes in fish and benthic fauna in Lake Ontario tributaries (Stanfield and Kilgour 2006). Studies have shown that above 10% impervious cover in subwatersheds, streams become impacted and show some impairment; above approximately 25% impervious cover in subwatersheds, streams become permanently impaired and non-supporting (Schueler 1994). Impervious cover thresholds of 10-12% have been observed for a number of different taxa as the point at which a decline in habitat potential for multiple species is observed (Randhir and Ekness 2009). However, another study (Cuffney et al. 2010) has found degradation in macroinvertebrate assemblages at even low levels of impervious cover (such as 5-10%). It is important to note, however, that the essential habitat requirements of many sensitive or endangered species are determined by specific stream quality indicators, rather than the average behaviour of all stream quality indicators indicated by impervious cover models; consequently caution must be exercised in applying impervious cover thresholds to individual species (CWP 2003).

Urban development uses materials that tend to absorb and retain heat effectively. As a result, urban areas are generally warmer than surrounding rural areas – an effect called the Urban Heat Island. The higher temperatures in urban areas can have health impacts on urban residents during hot summer days, and decrease air quality by increasing the production of pollutants such as ozone.

Streams in urbanized watersheds or subwatersheds tend to suffer from Urban Stream Syndrome – rapid increases in runoff during storm events, elevated concentrations of nutrients and contaminants, altered channel morphology, increased stream temperatures, depletion of dissolved oxygen, reduced biodiversity and an increase of tolerant species, and reduced nutrient uptake (Schueler 1994, CWP 2003, Walsh et al. 2005). A study of streams in a number of Lake Ontario streams showed that the percentage of impervious cover was a significant modifier of fish, benthos, stream temperature, stream width:depth ratio, and percent stable banks even after accounting for landscape variables (Stanfield and Kilgour 2006). Fish and benthic assemblages were clearly altered above 10% impervious cover, with no coldwater streams above that threshold. Impervious cover of 10% in the Stanfield and Kilgour study corresponded with urban cover of approximately 40-50% or agriculture cover of 80-100%, or a combination of the two.

The Credit River Watershed has >10% impervious cover over much of the Lower Watershed, and <10% impervious cover in the Middle and Upper Watersheds (CVC 2005). Given estimated urbanization growth patterns, one might reasonably begin to see additional changes in the structure and composition of streams within the watershed in the future.

6.5 Water taking

Water taking faces competing demands from golf courses, aggregate extraction, bottled water production, agricultural or greenhouse operations, commercial and residential use.Some municipalities in the watershed (for example, Georgetown and Orangeville) are experiencing difficulty in obtaining adequate groundwater supplies for their growing populations. Unsustainable rates of water taking can impact drinking water quality as the ability of lakes and streams to dilute contaminants is decreased.

Groundwater extraction can result in a cascade of effects on aquatic and terrestrial ecosystems including impacts on soil hydrology, stream baseflows, species health and productivity, and biodiversity (Bernaldez et al. 1989, Stromberg et al. 1996, Pringle 2001). Developing an integrated Natural Heritage System can help maintain or enhance the quality and quantity of groundwater in the watershed.

6.6 Pollution

A significant proportion of air pollution (ozone, fine particulate matter, nitrogen oxides, and volatile organic compounds) in Ontario is caused by trans-boundary air pollution from the United States (Regional Municipality of Peel). The remaining comes from local emissions within the watershed and neighbouring areas, making the Lower Watershed one of the most polluted zones in the watershed.

Since 1982 there have been over 6000 spills reported within the watershed's municipalities. Spills include bypasses from waste water treatment plants, vehicle accidents, sediment, and disposal of hazardous chemicals down local storm sewers (CVC 2006b). Ammonia, chloride, nitrate, and *E. coli* loadings have been detected in waterways as a result of degrading septic systems in some watershed communities.

Pollution issues in rural environments of the watershed include excess nutrients, organic pollution, overuse or misuse of pesticides, and livestock access to waterways (CVC 2006b). Some areas show evidence of groundwater contamination from fertilizer.

Pharmaceuticals and personal care products, excreted with human or animal waste or washed off bodies, have been detected in trace amounts in surface water, drinking water, and wastewater effluent in North America. These substances are of increasing concern because of their potential to be active in low concentrations and to spread throughout the food chain. Some of the known potential impacts on organisms include delayed development in fish, delayed metamorphosis in frogs, and altered behaviour and reproduction, particularly in aquatic species.

An increase in total natural cover and protection of groundwater and surface water through identification of a Natural Heritage System would help mitigate some of the effects of regional pollution through improved air pollutant capture, infiltration or dilution.

6.7 Pathogens, pests, and invasive species

A number of tree and plant species in the watershed are threatened by pathogens, pests, or invasive species that are non-native (i.e., arrive from outside Canada), spread rapidly due to lack of natural predators, and have multiple ecological impacts (Mooney and Cleland 2001). Most notably Emerald Ash Borer (*Agrilus planipennis*), an introduced beetle from Asia attacks and kills all ash species, and Asian Long-horned Beetle (*Anoplophora glabripennis*) causes crown dieback and eventual tree mortality of hardwood trees. Examples of pathogens that contribute to tree decline and mortality include Dutch Elm disease (*Ophiostoma ulmi*) affecting elm trees, and Beech Bark Disease (*Nectria coccinea*) affecting beech trees. Invasive species (non-native species that spread rapidly) are a significant and growing threat to natural areas within the watershed. These species tend to be tolerant to disturbance and reproduce rapidly, often eliminating more sensitive native species locally. The effects of invasive species may be widespread as wildlife species lose the food sources on which they are dependent. Examples of invasive species in the watershed are Garlic Mustard (*Alliaria petiolata*), Common Buckthorn (*Rhamnus cathartica*), Dog-strangling Vine (*Cynanchum nigrum*), Norway Maple (*Acer* platanoides), Round Goby (*Neogobius melanostomus*) and Quagga Mussel (*Dreissena rostriformis bugensis*). Impacts of non-native species are direct (significant tree losses) and indirect (loss of ecosystem services provided by trees) and have been estimated at several billion dollars per year (Colautti et al. 2006).

Pathogens, pests, and invasive species will impact the ecological integrity of a watershed Natural Heritage System. Creation of a Natural Heritage System for the watershed will need to include invasive species management and a focus on maintaining ecosystem function. The Credit River Watershed's Invasive Species Strategy (CVC 2009) has the potential to be integrated with the Natural Heritage System to target areas for invasive species management.

6.8 Aggregate extraction

Approximately 4% of the watershed's area is under aggregate extraction with pits and quarries. Dewatering for the purposes of extraction below the water table can alter baseflows to rivers and creeks, leading to altered surface water quantity and/or quality, loss of natural habitat, and fisheries impacts. Alteration of hydrology through extraction can also cause negative impacts on nearby ponds and wetlands, while the ponds associated with quarrying can raise water temperatures and may impact coldwater fisheries. Other impacts associated with aggregate extraction include noise, dust, and increased traffic.

The location of aggregate supplies coincides with important natural ecosystems on the Niagara Escarpment and the Oak Ridges Moraine. These unique areas contain significant natural heritage features and serve as key provincial scale natural corridors that allow for ecosystem resilience through species and gene flow over generations. By virtue of their location, aggregate extraction sites pose a challenge to the connectivity of a watershed Natural Heritage System.

6.9 Agriculture

Agriculture can be both beneficial and detrimental to natural heritage systems. A number of terrestrial wildlife species use non-intensive agricultural land for feeding or movement (CVC 2002a, 2002b, 2002c), and pasture and forage crops play an important role in supporting grassland species in the watershed's landscape. On the other hand, unsustainable farm practices have led to declining water quality, aquatic habitat, soil erosion, and loss of habitat for species (Tilman 1999). Sustainable farm practices such as nutrient management, soil and water conservation and integrated pest management have reduced and in some cases reversed these adverse impacts. Much of the forest in southern Ontario was cleared for agriculture in the 1800s and subsequent development of agricultural land has led to permanent losses of this valuable resource. The creation of

'novel ecosystems' such as meadows, old fields, and grasslands following the clearing of land for agriculture has resulted in a suite of species (such as grassland birds) that now inhabit these areas. These areas represent opportunities for stewardship to enhance relatively new flora or fauna communities.
The Credit River Watershed has a greater proportion of non-intensive agriculture (hayfields, pasture, horse and cattle farms) than intensive agriculture such as corn or wheat (CVC unpublished data). However, parts of the Lower Watershed have intensive agriculture such as horticultural operations and greenhouses.

On the whole, agricultural systems are considered preferable to urbanization from an ecological standpoint (Marzluff and Ewing 2001) and can contribute to the health of a Natural Heritage System without compromising agricultural function in the long run.

6.10 Recreation

Like agriculture, recreation can be both beneficial and detrimental to natural heritage systems. Large recreational areas such as golf courses can impact water quality through pesticide and fertilizer application. Manicured open space (such as sports fields and lawns) also has the potential to impact water quality, particularly in urban watersheds (CWP 2003). Recreational areas can hinder the connectivity of natural areas or introduce opportunities for degradation of natural areas through unauthorized trails or mountain biking courses, littering, garbage dumping, and predation.

Recreational areas can also provide positive natural heritage benefits. Plants in recreational areas can support insect, bird, and small mammal populations. Manicured open space and shrubs provide a soft edge to adjoining natural areas, and can provide supportive habitat for wildlife within natural areas.

7. Landscape Scale Analysis of the Credit River Watershed's ecosystems

The existing natural heritage features of the Credit River Watershed have been described in previous sections. The following sections will focus on a functional assessment of all natural and semi-natural areas of the watershed using a systems approach to identify those that are particularly important in terms of their contribution to ecosystem function by virtue of their location within the watershed.

A Landscape Scale Analysis (LSA) is a desktop analysis conducted using spatial data contained in a Geographic Information System, or GIS. The LSA can be defined as a tool for characterization and assessment of ecosystem features and functions at the landscape scale, using GIS mapping, a systems approach, and well-established ecological principles to ensure integration of the features and functions within the region of interest with those in the broader landscape.

The systems approach of the Landscape Scale Analysis identifies natural features that are important for maintaining biodiversity and healthy ecosystem function within a region. For example, larger and more compactly shaped natural patches in the landscape tend to hold and maintain more species than smaller, irregularly shaped patches; a greater area of the landscape containing streamside natural vegetation has been linked to improved regulation of flood water; and more connected patches allow species to move, preserving genetic diversity and ecosystem resilience in the landscape over time (Forman and Godron 1986, Forman 1995). Table 7 provides a list of commonly used landscape features corresponding to specific ecosystem services or functions, based on the scientific literature. A Landscape Scale Analysis can be conducted at various scales, including regional (e.g., Henson et al. 2005a), watershed, municipal or sub-municipal.

The Credit River Watershed Landscape Scale Analysis involved assessing natural and semi-natural features of the watershed with respect to the ecological functions they provide. The Analysis was conducted through the following steps (Figure 1):

1. Identify the **scale and the resolution of measurement** (these are often dictated by study goals and data availability);
2. Gather background data on the area of interest to provide appropriate context;
3. Identify **features that contribute highly to ecosystem function at the scale of interest through well-established landscape ecology and conservation biology principles**. For example, the presence of woodlands adjacent to streams is linked to improved water quality, water temperature and aquatic habitat.
4. **Score existing natural and semi-natural features** for their relative importance in contributing to watershed ecosystem function, using existing guidelines, best practices, and expert opinion to develop criteria and thresholds. For example, various documents (e.g., OMNR 2010) refer to woodlands of particular sizes as contributing highly to ecosystem function.

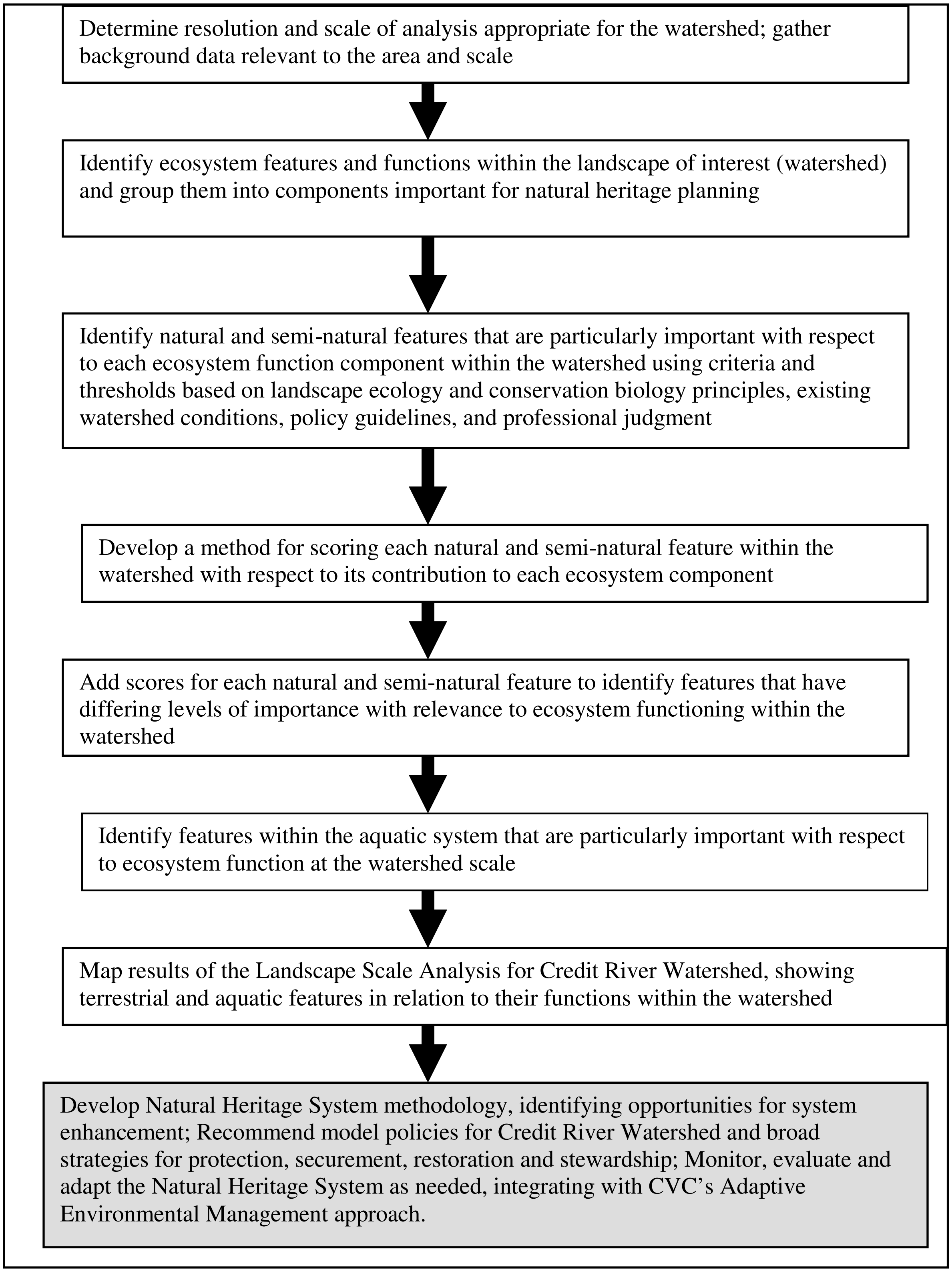
5. **Identify aquatic features** within the watershed that are important for ecosystem function at the watershed scale.
6. **Aggregate scores for the natural and semi-natural features in the watershed** and **identify habitat patches and aquatic features providing relative levels of ecological function** at the watershed scale.

Table 7: Features contributing to ecosystem functioning in the Credit River Watershed, along with supporting scientific literature.

Feature	Linkage between feature and ecosystem function	Relevant literature linking feature and function
Woodlands **Wetlands** **Successional habitat** **Valleylands and riparian habitat**	Larger woodland, wetland, or successional patches tend to support greater biodiversity than smaller patches under similar conditions; support increased groundwater recharge; possess greater potential for withstanding anthropogenic and natural disturbances; are source populations for other patches; control erosion; and sequester carbon. Woodlands (including forests, swamps, plantations, and cultural woodlands) provide habitat for the majority of species in the Credit watershed. Small urban woodlands in the watershed gain disproportionate importance relative to their size because they support airborne pollution uptake, provide shelter for migratory species, provide opportunities for local recreation and education, and relieve anthropogenic pressure on other, more sensitive woodlands. Wetlands of all sizes and hydroperiods provide critical species habitat as well as nutrient removal, carbon sequestration, flow moderation, sediment control, and biogeochemical cycling. Urban wetlands provide shelter for migratory species, opportunities for local recreation, education, and research, and relieve anthropogenic pressure on other, more sensitive wetlands. Successional habitats including meadows, thickets, and savannahs provide species habitat, including grassland bird and top predator (raptor) hunting grounds and migratory bird stopover habitat. A number of watershed woodland and wetland species utilize meadows, savannahs or thickets for part of their life cycle. Watercourses and adjacent natural areas including valleylands provide aquatic and terrestrial habitat or support aquatic productivity downstream. Terrestrial natural areas containing or adjacent to streams are transitional areas between aquatic and upland terrestrial systems. They provide aquatic habitat, filter sediment and nutrients, shade and cool surface water, and contribute organic and inorganic matter to watercourses. Natural areas adjacent to water bodies are important because they support watershed hydrologic functioning, biochemical cycling, species	Burke and Nol 2000; Castelle et al. 1994; Crawford and Semlitsch 2007; Environment Canada 2004; Environmental Law Institute 2003; Friesen et al. 1999; Forman 1995; Gartner Lee 2002; Gabor et al. 2001; Golet et al. 2001; Lee et al. 2001; Lee et al. 2002; Lindenmayer et al. 2002; MacArthur and Wilson 1967; Mayer et al. 2005; Mortberg 2001; Naiman and Decamps 1997; Naiman et al. 1993; OMNR 1999, 2000, 2010; Packett and Dunning 2009; Rowsell 2003; Semlitsch and Bodie 1998; Shafer 1995; Spackman and Hughes 1995; Wilson and Imhof 1998

Feature	Linkage between feature and ecosystem function	Relevant literature linking feature and function
	habitat, and species movement functions.	
Patch containing ELC community series diversity **Patch containing uncommon vegetation communities**	Greater community diversity in a natural patch means that there are a greater number of habitats within the patch, promoting greater biodiversity. Uncommon vegetation communities maintain biodiversity within the watershed and are identified for protection in CVC subwatershed plans. Provincial policy additionally provides protection for habitat of species at risk and rare vegetation communities.	Forman 1995; OMNR 1999, 2000, 2010; Ontario Nature 2004; Henson et al. 2005a, OMMAH 2005a
Patch contributing to ecological proximity	The matrix, or the type of landscape surrounding a patch, plays an important role in facilitating or limiting species movement across the landscape and among like or unlike natural patches. Matrix quality has commonly been identified using the percent of natural area contained within 2km of a patch (TRCA 2007, Henson et al. 2005a). Natural patches with higher matrix quality (more natural area surrounding them) tend to be associated with greater biodiversity.	Austen and Bradstreet 1996; Debinski et al. 2001; Fahrig 2001; Henson et al. 2005a; Herrmann et al. 2005; Lee et al. 2001; Lindenmayer and Franklin 2002; Saunders et al. 1991
Patch contributing to regional connectivity: Credit River and main branches	River valleys form the 'backbone' of a watershed (OMNR 1999). Natural areas along rivers and their main tributaries serve as regional movement and habitat corridors for a number of plant and wildlife species. Corridors containing water sources are considered more significant in terms of their ability to support wildlife than similar corridors without water (OMNR 2000).	Environmental Law Institute 2003; Henson et al. 2005a; Noss and Harris 1986; OMNR 1999, 2000, 2010; Semlitsch and Bodie 2003; Wichert et al. 2005
Patch contributing to provincial connectivity: Niagara Escarpment, Oak Ridges Moraine, Greenbelt Natural Heritage System, and Lake Ontario shoreline	Natural areas within or in close proximity to one or more regional or provincial corridors permit species movement at larger scales, promoting genetic diversity and ecological resilience. Natural areas within the Niagara Escarpment, Oak Ridges Moraine, and Greenbelt Natural Heritage System link the Lake Ontario shoreline and the Credit River with the broad north-south corridor of the Niagara Escarpment and the east-west corridor of the Oak Ridges Moraine, permitting long range genetic movement, adaptation, and evolution. Natural areas from line of wave action of Lake Ontario up to 2km inland support migratory stopover sites for land and shore birds and shoreline dependent species. Other corridors such as the Paris Moraine and the Eramosa River – Blue Springs Creek Wetland Complex provide opportunities for cross-watershed species movement and gene flow.	Environmental Law Institute 2003; Ewert et al. 2006; Henson et al. 2005a; Lake Ontario Biodiversity Conservation Strategy Working Group 2009; Noss and Harris 1986; OMNR 1999, 2000, 2010; Semlitsch and Bodie 2003; Waterfront Regeneration Trust 1995; Wichert et al. 2005

Figure 1: Schematic showing steps in the Landscape Scale Analysis of the Credit River Watershed. Future work is shown in shaded grey boxes.



7.1 Strengths and limitations of Landscape Scale Analyses

It is important to know what a Landscape Scale Analysis can and cannot do. It is a science based analysis capable of identifying and prioritizing for protection a set of natural habitats that provide or have the potential to ensure the healthy functioning of an area of interest. Consideration of large areas (on the scale of species movements) and long time frames (to allow for adaptation and evolution) are critical for planning and implementing the conservation of biodiversity and ecosystem functions. An analysis at a watershed scale can help identify which areas within the watershed are significant for maintaining ecosystem functions. A Landscape Scale Analysis can be integrative, identifying features that are important for land and water related functions. Further, it can identify local connections that allow species to move among natural habitats, improving the resilience of the system; and it can identify corridors that connect the system to larger, bioregional natural systems. A Landscape Scale Analysis is a key first step in identifying a Natural Heritage System for an area of interest.

There are a few things the Landscape Scale Analysis cannot do. First, an LSA cannot determine the composition or level of ecological integrity of the natural habitats in the analysis. To use an example, it cannot specifically identify woodlands that contain a high proportion of native plant species, or meadows that support viable populations of grassland birds. However, it does identify high quality sites, that is, areas that have the potential to provide multiple ecological functions by virtue of their placement in the landscape. The Landscape Scale Analysis also contains data consistent across the watershed, and offers a credible, science based substitute for more detailed site level information which is lacking at a watershed wide scale. The Landscape Scale Analysis uses criteria (or measures) that have been proven to be related to ecological integrity (for example, larger patches are more likely to have less disturbed area and contain more diversity), adjacent land uses or land use history may have modified the structure and composition of specific natural or semi-natural areas. Ecological integrity itself is best determined through detailed site level studies, such as the Natural Areas Survey (City of Mississauga 2006) or the Natural Areas Inventory (currently being undertaken by CVC). The analysis uses existing, well-established principles of landscape ecology or conservation biology to determine the functions that a particular habitat supports, or is capable of supporting.

Second, because the analysis uses GIS data from air photo interpretation at a relatively coarse scale (1:10,000) and a percentage of field verification, a certain degree of error is inherent in the analysis such that field measurements may not correspond exactly to measurements made on the map. In urbanizing areas, land use changes are constantly occurring. Therefore mapping requires constant updating in order to remain accurate, and at any point in time the analysis may include lands that are currently under development or that are slated for development. Credit Valley Conservation has recently updated its ELC mapping based on 2007 aerial photography. Hence mapping errors will be minimized during the Landscape Scale Analysis. A recent accuracy assessment of ELC mapping for the City of Mississauga involved a random survey of 30% of the City's area, or 583 samples. Results showed that CVC's ELC mapping had 90% accuracy, above the generally accepted threshold of 80%, in identifying the following classes: woodland, wetland, successional, aquatic, other natural (e.g. beach/bars), agriculture, open space, residential, commercial/industrial, and educational/institutional (CVC 2008 *unpublished data*).

In general the strengths of landscape scale analyses far outweigh their weaknesses. Consequently this level of analysis and accuracy is generally considered acceptable for implementation into municipal Official Plans. Spatial analyses have been used extensively in designing significant features or systems in Ontario (Lower Trent Conservation 2001, NHIC 2002, Gartner-Lee Ltd. 2002, OMMAH 2002, Rowsell 2003, OMMAH 2004c, NVCA 2004, Dougan and Associates 2009, UTRCA 2003, City of Hamilton 2005, 2006, City of Mississauga 2005, Henson et al. 2005a, Regional Municipality of Peel 2005, Region of Waterloo 2006, Wichert et al. 2005, Cataraqui Region Conservation Authority 2006, City of London 2006, UTRCA and County of Oxford 2006, The Land Ethic Group 2006, Toronto and Region Conservation Authority 2007, Beacon Environmental and LSRCA 2007, North-South Environmental Inc. et al. 2009). This level of accuracy is also sufficient to drive stewardship, securement, and restoration strategies.

As planning applications generally require additional site level study (e.g., Environmental Impact Study), the boundaries of the system and the functional importance of its component natural features can be refined at that time.

In addition, much of the watershed's lands are privately owned. The implementation of any Natural Heritage System study needs to be sufficiently adaptable and flexible in its application without compromising the overall health and functioning of the system and its component features.

A watershed scale Natural Heritage System is part of a hierarchical framework for protecting features and functions within a watershed. Subwatershed or smaller scale subregional studies help to refine the watershed scale Natural Heritage System by identifying locally important features and functions and establishing system or feature boundaries. Credit Valley Conservation has completed a number of subwatershed studies that identify high quality sites at the subwatershed scale (e.g., CVC 2003a, 2003b, 2007c). Site level studies provide guidance for specific protection, restoration, or stewardship activities within the system.

7.2 Scale and resolution of measurement

For the purposes of this Landscape Scale Analysis, the area included within the jurisdiction of Credit Valley Conservation was defined as the landscape. The study was limited to the Credit Valley Conservation jurisdiction for two main reasons: 1) CVC is authorized to carry out a Natural Heritage System Study within its jurisdiction and with a watershed focus, as authorized by the *Conservation Authorities Act*; 2) As a consequence of area jurisdiction, much of the data used in the analysis were available only for the area contained within the watershed. However, it was recognized that species and ecosystem functions cross this jurisdictional boundary, and the analysis attempted to take this into account to the extent possible. Design of the Natural Heritage System will take into account the need for system connectivity to neighboring watershed systems such as the Humber, Grand and Nottawasaga.

The Landscape Scale Analysis focused on the functional assessment of natural and semi-natural features and aquatic features within the boundary of the Credit River Watershed.

A review of existing spatial data for the CVC jurisdiction was conducted to assess the best ecological and non-ecological data available for the landscape characterization. The most detailed base layer for ecological data was the ELC (Ecological Land Classification) community series (OMNRSTU 1996, Lee et al. 1998, OMNR 1999) and land use layer, at a scale of 1:10,000. The CVC ELC layer used for the analysis was last updated in 2008.

The ELC community series data formed the basis of the Landscape Scale Analysis. Individual **ELC community series** were aggregated into four different types of **communities**: Forest, Wetland, Successional, and Cultural Forest, with a fifth community, Woodland, which crossed categories and included forest, cultural forest, and treed wetlands (Tables 8 and 9, and Figure 2). In turn, communities were aggregated into **habitat patches**, which were defined as natural or semi-natural areas separated from other habitat patches by a different land use type or a 30m gap on a 1:10,000 scale air photo (Appendix B, CVC 1998; Tables 8 and 9; Figure 2). Examples of natural areas are forests and wetlands; examples of semi-natural or cultural communities are cultural meadows, cultural thickets, and cultural woodlands. Because non-forested wetland units (marsh, fen, and bog) are difficult to identify to community series through air photo interpretation, these were generally grouped into the ELC community class ‘marsh’ in the analysis. Information on other natural but rare communities such as prairies or sand barrens was not available for analysis at this scale.

Table 8: Definitions of units used in the Credit River Watershed Landscape Scale Analysis, using Ecological Land Classification (ELC) except where indicated.

Habitat patch:
A habitat patch is defined as a contiguous area, boundaries delineated by a >=2mm gap on a 1:8000 air photo (CVC 1998). It includes natural and semi-natural communities. Habitat patches were uniquely identified based on their Habitat ID. Figure 2 provides an example of the structure of a habitat patch.

Community:
A community is defined as a contiguous, relatively homogeneous area, boundaries delineated by a patch of a different type or by a 30mm gap on a 1:10,000 air photo (CVC 1998). A community consists of one of the following types: Forest, Wetland, Cultural Forest, or Successional. A fifth community type, Woodland, consists of a combination of Forest, Cultural Forest, and treed Wetland.

Forest
A Forest is defined as a terrestrial vegetation community with at least 60% tree cover (Lee et al. 1998). In this analysis, the following ELC communities were defined as Forest: coniferous forest, deciduous forest, and mixed forest.

Wetland
A Wetland is defined as an area of land that is saturated with water long enough to promote hydric soils or aquatic processes as indicated by poorly drained soils, hydrophytic vegetation and various kinds of biological activity that are adapted to wet environments (Lee et al. 1998). The following ELC communities were defined as Wetlands: coniferous swamp, deciduous swamp, mixed swamp; marsh; and thicket swamp.

Successional
A Successional patch is human disturbed land dominated by native and non-native graminoid or shrub vegetation (CVC 1998). The following ELC communities were defined as successional: cultural meadow, cultural savannah, and cultural thicket.

Cultural Forest
A cultural forest is defined as a cultural community with >35% tree cover; this includes coniferous plantation, deciduous plantation, mixed plantation; and cultural woodland. The definition of plantation excludes areas that are managed for the production of fruits, nuts, Christmas trees or nursery stock (CVC 1998).

Woodland (PPS definition)
The Provincial Policy Statement (OMMAH 2005a) defines woodlands as follows: *"Woodlands means treed areas that provide environmental and economic benefits such as erosion prevention, water retention, provision of habitat, recreation and the sustainable harvest of woodland products. Woodlands include treed areas, woodlots, or forested areas and vary in their level of significance"*.

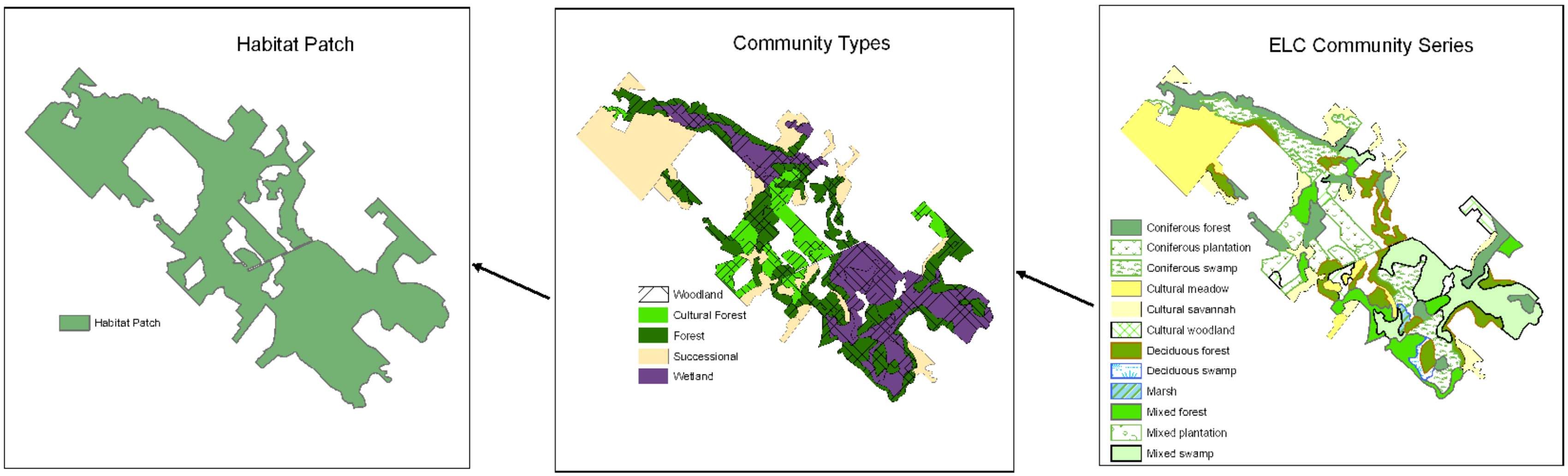
ELC community series
An ELC community series is a relatively homogeneous area identified by the type of cover (open, treed, or shrub) as well as plant form (deciduous, coniferous, or mixed) that is characteristic of the area. It is a unit that is normally visible and consistently recognizable on an air-photo or a combination of maps, air-photo interpretation and other remote sensing techniques. Community Series are the lowest level in the ELC classification that can be identified without a site visit (Lee et al. 1998). Examples of community series are: deciduous forest, mixed forest, thicket swamp.

Table 9: Community types of the Credit River Watershed based on ELC community series or class[1, 2, 3] (Lee et al. 1998).

Habitat patch[2]	Community type	ELC (Ecological Land Classification) series
Habitat patch	**Forest**	Coniferous forest (FOC) Deciduous forest (FOD) Mixed forest (FOM)
	Wetland	Coniferous swamp (SWC) Deciduous swamp (SWD) Mixed swamp (SWM) Marsh or Bog/Fen[1] (MA or BO/FE) Thicket swamp (SWT)
	Successional	Cultural savannah (CUS) Cultural thicket (CUT) Cultural meadow (CUM)
	Cultural Forest	Coniferous plantation (CUP3) Deciduous plantation (CUP1) Mixed plantation (CUP2) Cultural woodland (CUW)
	Woodland[3]	Coniferous forest (FOC) Deciduous forest (FOD) Mixed forest (FOM) Coniferous swamp (SWC) Deciduous swamp (SWD) Mixed swamp (SWM) Coniferous plantation (CUP3) Deciduous plantation (CUP1) Mixed plantation (CUP2) Cultural woodland (CUW)

[1]Marshes and bogs/fens are ELC community classes. However, air photo interpretation does not permit distinction of these categories, or classification of these wetlands to the community series layer. Therefore, non-forested wetland communities were classified as marshes in this analysis. For the sake of brevity and to minimize confusion, all the above ELC units are referred to as ELC community series in the text.
[2] The ELC categories of Beach/Bar (BB) and Bluff (BL) were also included in the delineation of a habitat patch, but because they were small in size (generally <=2ha), they were not analyzed in the landscape characterization except as they contributed to the area of a habitat patch.
[3] A fifth community type, namely **Woodland**, was created for part of the analysis involving the importance of wooded areas for species habitat based on the PPS definition. This patch was composed of a combination of other patch components with significant tree cover: coniferous/deciduous/mixed forest, coniferous/deciduous/mixed swamp, coniferous/deciduous/mixed plantation, and cultural woodland.

Figure 2: Schematic showing scales of analysis in landscape characterization: ELC community series, community, and habitat patch scales. ELC community series units listed in the figure are clustered into communities, which in turn are merged into habitat patches that represent most natural or semi-natural features in the Credit watershed. Areas outside a habitat patch may be agricultural, urban or aquatic. See Tables 8 and 9 and Glossary for definitions and composition of units.



The Landscape Scale Analysis was conducted on habitat patches (Tables 8 and 9; Figure A14, Appendix A), although data at finer scales were also incorporated into the analysis. Habitat patches were selected as the primary unit for landscape analysis because approximately half of all wildlife species in the Credit watershed depend on more than one habitat or community type (CVC 2002a, 2002b, 2002c) for completion of their life cycle. For example, Leopard Frogs breed in wetlands but disperse to adjoining meadows and other open habitats for the summer. Spotted Salamanders travel in spring from overwintering sites located below ground in forests to vernal pools for breeding. Once the breeding season is over, the adults then move back into upland forest habitat to forage, while their young remain in the pool until late summer to complete development. The Red-shouldered Hawk depends on high quality wetland habitat for feeding on amphibians or reptiles, but nests in high quality upland or lowland forest. The Sharp-shinned Hawk hunts at woodland edges and in meadows but prefers to nest in very dense coniferous or mixed forest. The Wood Duck prefers to nest in cavities in old trees in forests next to open water, taking its ducklings to nearby rich wetlands for refuge and food. Blue-winged Teals and Mallards nest in upland meadows and take their young to wetlands for feeding.

Table 10 shows the percentage of species that utilize the different types of communities within the watershed, based on 2002 data (CVC 2002a, 2002b, 2002c).

In landscapes fragmented by roads and other land uses that make the landscape relatively impermeable to movement of certain species or species groups, it is critical that areas used for breeding, feeding, movement, and reproduction are kept as contiguous as possible. Second, habitat patches and communities are the scale at which one can most likely capture the potential for both smaller (e.g., mouse, herbs) and larger (e.g., red-tailed hawk, coyote, tree) species to survive and move or spread within the watershed.

It is worth noting that a high proportion of all species in the Credit watershed also utilize agricultural lands (particularly non-intensive agricultural lands such as hayfields and wet meadows) in some way including movement or feeding. Agricultural lands in rural areas of the watershed are important not only for maintaining biodiversity and permitting species movement in the Credit watershed but also for acting as buffers against disturbance of existing natural and semi-natural features.

The minimum mapping unit was set at 0.5ha, because this is generally the smallest area that can be determined with accuracy through air photo interpretation (CVC 1998) at a scale of 1:10,000. Therefore, only communities greater than or equal to 0.5ha (rounded to the nearest 10^{th} of a hectare) were mapped (see GIS Methodology in Appendix for details). Landscape features smaller than 0.5ha were merged with their adjoining feature and were not used in the analysis. Habitat patches within the Credit River Watershed are shown in Figure A14 (Appendix A).

Small habitat patches (<0.5ha) constitute a very small percentage of watershed area (86 patches, comprising 12ha in total or 0.01% of the watershed). Therefore, exclusion of these small habitat patches from the analysis has little effect on the Landscape Scale

Analysis of the Credit River Watershed, although this does not necessarily mean that their protection at a local scale based on a site specific analysis is unimportant. Some features smaller than 0.5ha have been deemed significant at provincial or local scales (e.g., Provincially Significant Wetlands) based on field studies and as such will form part of the Natural Heritage System for the Credit River Watershed.

Table 10: Terrestrial wildlife species utilizing[1] communities and community combinations in the Credit River Watershed.

Community type or community combination[1]	Number of species utilizing[2] habitats	Percent species utilizing habitats
Forest and Cultural Forest	220	70%
Wetland	260	83%
Successional	191	61%

[1]In this analysis, 'Forest and Cultural Forest' includes the ELC categories of deciduous, coniferous, and mixed forest; deciduous, coniferous and mixed plantation; and cultural woodland. 'Wetland' includes the ELC categories of deciduous, coniferous, mixed, or thicket swamp, marsh, fen and bog. 'Successional' includes the ELC categories of cultural meadow, cultural savannah, and cultural thicket. Categories are not exclusive, that is, species shown as utilizing one type of habitat (e.g., Successional) frequently utilize other habitats for their life cycle requirements. See glossary for definitions of ELC categories.
[2]'Utilizing' indicates that a species prefers or utilizes the habitat(s) for breeding, feeding, denning, wintering or movement (CVC 2002a, 2002b, 2002c).

7.3 Identification of features related to ecosystem function

Important steps in natural heritage system planning are to identify natural and semi-natural features within the study area and to assess their ecological importance (OMNR 1999, 2010). Features (in this study, habitat patches) that rank high in functional importance based on sound landscape ecology and conservation biology principles can later be used to identify priority areas for conservation: in general, larger natural features are better than smaller ones; features near streams are preferred over those farther away from streams; features with greater habitat diversity are generally preferred over lower habitat diversity; features that are connected locally and to regional wildlife corridors are preferred over isolated features. Table 7 provides a review of scientific principles and literature relating features to their ecosystem functions and ecosystem services.

The Landscape Scale Analysis was used as a tool to assess features based on their contribution to ecosystem function within the Credit watershed. Features identified were based on well established conservation biology principles and have been used or recommended by others to varying degrees to identify Natural Heritage Systems or significant features (OMNR 1999, 2010, Lower Trent Conservation 2001, NHIC 2002, OMMAH 2002, 2004a, 2004b, 2004c, 2005, NVCA 2004, Dougan and Associates 2005, 2009, UTRCA 2003, City of Hamilton 2005, 2006, City of Mississauga 2005, Henson et al. 2005a, Regional Municipality of Peel 2005, 2009, Region of Waterloo 2006, Wichert et al. 2005, Cataraqui Region Conservation Authority 2006, City of London 2006, The The Land Ethic Group 2006, Beacon Environmental and LSRCA 2007, North-South Environmental Inc. 2009, North-South Environmental Inc. et al. 2009).

Features used in previous natural heritage planning studies are as follows:

- **Patch area** (e.g., woodland or wetland area; Lower Trent Conservation 2001, UTRCA 2003, City of Hamilton 2004, OMMAH 2004c, City of Mississauga 2005, Dougan and Associates 2005, Henson et al. 2005a, Regional Municipality of Peel 2005, TRCA 2007, Region of Waterloo 2006, Beacon Environmental and LSRCA 2007, North-South Environmental Inc. 2009, North-South Environmental Inc. et al. 2009, Regional Municipality of Peel 2009)
- **Forest interior or shape** (Lower Trent Conservation 2001, UTRCA 2003, City of Hamilton 2004, Dougan and Associates 2005, Henson et al. 2005a, Cataraqui Region Conservation Authority 2006, TRCA 2007)
- **Slope** (Dougan and Associates 2005)
- **Matrix influence or matrix quality** (a local proximity analysis that utilizes natural cover within a 2km radius; Henson et al. 2005a, TRCA 2007)
- **Proximity to another natural heritage feature** (Lower Trent Conservation 2001, UTRCA 2003, OMMAH 2004b, 2004b, Dougan and Associates 2005, Cataraqui Region Conservation Authority 2006, Beacon Environmental and LSRCA 2007, North-South Environmental Inc. et al. 2009)
- **Areas of potential sensitive groundwater recharge or discharge** (Dougan and Associates 2003, UTRCA 2003, OMMAH 2004a, Dougan and Associates 2005)
- **Riparian zone, valleyland, and/or floodplain** (Lower Trent Conservation 2001, Dougan and Associates 2003, UTRCA 2003, City of Hamilton 2004, City of Mississauga 2005, Dougan and Associates 2005, Henson et al. 2005a, Cataraqui Region Conservation Authority 2006, The Land Ethic Group 2006, Beacon Environmental and LSRCA 2007, North-South Environmental Inc. 2009, North-South Environmental Inc. et al. 2009)
- **Corridors for species movement** (UTRCA 2003, OMMAH 2004b, Henson et al. 2005a, North-South Environmental Inc. 2009, North-South Environmental Inc. et al. 2009)
- **Diversity of vegetation communities** (Dougan and Associates 2003, 2005, Henson et al. 2005a, North-South Environmental Inc. et al. 2009)
- **Roadlessness; distance from roads** (Henson et al. 2005a)

Certain measures were not included in this analysis. Patch shape is closely related to biodiversity and species habitat, with shapes that contain greater interior area being more valuable for long term species survival and biodiversity than more linear or narrow shapes (OMNR 1999, 2010, Forman and Godron 1986, Forman 1995, Gutzwiller 2002). Shape was an inappropriate measure for this Landscape Scale Analysis because under the definition of habitat patch, habitat patch boundaries were frequently roads, resulting in rectilinear boundaries for most habitat patches. Further, the size criterion can be used to capture areas that contain some interior (some larger patches contain interior area, and all patches containing interior area have a relatively large area in a southwestern Ontario context). Nevertheless, shape is an important measure because if a patch is shaped such that it encloses significant interior or non-edge area, then that patch becomes important for species habitat and biodiversity over the long term.

Areas of high groundwater recharge are very important from a natural heritage planning perspective (OMMAH 2005a) because these areas constitute strong links between surface and ground water, and assist in maintaining natural watershed hydrology. Conservation of groundwater resources is also recommended for maintaining biodiversity and ecological function (Chu et al. 2008, ECO 2000). However, groundwater mapping was ultimately excluded from the Landscape Scale Analysis because of the difference in scales used to map groundwater recharge areas vs. other natural features. Groundwater recharge areas are delineated based on a relatively coarser scale of mapping, whereas other natural heritage features are mapped on a finer scale.

Road density was also excluded from analysis because most habitat patches were delineated (and therefore bounded) by roads. However, there is no doubt that roads pose significant barriers to species movement and have a severely deleterious effect on species and ecosystem health (Forman 2000, Trombulak and Frissell 2000, Hels and Buchwald 2001, Mazerolle 2004, Gibbs and Shriver 2005, Strasberg 2006, Palomino and Carascal 2007, Karraker et al. 2008). Development of the Credit River Watershed Natural Heritage System will include an analysis of road impacts with recommendations for mitigating the barrier effect of roads where feasible.

The watershed Landscape Scale Analysis was limited to features that were available at a reasonable level of accuracy within the 1:10,000 scale mapping for the entire watershed. Due to this limitation, there are a number of other ecologically important features that could not be mapped or used in the analysis due to incomplete information at the scale of this analysis (i.e., at watershed scale). These included old growth woodlands, rare vegetation communities, habitat of species at risk, fish habitat, and significant wildlife habitat, all identified by the province as important features for inclusion in a Natural Heritage System (OMNR 1999, 2000, 2010). Their inclusion within a Natural Heritage System contributes to maintenance of the full range of biodiversity and improves the resilience of the system, but because these features have not been exhaustively catalogued for the watershed and require field studies for confirmation, they are best identified through finer scale studies rather than in this Landscape Scale Analysis.

Feature characteristics used in the watershed Landscape Scale Analysis were almost all highly skewed in distribution; for example, the watershed has a large number of very small forests, and relatively few large forests. Because of these skewed distributions, the mean and standard deviation are not useful for accurate description of these measures. In such cases, percentile values (e.g., median) provide better representation of the central tendency or distribution of these measures (Zar 1999).

7.4 Scoring methodology

All habitat patches greater than 0.5ha were assessed in the Landscape Scale Analysis for their relative importance in ecosystem functioning within the Credit River Watershed based on nine specific criteria and thresholds. The assessment included a simple scoring system wherein a habitat patch received a score of one if it met the threshold for a criterion and a score of zero if it did not. A habitat patch receiving a score of one for a specific criterion was considered to be a high functioning patch with respect to that criterion. A score of zero does not imply that the habitat patch is not providing any ecosystem function; it simply suggests that the patch contributes to a lesser degree to ecosystem function at the watershed scale relative to other habitat patches. The following section describes the specific criteria and thresholds used to score a habitat patch.

All nine criteria received equal weighting because there was little ecological justification for specific relative weightings for the different criteria.

At the conclusion of the Landscape Scale Analysis, all habitat patches in the watershed received scores that ranged from a minimum of zero (the habitat patch was not high functioning with respect to any criteria) to nine (the habitat patch was high functioning with respect to all nine criteria). The overall score represented patch quality at the watershed scale.

7.5 Identification of criteria and thresholds for scoring habitat patches

Identification of high functioning habitat patches proceeded in two ways: 1) Available federal or Ontario provincial guidelines for natural heritage protection provided policy or planning context for protection of specific natural features and functions; 2) Where federal or provincial guidelines were not available, the analysis of existing conditions within the watershed, best practices, expert opinion, or top percentile values were used to identify high functioning habitat patches. In all cases, the best available science guided the development of criteria and thresholds.

Available federal guidelines included the Environment Canada document *How Much Habitat is Enough* (Environment Canada 2004). In this document, Environment Canada has provided science based criteria to guide habitat rehabilitation in Great Lakes watersheds. Where applicable, criteria for the Credit watershed were developed using the scientific literature on which the guidelines were based.

Ontario provincial guidelines used in identifying features or functions for protection included the Ontario *Provincial Policy Statement* (*OMMAH 2005a)* and related Ontario Ministry of Natural Resources documents: the *Natural Heritage Reference Manual* (OMNR 1999, 2010) and *Significant Wildlife Habitat Technical Guide* (OMNR 2000). Where applicable, reference was made to best practices applied by planning authorities in southern Ontario.

For features that did not have provincial or federal guidelines, threshold values were derived through available science, analysis of existing conditions within the watershed, best practices, or technical committee and peer reviewers' expert opinion. The 75th percentile was used as one guideline to be combined with technical committee and peer reviewers' expert opinion where other guidelines or best practices were absent. The 75th

percentile threshold was selected for several reasons: 1) there already exists a precedent for using this threshold. The Ministry of Environment commonly uses the 75th percentile value for background conditions and to compare against water quality objectives; 2) the 75th percentile was felt to be a reasonable threshold for determining relative importance within a given range of values; 3) the 75th percentile has been considered a reasonable threshold in another natural heritage study (Dougan and Associates 2003); and 4) results from these and other analyses showed that the 75th percentile identified approximately one-third of the study area as high functioning for at least one criterion. A minimum of 30% forest cover is recommended for watersheds and Areas of Concern (Environment Canada 2004), hence the 75th percentile appears to be a conservative threshold.

The section below titled '*Criteria and Thresholds for Landscape Scale Analysis*' describes specific criteria and thresholds used in scoring habitat patches within the Credit River Watershed Landscape Scale Analysis.

7.6 The importance of total natural cover

The total amount of natural cover in a landscape has a strong influence on biodiversity and ecological functions such as species movement and reproduction, although responses differ among species (Environmental Law Institute 2003 and references therein). Considerable research shows that the total amount of suitable habitat in an area is a very important explanatory variable of species distribution or abundance (Askins and Philbrick 1987, Andren 1994, Forman 1995, Fahrig 1997, 2001, 2002, Trzcinski et al. 1999, Austen et al. 2001, Golet et al. 2001, Mortberg 2001, Fahrig 2002, Lee et al. 2002, Rosenburg et al. 1999).

Research also suggests that as suitable habitat falls below 20-30%, fragmentation effects are apparent and the habitat configuration or the spatial arrangement of habitat patches becomes more important (Freemark 1988 cited in Environment Canada 2004, Andren 1994, Fahrig 1997). A simulation study found that fragmentation is likely to affect population survival when the breeding habitat of an organism covers less than 20% of the landscape (Fahrig 1998). For some species, both forest cover and the spatial arrangement of patches is important (Villard et al. 1999). A higher percentage of forest cover is also associated with stream health. Studies have shown that watersheds with at least 65% forest cover were associated with minimally impacted streams or a healthy aquatic insect community (Booth 2000, Booth et al. 2002) and that watershed tree cover greater than 45% was correlated with good and excellent stream health ratings (Goetz et al. 2003, CWP 2003).

Given that terrestrial natural cover (primarily forest and wetland) within the Credit watershed is at 18%, the spatial arrangement of patches gains importance, highlighting the need for both increasing total natural cover and improving spatial configuration of habitats, for example through a Natural Heritage System.

The extent of natural cover in the watershed dictates to some extent the thresholds for use in the Landscape Scale Analysis.

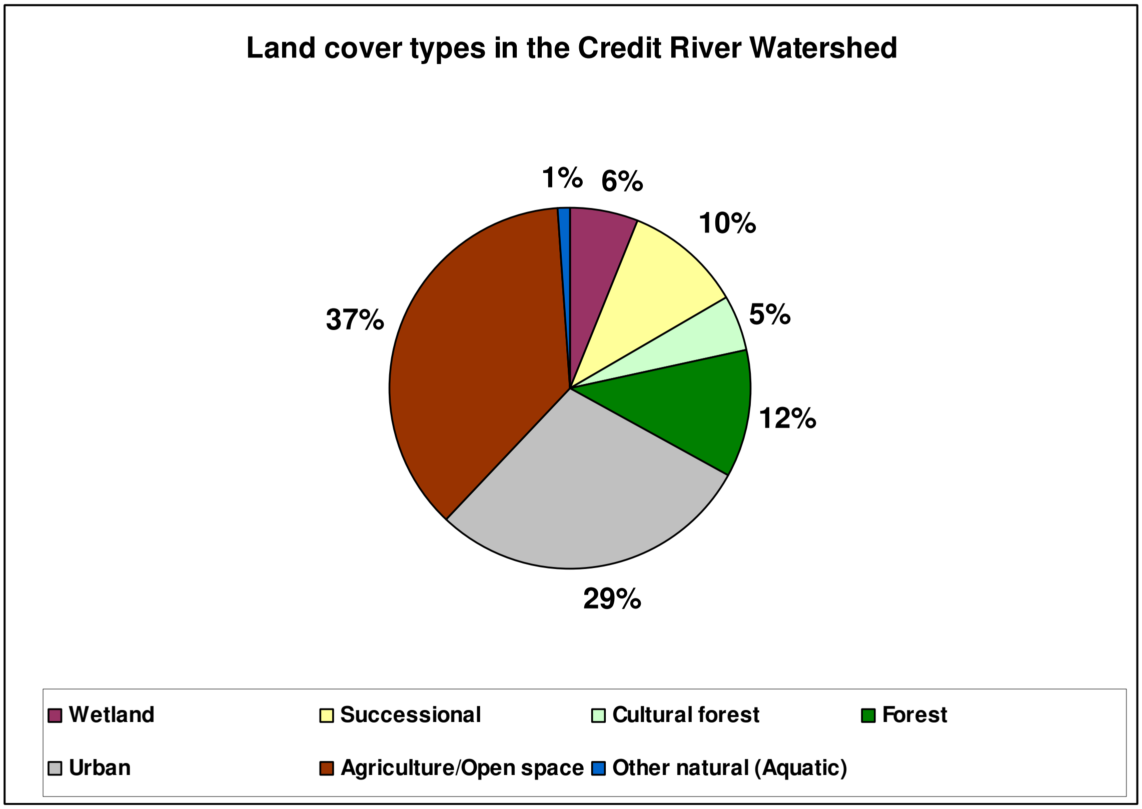
Watersheds with high amounts of total natural cover may have different thresholds for determining high functioning patches compared to those with low amounts of total natural cover. For example, as total natural cover declines, smaller forest patches that could be lost without great consequence in a highly natural watershed may be considered important for retention in a watershed with little remaining natural cover. In fragmented watersheds with lower amounts of natural cover, smaller patches play an important role in maintaining the existing set of species and ecosystem functions, while also playing an important social role when they are located in highly urbanized settings.

Figure 3 shows the extent of natural and semi-natural cover in the Credit watershed as a percent of total watershed area. Upland forests (i.e., coniferous, deciduous or mixed forest) represent about 12% of total watershed area. Wetlands, including swamps, represent 6%, and successional habitats such as meadows, thickets, and savannahs, represent 10% of watershed area (refer to Table 8 for definitions). Both forest and wetland areas in the watershed fall below Environment Canada minimum guidelines for maintenance of viable wildlife populations and system hydrology, and thresholds identified in the scientific literature (namely, at least 30% of watershed area under forest cover and greater than 10% of each major watershed in wetland habitat). Cultural Forests (plantations and cultural woodlands, see Tables 8 and 9) represent approximately 5% of watershed area. Cultural forests and cultural woodlands support a number of species in the Credit watershed (Milne and Bennett 2007), and as such play an important supporting role in contributing to overall woodland cover. When forests, treed swamps, plantations, and cultural woodlands were combined (see Tables 8 and 9), the resulting Woodlands community type covers 21% of total watershed area.

Urban areas account for 29% of total watershed area, while agriculture accounts for 37% of total watershed area and natural areas account for 34% (based on ELC data for the Watershed updated in 2008; Appendix B). The agriculture category includes manicured open spaces such as City parks maintained for recreation.

The Middle and Upper Watershed physiographic zones have woodland cover that might be considered good to moderate (at 31% and 24% respectively). Woodland cover is low in the Lower Watershed zone, currently at 7%; there are indications that this may be declining (e.g., City of Mississauga 2006).

Figure 3: Land cover types in the Credit River Watershed showing percent cover of natural and cultural communities in relation to total watershed area.



7.7 The role of agriculture and urban areas in ecosystem functioning

Agricultural and urban areas provide supporting habitat for a number of species. Farm lands in rural areas may function as linkages or movement corridors among natural areas as they do not impede the movement of some species. Hay fields are an important source of food for many species including declining grassland species (Bird Studies Canada et al. 2004, Brennan and Kuvlesky 2005). Agricultural land is pervious and permits the infiltration of water, contributing to maintenance of watershed hydrology. Hedgerows bordering fields provide pollen for insects, food and shelter for birds and small mammals, and movement opportunities for plants and wildlife in adjoining natural areas (Hannon and Sisk 2009, Wehling and Diekmann 2009, Van Geert et al. 2010). Naturalized riparian areas maintained by landowners provide organic inputs and shading for streams, remove pollutants from agricultural runoff, and function as habitat and movement corridors for a number of species. Most landowners demonstrate a strong environmental ethic and care for their land in ways that benefit and enhance existing natural areas.

Green spaces in urban areas such as backyard gardens, parks, golf courses, or commercial /industrial landscaping can often provide benefits for urban wildlife. Plantings of native species can help maintain native plant populations, support insect pollinators, and provide food for birds and small mammals. Decaying wood and leafy debris in gardens can support insects, fungi and bacteria. The urban forest, which includes street trees, shrubs, ground vegetation and forest remnants found within a city, contributes greatly to the health and well being of human residents (McNeil and Vava 2006). The urban forest provides habitat for a number of plant and wildlife species including migratory species and plays an important role in filtering and absorbing storm water runoff to improve in stream conditions for aquatic life. Unlike most developed areas, agriculture and open space lands retain the potential for restoration or stewardship to enhance ecological function.

Agricultural and urban areas cannot replace natural areas for supporting the full range of biodiversity and ecosystem function. These areas cannot support a range of sensitive wildlife species or plant species with specific habitat requirements (CWS 2007). However, they play a supportive role in natural heritage systems and agricultural lands in particular have been recognized by the province of Ontario as playing their part in natural heritage protection (OMMAH 2005a).

8. Criteria and thresholds for the Landscape Scale Analysis

8.1 A) Woodlands

It is now generally accepted that the bigger the natural area, the better for maintaining biodiversity and healthy, self-sustaining ecosystem function (Forman 1995, Shafer 1995, OMNR 1999, 2010, Burke and Nol 2000, Mancke and Gavin 2000, Mortberg 2001, Environment Canada 2004; Table 7). Because the number of species a natural area can support is strongly related to its size, size is one of the most important criteria for ensuring protection of biodiversity and the long term resilience of a natural system. Larger areas provide more habitat for the resource needs of species, tend to have a greater diversity of habitat types, and tend to have interior areas that support edge-intolerant species. Large natural areas are also somewhat more resilient to some of the negative effects of urbanization (such as domestic cat predation of birds, unsanctioned trails, invasive species, and litter).

Woodlands are critically important for the well being of humans and biodiversity in general. Forests and woodlands (which include other types of treed habitats such as plantations or swamps) play a strong role in global oxygen, carbon dioxide, and water cycles; moderate climate; store and purify water; prevent erosion and sedimentation; form soil; play a strong role in nutrient cycling; reduce air pollution in urban areas; provide food, fibre, genetic and medicinal resources, pollination and biological control services, and shelter; act as refugia and nurseries for species; and provide cultural, spiritual, aesthetic, and scientific information services (OMNR 1999, 2010, Costanza et al. 1997, de Groot et al. 2002). A number of studies have supported a 20-30% threshold of forest cover beyond which bird species persistence is likely to occur, or beyond which habitat configuration had little effect on species richness or abundance (Andren 1994, Fahrig 1997, Villard et al. 1999). Another study found that bird species favouring interior habitat conditions continue to increase in number from 20% to at least 35% of forest cover, depending on the scale of the analysis (Tate 1998). Currently, the Credit River Watershed has 12% forest cover (excluding supporting semi-natural cover such as plantations or cultural woodlands). Bird species are a very important wildlife component within the watershed, accounting for 77% of all reported terrestrial wildlife species in the watershed. Adequate habitat set aside for birds will likely result in self-sustaining populations of a number of other species that utilize the same natural communities as birds.

The significance of a woodland patch is a function of the percentage of vegetation cover in the area (Riley and Mohr 1994, OMNR 1999, 2010). In the past, 40ha was considered a minimum size for determining significant woodlands in watersheds containing between 15% and 30% natural woodland cover, based on area alone (OMNR 1999), but this is increasingly recognized as being too conservative and thresholds such as 20ha are now being recommended by OMNR (OMNR 2010) and thresholds such as 16ha in rural and 4ha in urban areas are being used (North-South Environmental et al. 2009). Other provincial guidelines for thresholds for significant woodlands are 0.5ha or 4ha (under the Oak Ridges Moraine Conservation Plan; Queen's Printer for Ontario 2007). For the

Greenbelt Natural Heritage System in the Protected Countryside, draft technical papers have identified 0.5ha, 1ha, 4ha, or 10ha as being significant woodlands (Greenbelt Natural Heritage System, OMNR 2008b), depending on woodland functions and the geographic location within the Greenbelt. A study of Neotropical migrant songbirds in southwestern Ontario reported high nesting success in small forest fragments surrounded by intensive agricultural use (Friesen et al. 1999).

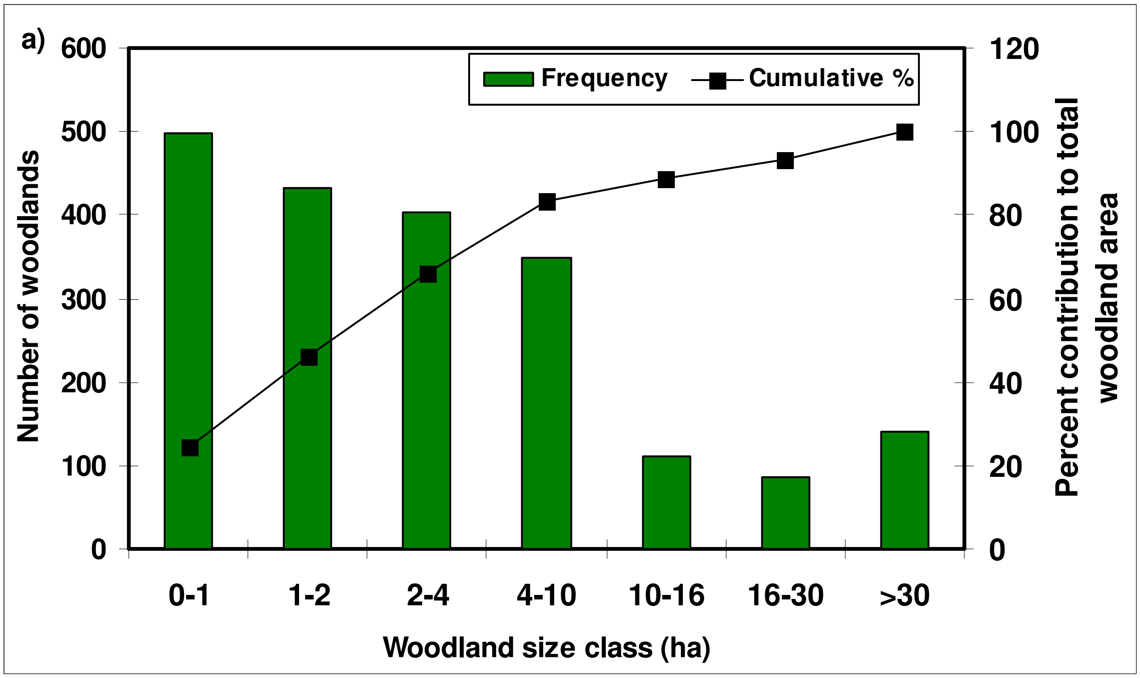
There are 2001 woodlands in the Credit River Watershed. The size of individual woodlands ranges from less than 0.5 hectare to 581ha (Figure 4a). The median size of woodlands is 2.2ha (i.e., half of all woodlands are above and half are below this size), a consequence of extensive fragmentation following European settlement. Only 17% of all woodlands are above 10ha.

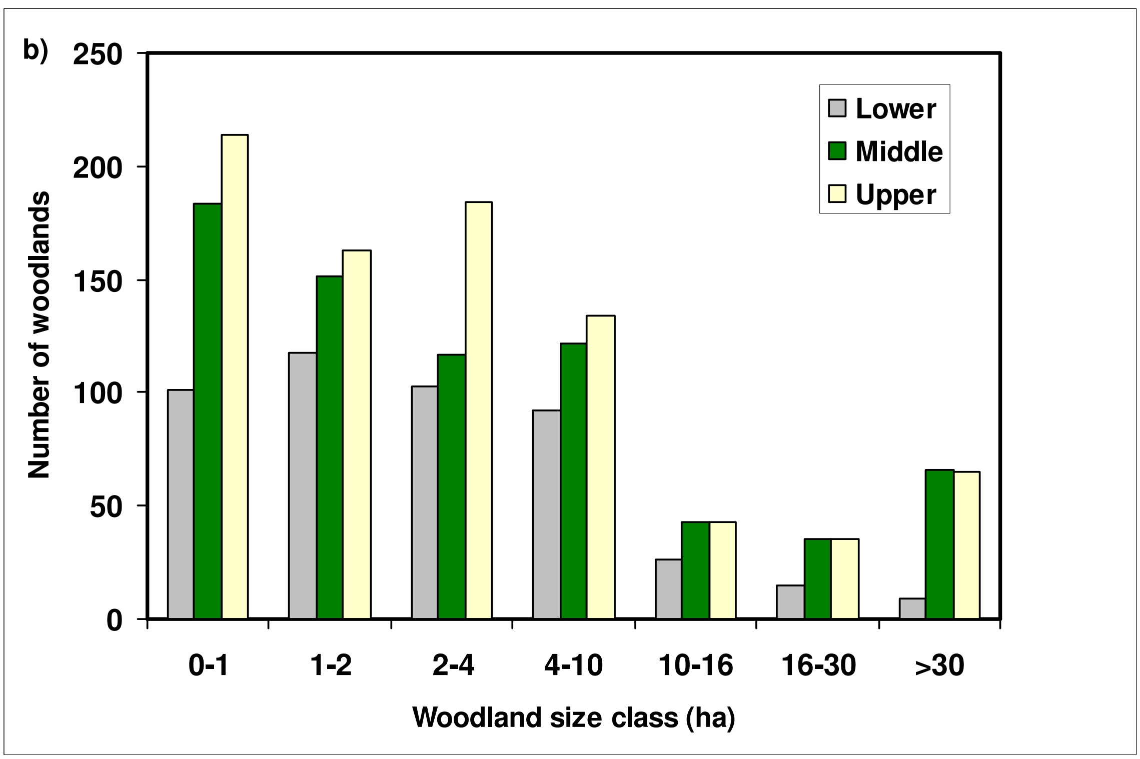
Larger woodlands play a key role in maintaining biodiversity as they contain a sufficiently large area interior from the edge. Habitat edges are associated with increased levels of light, sound, wind and other abiotic effects that deter ecological function and species presence or movement depending upon the species and intensity of the effect (Chen et al. 1999, Ries et al. 2004, Hilty et al. 2006). Edges are also associated with increased levels of nest predation, particularly when surrounding forest cover is low and edges are hard (Hartley and Hunter 1998, Batáry and Báldi 2004, Hilty et al. 2006). Large habitat fragments have been identified as important for maintaining forest-breeding birds in Ontario (Burke and Nol 1998). The impact of habitat edges is mediated by total natural cover - edges have lower impact when there is greater total natural cover in a landscape (Villard 1998).

Based on woodland size distribution in the watershed, it is likely that smaller woodlands play a role in maintaining overall biodiversity and ecosystem function within this fragmented landscape, particularly within the Lower Watershed. These woodlands serve as habitat for certain species, may support sensitive species if they are embedded in a well-forested matrix, and may function as linkages in the landscape.

Environment Canada guidelines recommend that at least one woodland in a watershed or other land unit be over 200ha to maintain watershed health (Environment Canada 2004). There are seven such woodlands in the Credit River watershed. All are located in the Middle Watershed and constitute the watershed's last remaining large intact areas. Areas such as these are considered to be hotspots of biodiversity for the watershed. Concerted efforts by CVC, municipalities, OMNR, the Ontario Ministry of Transportation and others will be necessary to ensure that these areas remain as unfragmented as possible over the long term.

Figure 4: Distribution of woodland size classes in the Credit River Watershed: a) all woodlands; b) woodlands by physiographic zone.





Forests within the Lower Watershed, particularly the City of Mississauga, are small in size (Figure 4b) but disproportionately important from a terrestrial, hydrologic and social perspective. Within the Credit River Watershed, these are the last remaining natural forests within the Iroquois Plain, South Slope and Peel Plain physiographic regions. They are also the last remnants of the Carolinian Ecozone within the watershed; this Ecozone is perhaps the most wildlife rich area in Canada, and also home to about one-third of Canada's species at risk. Woodlands in the Lower Watershed, particularly those within a few kilometers of Lake Ontario, provide critical resting and feeding areas for species making the long and energy consuming migration across or around Lake Ontario. Natural areas that support migrating species are considered Significant Wildlife Habitat (OMNR 1999, 2000, 2010) and in the Credit watershed, this entire potential habitat lies within the City of Mississauga. An Environment Canada study of forest breeding birds in urban areas has suggested that increasing vegetation species and height diversity, along with improving the urban tree canopy, may improve habitat for forest breeding birds and potentially provide habitat for migrating area-sensitive forest breeding birds (Environment Canada 2007). A literature review on migratory birds found that in rural and urbanizing contexts, even small woodlot patches can be of value (Dougan and Associates and North-South Environmental Inc. 2009).

Woodlands within highly impervious subwatersheds (such as those in the Lower Watershed zone) gain hydrological importance for contributing to the hydrologic cycle in these subwatersheds through their role in interception, infiltration, and evapotranspiration (CVC 2007b, CWP 2005).

Finally, woodlands in the Lower Watershed play an important social role in providing equitable access to green space for public wellbeing and recreation, education, localized shade and cooling effects, and some mitigation of noise, dust and pollutants.

In this analysis, woodlands are defined as any treed area with greater than 35% tree cover (OMMAH 2005a); these include forests, swamps, plantations, and cultural woodlands. These wooded areas are important for wildlife and provision of ecological services across the Credit River Watershed.

An analysis was conducted to determine an appropriate size for defining woodlands important for maintaining ecosystem functions in the Credit River Watershed. The impact on percent woodland cover for the watershed and its different zones was examined by successively removing all woodlands smaller than 16ha, 10ha, 4ha, and 2ha from the woodlands dataset. These thresholds were selected because they have been recommended or used in significant woodlands or significant natural heritage feature studies elsewhere (OMMAH 2004, City of Mississauga 2005, North-South Environmental Inc. et al. 2008, OMNR 2008b). The Lower Watershed is significantly different from the Middle and Upper Watersheds in terms of total woodland cover, and also in the size distribution of woodlands. Hence the Middle and Upper Watersheds were combined together for analysis while the Lower Watershed was analyzed separately from the other two zones.

Total woodland cover for the Middle and Upper Watershed combined was 27% (31% and 24% in Middle and Upper zones respectively), below the minimum 30% threshold recommended for maintenance of species (Andren 1994, Environment Canada 2004). As only those woodlands >=2ha, >=4ha, >=10ha and >=16ha are retained, the number of woodlands lost increases steeply, up to over 1338 or 87% of woodlands in this zone (Figure 5). The rate of woodland loss plateaus somewhat as woodlands >=16ha are retained (Figure 5). This is consistent with the fact that there are a large number of smaller woodlands in the watershed relative to larger woodlands. As woodlands of various sizes are lost, percent woodland cover remaining drops almost linearly. The loss of woodlands smaller than 10ha from the Middle and Upper Watersheds results in an 18% loss in woodland area in this zone. The loss of woodlands smaller than 4ha would have a relatively smaller effect of a 9% loss in woodland area, although the loss in number of woodlands (996 woodlands) would still be quite large (Figure 5).

Total woodland cover in the Lower Watershed was 7%, therefore a loss of woodlands <=16ha would cause a severe decline in woodland cover (Figure 6), a loss of almost 65% of the woodland area in this zone. Even a loss of woodlands <=4ha would have a strong impact on woodland function in the Lower Watershed, removing 69% of the woodlands in this zone and 24% of woodland area. A loss of woodlands <=2ha in this zone would have a smaller effect, resulting in a loss of 47% woodlands in this zone but a smaller impact on total cover, a loss of 11%.

The complete loss of smaller woodlands is unlikely to occur in the watershed due to Greenbelt Plan policies and the fact that a number of municipalities in urban areas incorporate protection of 2-4ha woodlands in their official plans (e.g., City of Mississauga 2005). This analysis simply serves as an exercise to determine an appropriate threshold for woodland size contributing to ecosystem functioning in the watershed when assumptions about policy are set aside.

Figure 5: Impacts of woodland loss, Middle and Upper Watershed: Number and area of woodlands lost

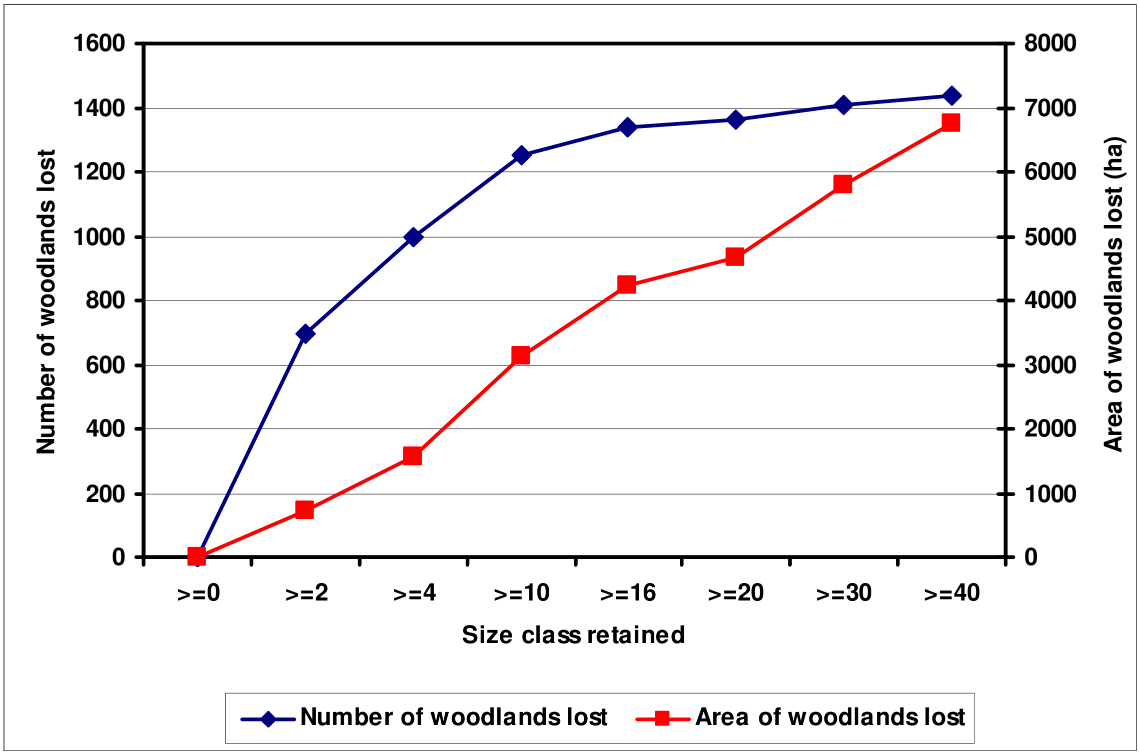
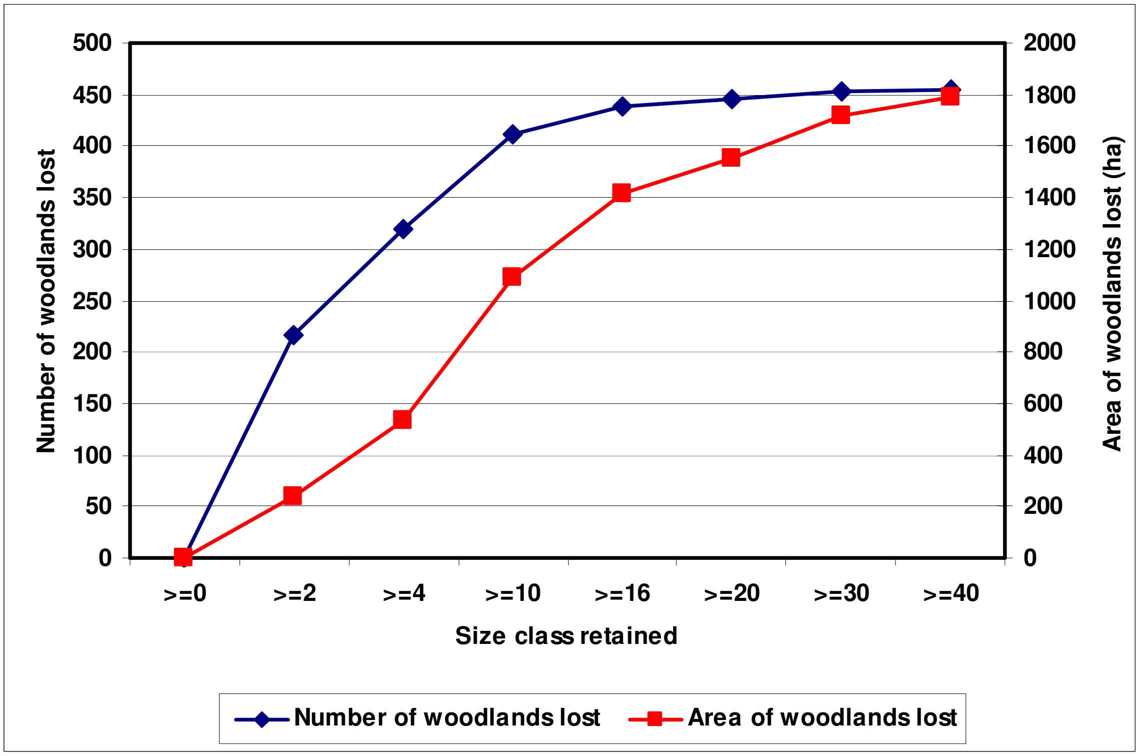


Figure 6: Impacts of woodland loss, Lower Watershed; a) Number and area of woodlands lost; b) Percent woodland cover remaining.



Based on the woodland analysis for the Credit River Watershed, impacts of loss, and minimum guidelines for woodland cover, it was determined that a reasonable threshold for important woodlands in the Middle and Upper Watersheds was >=4ha and >=2ha for the Lower Watershed. Woodlands of these sizes contribute to provision of habitat and linkages within their respective zones.

For the Landscape Scale Analysis, woodlands >=2ha in the Lower Watershed and >=4ha in the Middle and Upper Watershed were considered to be high functioning relative to other woodlands in those zones (Table 11). The selection of a lower threshold for the Lower Watershed additionally reflects the study objectives of ensuring adequate ecosystem representation across physiographic regions of the watershed.

Habitat patches scoring a 'one' under the *Woodlands* criterion are shown in Figure A15 (Appendix A) in green, while those scoring a 'zero' under this criterion are shown in brown.

Core area of woodlands

The amount of core area within a natural area is an important predictor of habitat quality (Forman 1995, OMNR 1999, Burke and Nol 2000, Mancke and Gavin 2000, Austen et al. 2001). The core area of a community type (generally forest or woodland) is defined as the area within that community beyond a specified edge distance or internal buffer width, usually 100m (McGarigal and Marks 1995, OMNR 1999; Figure 7), where adverse edge effects such as wind, invasive species and predators are minimized. Deep core areas are areas remaining within 200m of the edge of a community type.

The core of a natural area may support species such as Scarlet Tanager or Pileated Woodpecker which prefer to nest within high quality interior forest although care must be taken to distinguish among area sensitive species (those that prefer large areas) to forest interior species (those that require forest interior habitat for critical parts of their life cycle; Villard 1998, OMNR 2000).

Figure 7: Core area of a woodland represents the area contained after a 100m internal buffer has been created within the woodland.

A concept related to forest interior is forest edge. Smaller natural patches have a greater amount of edge area (such as the dark green area in Figure 20) relative to interior area. Edge effects have been shown to affect the distribution, abundance, and behaviour of species (Forman and Godron 1986, Forman 1995, Ries et al. 2004). The response of species to edges differs among species and at different edge distances (Environmental Law Institute 2003), but is generally consistent within species – that is, edges affect certain species in predictable ways (Ries et al. 2004). Examples of edge effects include microclimate changes within edges such as changes in light, heat, and moisture (Burke and Nol 1998, Chen et al. 1999, Meyer et al. 2001), increased nest predation along habitat edges (Batary and Baldi 2004), increased amphibian parasitism at edges (Schlaepfer and Gavin 2001 cited in Ries et al. 2004), active avoidance of edges by mammals (Jacob and Brown 2000 cited in Ries et al. 2004) and increased predation on plants at edges (Roach et al. 2001, Donoso et al. 2003, Tallmon et al. 2003 cited in Ries et al. 2004).

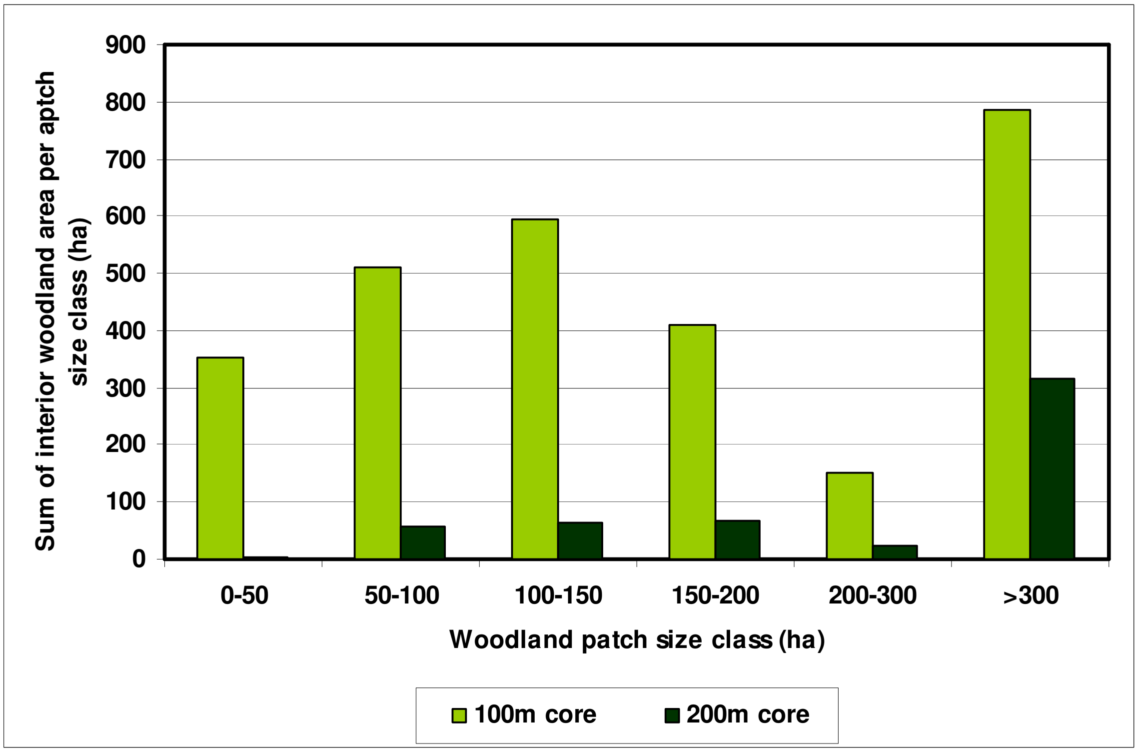
Minimum watershed restoration guidelines are >10% watershed with 100m forest core for protecting area-sensitive bird species (Environment Canada 2004). When treed areas such as woodlands are considered, the watershed contains approximately 3% woodland core area (100m from edge) and 0.5% woodland deep core area (defined as forest area that is 200m from the forest edge; Figure 8). When core area is significantly lost in a watershed, there is a decline in the number of area sensitive species and non-edge habitat and consequently a decline in overall biodiversity and health of an ecosystem (Environment Canada 2004).

At 3%, core area is rare in the watershed and edge effects are likely to be dominant. Species that are dependent on interior forest habitat or are sensitive to edge effects are at higher risk of extirpation from the watershed. While MNR has recommended that large areas, particularly with 4ha of core area are required to adequately protect area-sensitive species, it has also recommended that these guidelines be viewed within the context of the landscape of interest (OMNR 2000). As interior habitat is considerably below recommended guidelines for restoration of watersheds, all woodland interior habitat in the Credit watershed should be protected. Small woodland core areas, while they likely do not support area sensitive species, can act as nodes for expansion through stewardship or restoration, enabling support of these species in the future.

Figure 8: Core area of woodland in the Credit River Watershed as percentage of total watershed area.

The majority of woodland interior is contained within the largest woodlands in the watershed (Figure 9). For example, the five woodlands in the >300ha size class yield 787ha of interior woodland, while 1916 woodlands in the 0-50ha size class yield less than half that amount of interior (353ha). Large woodlands are therefore disproportionately important to maintaining healthy populations of forest interior species, relative to their number.

Figure 9: Total of interior woodland area within woodland patch size classes, Credit River Watershed.



Because there is so little core area within the Credit watershed, those woodlands containing any core area greater than 0.5ha (the minimum mapping unit for the analysis) were considered to contribute strongly to ecosystem function within the watershed.

Woodlands containing core area offer the best target for future restoration efforts to increase core area. Core area of woodlands is essentially a redundant criterion in this analysis because all woodlands containing core area would fall within the woodland size criterion. Therefore it was not included. However, if a different woodland size criterion were to be used in another analysis, woodland interior would be an important consideration in determining patch quality.

Table 11: Criteria and thresholds used to identify habitat patches (features) of particular importance with respect to ecosystem function in the Credit River Watershed.

#	Criteria	Threshold values for defining high functioning habitat patches, Credit watershed
A.	Woodlands	All habitat patches containing woodlands >=2ha in Lower Watershed and woodlands >=4ha in Middle and Upper Watersheds
B.	Wetlands	All habitat patches containing wetlands >0.5ha
C.	Successional habitat	All habitat patches containing >=10ha successional habitat
D.	Valleylands and riparian areas	All habitat patches containing or directly adjacent to watercourses or their crest of slope[1] *or* All habitat patches within or intersecting the greater of: Lake Ontario Flood Hazard, Lake Ontario Erosion Hazard, Lake Ontario Dynamic Beach Hazard, or 30m from the Lake Ontario shoreline
E.	Habitat diversity	All habitat patches with ELC community series diversity within top quartile (i.e., top 25% of patches)
F.	Uncommon vegetation communities	All habitat patches containing locally rare ELC community series (community series <=5% area of all natural)
G.	Ecological proximity	All habitat patches with matrix quality within top quartile (i.e., top 25% of patches)
H.	Regional linkage	All habitat patches within or intersecting 500m on each side of the Credit River up to 5km from the Lake Ontario shoreline and 300m on each side of the Credit River beyond 5km from the shoreline *or* All habitat patches within or intersecting the greater of 100m on each side of main tributaries of the Credit River
I.	Provincial linkage	All habitat patches overlapping or intersecting areas classified as Escarpment Natural Area and Escarpment Protection Area within the Niagara Escarpment Plan Area *or* All habitat patches overlapping or intersecting Natural Core or Natural Linkage Areas of the Oak Ridges Moraine Plan area *or* All habitat patches overlapping or intersecting the Greenbelt Natural Heritage System *or* All habitat patches <=2km of the L. Ontario shoreline

[1]Includes habitat patches on tablelands that are adjoining a watercourse or crest of slope.

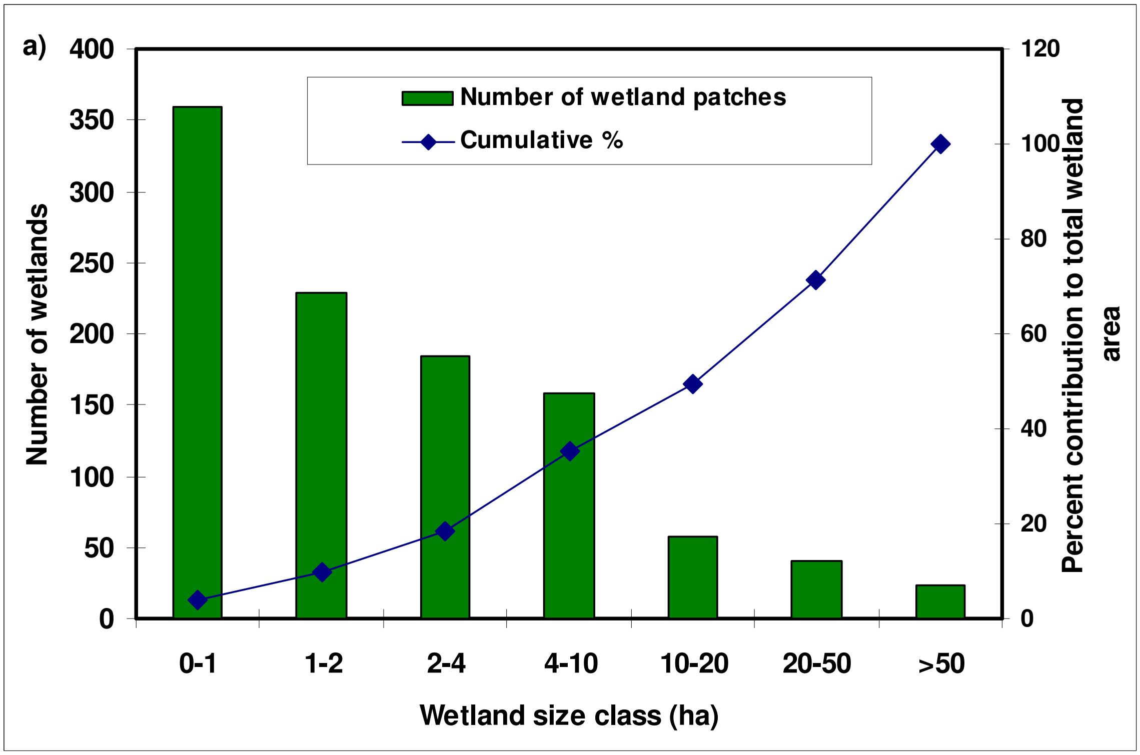
8.2 B) Area of wetlands

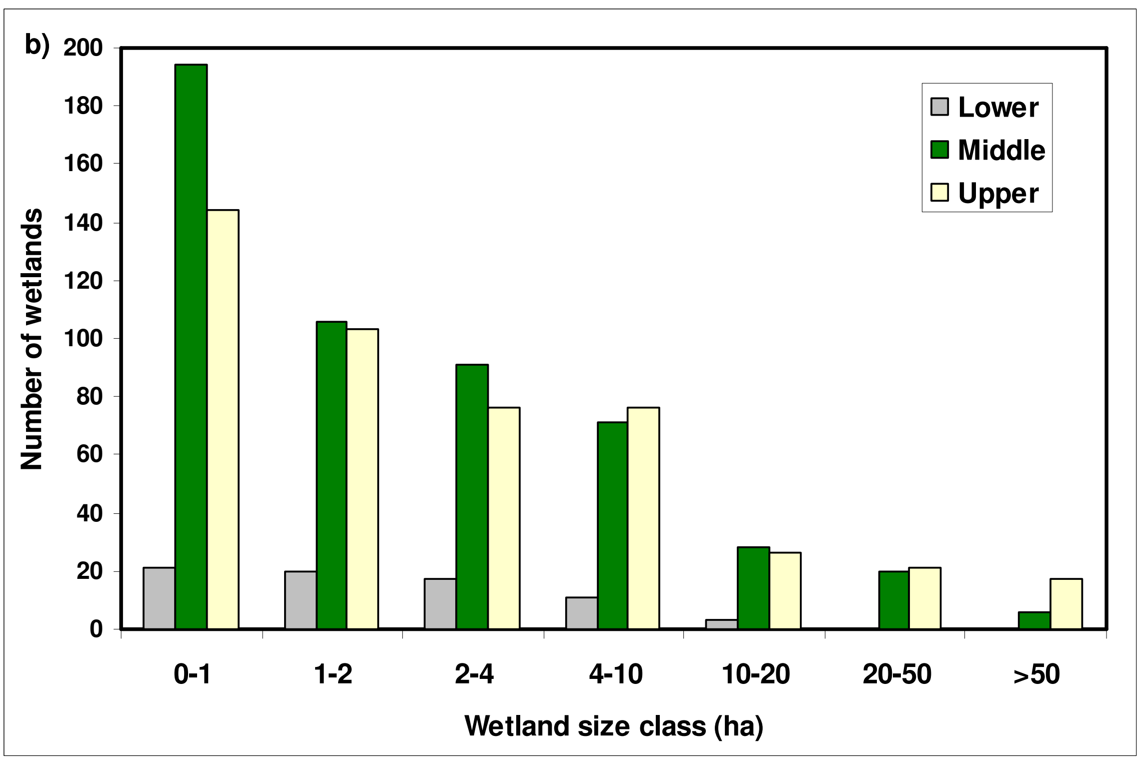
Wetlands, including swamps and marshes, are now recognized as being critical to the water balance of a region (Forman 1995, OMNR 1999, 2010, Daily et al. 2000). They reduce flooding and erosion hazards and costs, contribute to long term water supply, contribute to stabilization of shorelines, store carbon and produce oxygen, and enhance groundwater recharge and discharge. By providing essential habitat for a number of species, such as migratory waterfowl, amphibians, reptiles, fish, and insects, wetlands support complex food webs. Wetlands improve water quality by trapping sediments, removing or retaining excess nutrients, immobilizing or degrading contaminants, and removing bacteria. Wetlands act as natural sponges, absorbing water and releasing it slowly across the landscape. This absorption capacity enables wetlands to regulate high water flows. Wetlands also create soil through decomposition of rich organic matter.

Large wetlands are associated with greater species richness of birds, mammals, herptiles and plants (Findlay and Houlahan 1997). However, it is now accepted that wetlands of all sizes and hydroperiods are considered to be important for species habitat (Semlitsch and Bodie 1998, OMNR 1999, Snodgrass et al. 2000, Environment Canada 2004, Burne and Griffin 2005, CWP 2007). Waterbirds in urban and urbanizing areas have been found to use a variety of wetland sizes and types (Pearce et al. 2007). In the Credit watershed, over three-quarters of all amphibian, reptile, bird and mammal species depend on wetland habitat for some part of their life cycle (CVC *unpublished data)*. Data from CVC's terrestrial monitoring program indicate that plant species richness is greater in wetland plots than in forest plots in all zones of the watershed (CVC 2010). Wetlands of various sizes and hydroperiods contribute to ecological functioning of the overall watershed landscape.

There are 1051 wetlands in the Credit River Watershed, the majority of them rather small and under 4ha in size (Figure 10a). The size of individual wetlands ranges from less than 0.5 hectare to 246ha (Figure 10a). The median size of wetlands is 1.7ha (i.e., half of all wetlands are above and half are below this size). Over half (56%) of all wetlands are less than 2ha in size.

Figure 10. Distribution of wetland size classes in the Credit River Watershed: a) all wetlands; b) wetlands by physiographic zone.





There is some evidence for a threshold in watershed wetland cover for two wetland functions, namely flood flow and loading of suspended solids. Studies by Johnston (Johnston et al. 1990, Johnston 1994) found that watersheds that contained less than 10% wetlands were more sensitive to incremental loss of wetland area than those with more than 10% wetlands. A review by Mitsch and Gosselink (Mitsch and Gosselink 2000) concluded that the optimal amount of wetlands in a in temperate zone watersheds should be 3-7% for the optimization of ecosystem values such as flood control and water quality enhancement. Environment Canada has recommended that wetlands cover a minimum of 10% in a watershed and 6% within a subwatershed (Environment Canada 2004). Wetlands occupy only 6% of the Credit River Watershed's area and are unevenly distributed across subwatersheds with some subwatersheds containing much less than 6% wetland cover (Figure A16, Appendix A). Therefore, all existing wetlands are considered important for maintaining watershed health and function. In the Credit River Watershed, all wetlands are regulated through the *Conservation Authorities Act* (Government of Ontario).

Due to their considerable ecological importance and low coverage within the watershed, as well as the need for conservation of a variety of wetland hydroperiod types, all wetlands >=0.5ha (the minimum mapped size) were considered to be high functioning in the Landscape Scale Analysis (Table 11).

Habitat patches scoring a 'one' under the *Wetlands* criterion are shown in Figure A17 (Appendix A) in green, while those scoring a 'zero' under this criterion are shown in brown.

8.3 C) Area of successional habitats

Successional or historically human modified open country habitats such as cultural meadows, thickets, and savannahs perform a support function in maintaining biodiversity. When they are found adjoining natural areas they can act as buffers, reducing the impacts of sun and wind in forest interiors and providing a 'soft' edge that favours the movement of animals in search of food, shelter, or breeding habitat (Forman and Godron 1986, Forman 1995). Early successional forests act as effective carbon sinks – storehouses for greenhouse gases – as carbon uptake is rapid in the fast growing species of these habitats. Successional meadow and other open country habitats are important for grassland and prairie species (Berger et al. 2003, CVC 2002a, 2002b, 2002c), for several N. American mammal species (Fuller and DeStefano 2003), for some species of Neotropical migrant birds (Bay 1996, Ewert et al. 2006, Packett and Dunning 2009). Grassland bird species increased due to the clearing of land for agriculture post-European settlement. However, these species have declined dramatically in North America over the past few decades (Askins 2000, Bird Studies Canada et al. 2004) to the point where certain species (e.g., Henslow's Sparrow, Bobolink) have been listed as endangered or threatened in Ontario (http://www.mnr.gov.on.ca/en/Business/Species/2ColumnSubPage/276722.html). Studies have shown that agricultural fields (e.g., hayfields, pastures) and open meadow type habitats play an important role in supporting grassland and other bird species including raptors (Herkert 1994, Beacon Environmental and LSRCA 2007), and that larger old fields supported significantly more breeding bird species, likely due to lower rates of nest predation (Bay 1996).

In addition, successional habitats provide habitat heterogeneity that complements existing woodland and wetland habitat and supports a number of open country species including wildflowers and native pollinators. Habitat heterogeneity has been identified as a strong predictor of butterfly richness in Canada (Kerr 2001).

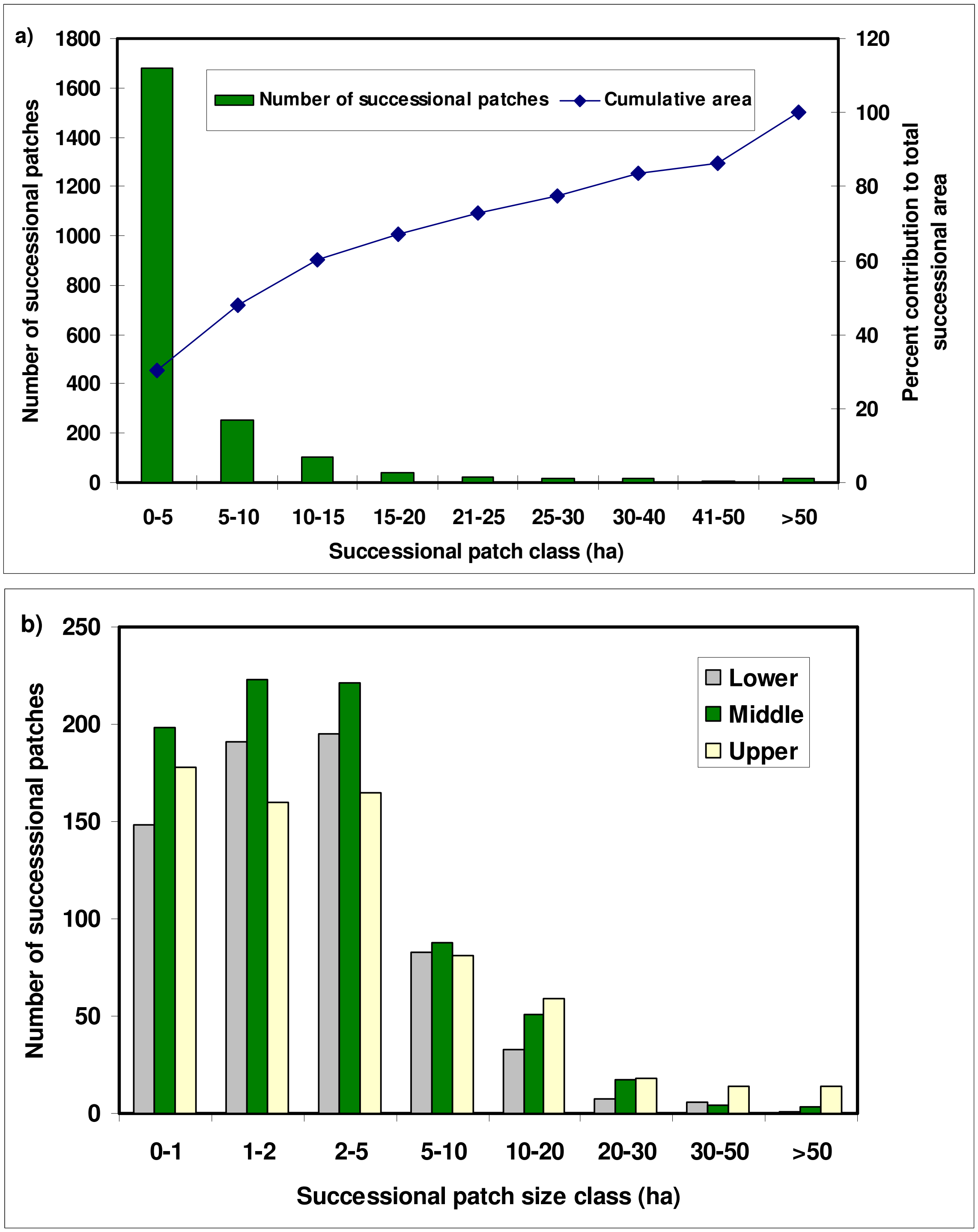
There are 2158 successional area patches in the Credit River Watershed; over three-quarters of them are rather small and under 5ha in size (Figure 11a). The size of individual successional areas ranges from less than 0.5 hectare to 143ha (Figure 11a). The median size of successional areas is 1.9ha (i.e., half of all successional areas are above and half are below this size).

Successional habitat, particularly meadow habitat, is considered significant for wildlife if it is large enough in size, approximately 10 hectares or larger (Bay 1996, OMNR 2000). These types of open habitats provide sufficient area for raptor winter feeding and roosting areas, and for the sustainable reproduction of some common grassland species (OMNR 2000). Lake Simcoe Region Conservation Authority has identified large 'grasslands' (cultural meadows or cultural thickets larger than 15ha) as contributing to significant wildlife habitat (Beacon Environmental and LSRCA 2007). There is anecdotal evidence that certain migratory birds in the Toronto area utilize fields and meadows in the spring and fall. In the Credit watershed, cultural meadows, cultural savannahs or cultural thickets greater than 10ha in area represent less than 10% of all successional area in the watershed. Large successional habitats are important features in ensuring the survival of a number of open country plant and wildlife species in the Credit watershed. For the purposes of this analysis, successional habitat was defined as cultural savannah, cultural meadow or cultural thicket (see Glossary for definitions of these terms). However, the majority of successional habitat in the watershed is meadow habitat.

For the purposes of the Landscape Scale Analysis, all successional areas >=10ha in size were considered to be high functioning successional habitat as they support or can potentially support a variety of successional or open country species (Table 11). These areas represent approximately 5164ha or 5% of watershed area. These larger successional areas are more prevalent in the Middle and Upper zones of the watershed (Figure 11b).

Habitat patches scoring a 'one' under the *Successional areas* criterion are shown in Figure A18 (Appendix A) in green, while those scoring a 'zero' under this criterion are shown in brown.

Figure 11. Distribution of successional area size classes in the Credit River Watershed: a) all successional areas; b) successional areas by physiographic zone.



8.4 D) Valleylands and riparian areas

Terrestrial natural areas adjoining streams (riparian zones) are transitional areas between aquatic and upland terrestrial systems. Riparian zones are defined as the stream channel between low and high water marks and the terrestrial zone from the high water mark towards upland area where vegetation may be influenced by elevated water tables or flooding and by the ability of soils to hold water (Naiman and Decamps 1997). In addition, vegetation outside the riparian zone that is not directly influenced by hydrologic conditions but contributes organic matter to the floodplain or channel may also be considered part of the riparian zone (Gregory et al. 1991). These critical interfaces between terrestrial and aquatic environments often contain concentrations of wildlife and plant biodiversity and may provide early indications of environmental change (Naiman and Decamps 1997, Environment Canada 2004, Environmental Law Institute 2003, Guerry and Hunter 2002, Semlitsch 1998, Roe and Georges 2007).

Natural and cultural areas adjacent to streams provide important ecosystem functions related to water quality improvement and flow, flood moderation, sediment and erosion control, bank stabilization, fish and aquatic habitat, moderation of stream temperatures, organic and inorganic inputs to watercourses, riparian biodiversity, plant and wildlife movement, and gene flow (Environmental Law Institute 2003, Hodges and Krementz 1996, Machtans et al. 1996, Naiman and Decamps 1997, Tabacchi et al. 1998, OMNR 1999, 2010, Wenger 1999, Environment Canada 2004, Sandin and Johnson 2004, Sweeney et al. 2004, Stanfield and Kilgour 2006, Roy et al. 2007). In addition, riparian areas are highly valued for recreation. Riparian zones cannot be mapped through air photo interpretation and need to be identified through field study. However, in the absence of detailed field data, riparian areas or buffers (or set distances from the stream edge) are frequently used as a surrogate measure to indicate the areas of the riparian zone that contribute to different ecological functions.

The amount and quality of natural cover adjacent to a stream has important ecological effects on water quality and aquatic plant and animals. The widths of riparian buffers (the areas on each side of a stream) and their associated functions have been widely studied (Castelle et al. 1994, Wenger 1999, Environmental Law Institute 2003, Lee et al. 2004, Sweeney et al. 2004, Mayer et al. 2005). Riparian buffers vary in their effectiveness in contributing to different types of ecological functions depending on their widths. Besides vegetation, parameters such as soil type, slope, and catchment conditions also play a role in determining the width of a riparian buffer that is effective in improving aquatic habitat through stream water quality and temperature (Castelle et al. 1994, Roy et al. 2005). In comprehensive reviews of riparian buffer widths for various ecosystem functions 30m or 100 feet was the most commonly recommended buffer width for detrital input, temperature and microclimate regulation, bank stabilization and nutrient or pollutant removal (Environmental Law Institute 2003) and water quality and aquatic habitat (Chase et al. 1995). This buffer width also provides limited habitat for some stream-associated terrestrial species (Chase et al. 1995, Environmental Law Institute 2003, Crawford and Semlitsch 2007). Buffers less than 30m wide can be effective in removing pollutants; however, buffers of 30m or more are generally recommended as a reasonable minimum to cover a number of ecological functions including provision of limited habitat (Chase et al. 1995). It is important to note that a 30m buffer width is insufficient in terms of providing habitat and movement for a wider variety of species; for these corridor functions, a buffer width of 100m is recommended (Environmental Law Institute 2003).

In a Toronto area study, the domain of stream degradation, i.e., a shift from good to fair biotic integrity, ranged from 75% removal of riparian forest from smaller streams at 0% urbanization, to 0% removal of riparian forest at 55% urbanization (Steedman 1987). Based partly on this study, the following Environment Canada guidelines for watershed restoration were developed:1) that 75% of stream length be naturally vegetated, and 2) that 100% of the area within a 30m buffer on streams be naturally vegetated. The Credit River Fisheries Management Plan recommends that 90% of streambanks of all tributaries be restored with natural vegetation (OMNR and CVC 2002). Natural vegetation and buffers are particularly important on first to third order (smaller) streams, as water quality downstream is strongly dependent on water quality from upstream feeder tributaries (Steedman 1987, Environment Canada 2004; see Environment Canada 2004 and OMNR and CVC 2002 for additional detail on the importance of stream orders and the River Continuum Concept). A review of vegetated buffers and a meta-analysis of their efficiency in removing nonpoint source pollution showed that buffers of 30m width on favourable slope conditions removed more than 85% of the pollutants studied (Zhang et al. 2010).

A preliminary analysis of streams within the Credit River Watershed showed that approximately 74% of the total length of all streams in the watershed is covered in natural or semi-natural vegetation (CVC *unpublished data*). Within the recommended buffer zone of 30m on each side of a stream, approximately 68% of the area contained natural vegetation (CVC *unpublished data*). Because these numbers are below recommended guidelines for watershed restoration, all natural and semi natural riparian areas within the Credit River Watershed are currently important for maintaining healthy aquatic habitat.

Similar riparian areas around other aquatic habitats serve as a link between terrestrial and aquatic function and filter sediments from water flowing into lakes. A minimum buffer width of 30m around aquatic features is important for water quality and aquatic habitat improvement (Environmental Law Institute 2003). Natural features near lakes provide habitat for terrestrial species that utilize lakes, and serve as resting or staging areas for migratory species including birds and butterflies (Macdonald et al. 2006, OMNR 2000). Natural features within hazard lands associated with Lake Ontario, namely, Lake Ontario Flood Hazard, Erosion Hazard and Dynamic Beach Hazard – protect the shoreline from storm swells and erosion and moderate the effect of these disturbances on natural areas further inland. Under current climate change predictions of increased extreme weather events, the disturbance regulation capacity of lands adjacent to surface water is of high importance.

Consistent watershed wide mapping of crest of slope exists and has been used by the Region of Peel to delineate Core Valleylands (Regional Municipality of Peel 2005).

Mapping for all meander belts and floodplains was identified as a data gap in this analysis as these areas could not be delineated as specific polygons (*CVC GIS and Water Resources group, personal communication*). Therefore, only crest of slope mapping was utilized in this analysis. Any habitat patches that are on tablelands but adjoining watercourses or their crest of slope generally function as part of the riparian corridor and were included within this criterion. Hazard lands, including crest of slope, meander belt, and floodplain, continue to be regulated and could constitute feasible areas for restoration within a Natural Heritage System.

Other landscape features contributing to surface water quality and healthy ecosystems were considered but ultimately not included in the analysis because they required a level of field verification that was outside the scope of this Landscape Scale Analysis. Low order or headwater channels can make up the majority of the drainage network or density (Nadeau and Rains 2007, Peterman et al. 2008) and are fundamental to the maintenance of the flow and sediment regime and contribute substantial quantities of organic matter to the stream system. These features are important to protect due to their contributions to biodiversity, ecosystem functioning, and cumulative impact on downstream aquatic habitat and water supply (Meyer et al. 2007, Nadeau and Rains 2007). However, because these features can be small and require field verification, they are best addressed in subwatershed studies or through Environmental Impact Studies, through appropriate field work. Drainage density is another measure that is best addressed in subwatershed studies through appropriate field work.

For the purposes of this analysis, all habitat patches containing or directly adjacent to the watercourses or their crest of slope were scored as high functioning in terms of their contribution to water quality and aquatic habitat and were given a score of one. In addition, all habitat patches within or intersecting the greater of the Lake Ontario Flood Hazard, Lake Ontario Erosion Hazard, Lake Ontario Dynamic Beach Hazard, or 30m from the edge of Lake Ontario were also considered high functioning in terms of contributing to water quality and aquatic habitat (Table 11).

Habitat patches scoring a 'one' under the *Valleylands and Riparian areas* criteria are shown in Figure A19 (Appendix A) in green, while those scoring a 'zero' under these criteria and thresholds are shown in brown.

8.5 E) Habitat diversity

The vast majority of all amphibian, reptile, bird, and mammal species in the Credit watershed depend upon more than one ELC community series for completion of their life cycle (CVC 2002a, 2002b, 2002c and *unpublished* data). More diverse habitats are linked to greater biodiversity and ecosystem function (OMNR 1999, 2000 and references therein). Greater biodiversity within an area allows complex food webs to be sustained even when some species are lost, giving the natural system greater resilience and ability to recover from disturbance (Loreau et al. 2001, Hooper et al. 2005). Maintaining a range of diversity in species and habitats gains increasing importance under conditions of climate change, where impacts on individual species are unknown.

Patch size and habitat diversity are correlated because larger patches tend to have greater diversity than smaller patches. However, certain patches are likely to support particularly high diversity – for example, patches that contain a number of microhabitats, elevation or soil gradients, or plant communities compared to others of similar size.

Within the Credit River Watershed, some areas with high species and community diversity have been identified and are protected as Environmentally Sensitive Areas (ESAs) or as provincially significant Life Science Areas of Natural and Scientific Interest (ANSIs). However, there are likely other highly diverse areas that have not yet been identified. The only data on diversity that are available across the entire Credit River Watershed are data on ELC community series within habitat patches. Community series data are a reasonable surrogate for identification of areas with high species diversity. Because ELC community series represent distinct ecological communities containing distinct species of plants, it is reasonable to assume that areas with a high diversity of plant communities are likely to support a high diversity of plants and wildlife.

To identify high diversity areas within the Credit watershed, the number of different ELC community series of all types within each habitat patch was tallied. To avoid double counting, a community series was counted only once even if it occurred multiple times within the habitat patch. The majority (61%) of habitat patches in the Credit River Watershed contain only one type of ELC community series (e.g., deciduous forest; see Table 9 for examples of ELC community series); 22% of habitat patches contain 2 to 3 ELC community series; and only 18% of habitat patches contain high diversity (4 or more different ELC community series types; Table 12).

Table 12: Number of ELC community series per habitat patch, Credit River Watershed.

Number of ELC community series per habitat patch	Number of habitat patches	Percent of habitat patches
1	1084	61%
2	260	15%
3	119	7%
4	75	4%
5	42	2%
6	43	2%
7	31	2%
8	27	2%
9	21	1%
10	20	1%
11	20	1%
12	23	1%
13	18	1%
14	3	<1%

For the purposes of the Landscape Scale Analysis, habitat patches containing four or more different ELC community series types (top 18% of habitat patches) were considered high functioning in terms of maintaining species diversity over the long term and were given a score of one (shown in green in Figure A20), while all other patches were given a score of zero (shown in brown in Figure A20) under this *Habitat diversity* criterion (Figure A20, Appendix A).

Habitat diversity is also strongly determined by the combination of soils, physiography, and climate (Hill 1968, Lee et al. 1998); hence a watershed based Natural Heritage System that includes adequate representation of forest and wetland cover on different physiographic and soil types is likely to contain greater biodiversity over the long term. Forest cover is currently unevenly distributed among Credit River Watershed physiographic regions. Forest and wetland cover within the different physiographic regions are shown in Table 13 and Figure A21 (Appendix A) and are related to land use within the watershed. The Iroquois Plain, Peel Plain and South Slope have low forest cover because they are heavily urbanized while the South Slope is urbanized and rapidly urbanizing. The Guelph Drumlin field also has low forest cover because it is partly urbanized but also contains agriculture and successional land. The Dundalk Till Plain has low forest cover mainly due to agriculture.

The distribution, size, and number of wetlands differ among physiographic regions. Wetlands are poorly represented on eskers but this is likely due to physical factors that naturally limit wetlands on these features. The challenges associated with combining soil and physiographic data (which are of lower resolution) with forest cover data (of higher resolution) made it difficult to use physiographic region data in the Landscape Scale Analysis. It was felt that physiographic diversity was captured to a degree through selection of woodlands and wetlands in all physiographic zones (criteria A and B, Table 11).

Table 13: Natural forest and wetland cover by physiographic region within the Credit River Watershed in hectares (rounded to nearest whole number) and as a percentage of Physiographic Region area (rounded to nearest whole number)[1].

Physiographic Region	Physio-graphic Zone	Forest cover within Physio-graphic Region (ha)	Forest cover as a percentage of Physio-graphic Region area	Wetland cover within Physio-graphic Region (ha)	Wetland cover as a percentage of Physio-graphic Region area
Iroquois Plain	Lower	538	6%	46	0.5%
South Slope	Lower/ Middle	835	4%	161	0.9%
Peel Plain	Lower	597	8%	111	1%
Niagara Escarpment	Middle/ Upper	3,023	24%	554	4%
Oak Ridges Moraine	Middle	943	25%	170	4%
Horseshoe Moraines	Middle/ Upper	2,194	17%	1632	13%
Flamborough Plain	Middle	39	12%	33	10%
Guelph Drumlin Field	Upper	2,011	10%	1923	10%
Hillsburgh Sandhills	Upper	804	8%	1198	12%
Dundalk Till Plain	Upper	36	3%	46	4%

[1]Numbers are not likely to be precise because of overlaying maps at different scales, namely, forest or wetland cover at 1:10,000 and physiographic regions at approximately 1:50,000; nevertheless the table allows for comparison of relative amounts of forest and wetland cover among physiographic regions.

8.6 F) Uncommon vegetation communities

To maintain the range of biodiversity within a region, there must be adequate representation of both uncommon and common natural (i.e., not extensively human modified) habitats within a protected area system. Common ELC community series are well represented by virtue of the frequency of their occurrence in the watershed. Uncommon ELC community series contribute to the overall diversity of habitats, species, and genes within the watershed. For the purposes of this analysis, uncommon ELC community series were defined as those natural (i.e., not cultural) ELC community series representing less than 5% of the total natural and semi-natural area combined within the watershed boundary. This approach is consistent with standard CVC subwatershed analysis methodology which identifies uncommon or "locally rare" vegetation communities (CVC 1998). Under this criterion, ELC community series with less than 5% representation in the watershed are deciduous swamp, mixed swamp, thicket swamp, marsh, bog, fen, treed bog, beach/bar, and bluff. Additional uncommon communities may be identified in future as they are discovered through CVC's Natural Areas Inventory program. Aquatic areas were not included in this analysis as they were assessed as part of the aquatic system for the watershed. It is possible that human modification of the watershed may have caused certain communities to become rare in the watershed relative to their original representation in pre-settlement times. However, a number of these communities are naturally rare in the watershed because they exist due to a combination of abiotic conditions.

All habitat patches containing Species at Risk habitat, provincially rare ELC vegetation types, and mature forest should be included within this category, as these features contribute to maintaining diversity within the watershed. However, given the lack of watershed wide data for these features, including only known features of this type would have skewed the results of the analysis. Therefore, rare vegetation communities and the habitats of Species at Risk were not included within the Landscape Scale Analysis. These habitats receive protection under existing provincial and municipal policies (OMMAH 2005a, City of Mississauga 2005, Regional Municipality of Peel 2005, and City of Brampton 2008) and will form part of the Credit River Watershed Natural Heritage System. The ongoing CVC Natural Areas Inventory (NAI) program will contribute significantly to improving our knowledge of these features within the watershed.

Habitat patches scoring a 'one' under the *Uncommon vegetation communities* criterion are shown in Figure A22 (Appendix A) in green and represent habitats that are particularly important for providing ecosystem functions that are dependent on biodiversity. Habitat patches scoring a 'zero' under this criterion are shown in brown.

8.7 G) Ecological proximity or matrix quality

The proximity of natural areas to one another, or the quality of the land use between natural areas, can be used as a surrogate for connectivity at a local scale.

Connectivity can be defined as the degree to which species can move between and among habitat patches (Hunter 1996 cited in Gutzwiller 2002). Animal species move among habitats for feeding, breeding, refuge, or migrating. Plant species reproduce and maintain themselves using seeds or vegetative structures to spread into neighbouring habitats. Connectivity is essential in allowing habitat patches to recover from disturbance by receiving genes and species from neighbouring habitat patches, and in allowing longer distance migration of genes and species to enable adaptation and evolution to occur.

While it is generally agreed that connectivity is important for biodiversity (Damschen et al. 2006) and healthy ecosystems (Taylor et al. 1993, Forman 1995, Gutzwiller 2002, Tewksbury et al. 2002, Levey et al. 2005a), measuring connectivity can be problematic.

Landscape ecology defines two types of connectivity: functional connectivity and structural connectivity. Functional connectivity refers to how connected an area is for a process, such as an animal moving through the landscape (Forman 1995). Functional connectivity is dependent upon the particular species of plant or animal and the type of intervening habitat. For certain species, agricultural land is a barrier, while for other species, it is not (Belisle and Desrochers 2002); for some species groups, such as amphibians or reptiles, roads are a life-threatening barrier, while some generalist bird species groups cross such gaps relatively easily.

Structural connectivity refers to the connectivity or spatially continuous nature of a corridor, network, or matrix (Forman 1995). Greater structural connectivity appears to be associated with greater ability of species to move across the landscape (Forman and Godron 1986, OMNR 1999, 2010, Environmental Law Institute 2003). A landmark set of studies on connectivity using experimental landscapes has found that habitat patches connected by corridors or linear strips of vegetation (i.e., structurally connected patches) retained more native species than isolated patches, that corridors did not promote invasion by exotic species and that corridors facilitated ecosystem functions such as pollination and seed dispersal (Tewksbury et al. 2002, Levey et al. 2005a, Damschen et al. 2006). The finding that corridors did not promote invasion of exotic species was ascribed to the fact that invasive species by definition are good dispersers, while native species are poorer dispersers; therefore corridors are hypothesized to provide a net benefit to ecosystems (Levey et al. 2005b response to Proches et al. 2005).

Habitat connectivity can be managed in two main ways (Bennett 2003): 1) by managing the entire landscape to facilitate species movement; or 2) by maintaining habitat that supports species survival, reproduction, and/or movement. Habitat that is maintained to facilitate movement can be continuous, as in a corridor, or discontinuous, such as stepping stone habitat for species.

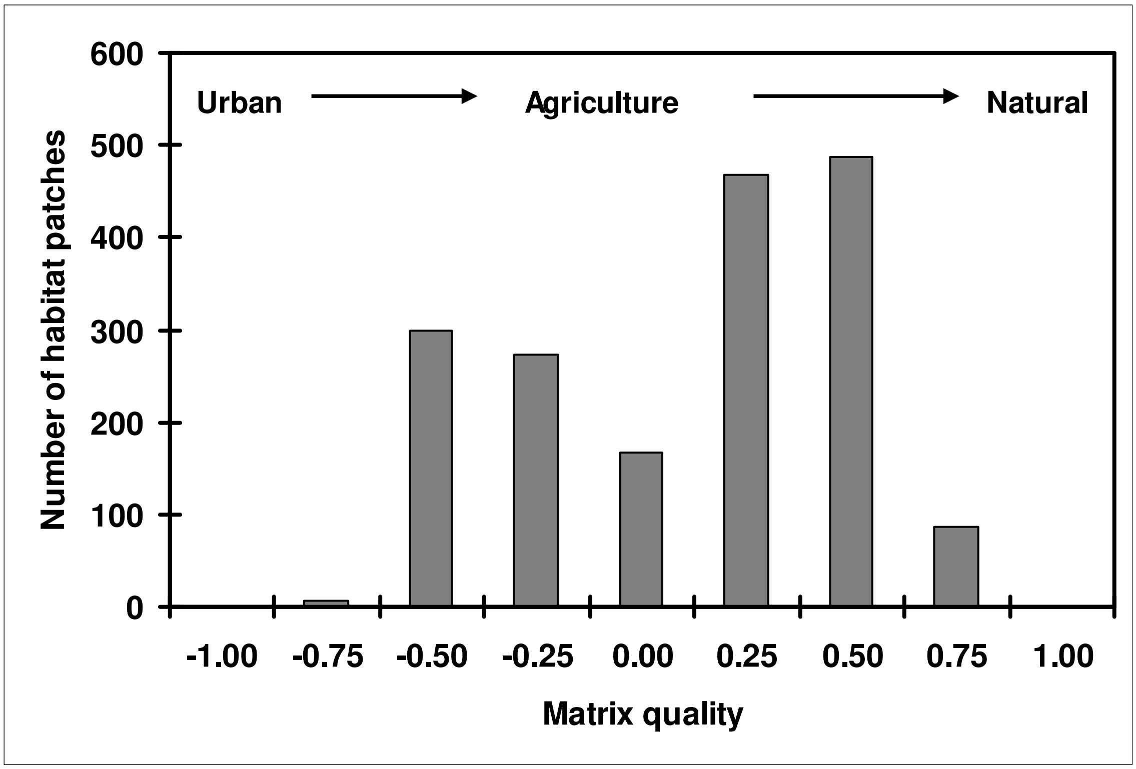
Planning to ensure connectivity for all species in a Natural Heritage System is virtually impossible in a fragmented landscape; nevertheless it is essential to plan for local and regional connectivity to maintain healthy ecosystems that are resilient to disturbances. Because functional connectivity is so species specific, Natural Heritage Systems approaches have commonly focused on structural connectivity, as evidence suggests that habitats closer together improve the ability of the majority of species to disperse, feed, reproduce, and migrate (Table 7). Structural connectivity includes the identification and protection of corridors or stepping stones linking habitat patches (e.g., Yukon to Yellowstone corridor, City of Oakville's Draft North Oakville Secondary Plan http://www.oakville.ca/3690.htm, OMMAH 2002, Natural Heritage component of the Central Pickering Development Plan http://www.mah.gov.on.ca/Page1733.aspx) or improving the matrix by minimizing the gaps among natural features (TRCA 2007).

The quality of the matrix, or area surrounding a habitat patch, has a strong influence on the ability of a species to move from one habitat patch to another. Natural areas that are closer together have a greater degree of species persistence because they favour persistence and movement of species and genes over the short and long term (Forman and Godron 1986, Andren 1994, Forman 1995, OMNR 1999, Hames et al. 2001, Damschen et al. 2006). For some species, an urban or agricultural matrix prevents movement between neighbouring habitat patches. For other species, an urban matrix may impede movement, but an agricultural matrix may allow limited movement en route to an adjacent habitat patch. In general, habitat patches with a matrix containing a high percent of natural area are likely to support a greater degree of species and genetic movement than those surrounded to a high degree by urbanization or agriculture (Austen and Bradstreet 1996, Dunford and Freemark 2004, Henson et al. 2005a, Lindenmayer and Franklin 2002, Petit et al. 2004, Saunders et al. 1991, TRCA 2007). In general, matrix quality has been calculated based on the percent of natural, agricultural, or urban area found within 2km of a natural area (Dunford and Freemark 2004, Henson et al. 2005a, TRCA 2007). Matrix quality or ecological proximity may be viewed as one aspect of connectivity as it can help to sustain metapopulations in the landscape.

For the purposes of this Landscape Scale Analysis, matrix quality for a habitat patch was calculated for a 2km external buffer around the patch based upon the method identified by the Toronto and Region Conservation Authority: (percent natural area*(1) + percent agricultural/open space area*(0) + percent urban area*(-1)). This formula recognizes the relative order of permeability of various land covers, with natural being most permeable, agriculture or open space such as parks being relatively neutral (permeable for some species and impermeable for others), and urban being relatively impermeable compared to natural and agricultural land cover. The values for matrix quality range from -1 to +1, where -1 represents a patch completely surrounded by urban land cover, while +1 represents a patch completely surrounded by natural land cover. A patch surrounded completely by agriculture would have a matrix quality score of 0, which is intermediate between that for a completely urban and a completely natural matrix.

In the Credit watershed, matrix quality for habitat patches ranged from -0.81 to 0.71. Habitat patches lying within the top 25% of patches in terms of matrix quality (quality >=0.32) tended to be those with an average of 52% natural cover surrounding the patch within a 2km radius. These top quartile patches had natural cover ranging from 37% to 81% surrounding them within a radius of 2km. Figure 10 shows the range of matrix quality of habitat patches within the Credit River Watershed.

Figure 12: Matrix quality for individual habitat patches in Credit River Watershed, showing the range of values from urban to natural.



For the purposes of this analysis, any habitat patch with matrix quality equal to or greater than the 75th percentile value was considered to be high functioning with respect to the *Ecological proximity* criterion (Table 11) and is shown in green in Figure A23 (Appendix A). Habitat patches scoring a 'zero' for this criterion are shown in brown in the same figure.

8.8 H) Regional linkage: Credit River and its main tributaries

Credit River

The Credit River comprises a natural north-south regional corridor that links the Lake Ontario shoreline and Carolinian zone with the Niagara Escarpment, Greenbelt, and the Oak Ridges Moraine farther to the north (Figure A24, Appendix A). The Credit River also provides an important cross-watershed linkage to natural areas within the Nottawasaga Valley Conservation Authority near Orangeville. The main tributaries of the Credit and their riparian areas serve as important subwatershed corridors that can support species, material and energy flows across subwatersheds and from one part of the watershed to another (Figure A24, Appendix A).

In general, wider riverine corridors favor movement of wildlife; and corridors containing water are more significant for wildlife than similar corridors without water (Wenger 1999, OMNR 2000, Environmental Law Institute 2003). Valley lands form the 'backbone' of a watershed and should be assessed as an integral part of a planning authority's natural heritage system (OMNR 1999, 2010). Provision for large wildlife corridors is recommended under provincial and federal guidelines (Environment Canada 2004, OMNR 1999). Corridors to support wildlife movement are recommended to be at least 200m in width and include any adjoining areas of natural cover (OMNR 2000, NHIC 2002, Environmental Law Institute 2003). An extensive review of publications on recommended corridor/buffer widths found that 75 percent of values extended up to 100m on each side (for a total corridor width of 200m; Environmental Law Institute 2003). The 100m buffer widths were recommended to cover a range of ecological functions including shading and micro-climate for aquatic life; stabilization of stream banks and prevention of erosion; provision of organic matter and woody debris; regulation of sediment, nutrients and contaminants; flood attenuation and storage, and wildlife habitat (Environmental Law Institute 2003). A meta-analysis of corridor studies has found that corridors improved movement of species among patches and that natural corridors (e.g., riparian corridors) supported greater species movement than created corridors (Gilbert-Norton et al. 2010). Corridor width must be sufficient to permit habitat for or passage of disturbance sensitive species; to provide habitat for species during movement; and to minimize edge predation or mortality. The provincial guidelines for significant wildlife habitat recommend a corridor width of 200m to allow for plant and wildlife movement at a large scale (OMNR 2000). A literature review and data assessment of migratory birds in Toronto (Dougan and Associates and North-South Environmental Inc. 2009) found that well-vegetated river valleys and ravines, particularly in urban areas, provide good habitat for migrant birds, particularly when these extend south to the lakeshore. The Region of Peel and Town of Caledon Significant Woodlands and Significant Wildlife Habitat Study recommends that natural features within major river valleys and creeks and within 500m of major river valleys near the Lake Ontario shoreline promote migratory bird movement up the Credit River corridor (North-South Environmental et al. 2009).

For the purposes of this analysis, the Credit River corridor regional linkage was defined as the following:

- All habitat patches within or intersecting 500m on each side of the Credit River up to 5km from the Lake Ontario shoreline; *and*
- All habitat patches within or intersecting 300m on each side of the Credit River above 5km from the Lake Ontario shoreline (Table 11).

The Credit River consists of 6^{th} and 7^{th} order streams and generally represents the widest aquatic corridor in the CVC jurisdiction (see Glossary for Stream order classifications; Figure A24, Appendix A). The regional corridor width of 500m narrowing to 300m on each side of the Credit River was selected based on the following considerations: 1) a wider corridor at the mouth of the Credit River allows migrants which are found at higher densities along the Lake Ontario shoreline to be funneled into the valleylands of the Credit River in Mississauga. These valleylands form the widest and most naturally vegetated north-south corridor in the City of Mississauga; 2) a minimum corridor width of 300m on each side of the Credit provides for some interior or non-edge habitat that may provide some relief from predation and other edge effects as migratory birds move up through the valleylands of the Credit. In general, interior habitat is the habitat found 100m inwards from a natural area (Environment Canada 2004, OMNR 2010; Figure 7).

Main tributaries of the Credit River
The main tributaries of each subwatershed and their riparian areas form a hydrological and terrestrial network that links all the subwatersheds of the Credit River Watershed (Figure A24, Appendix A). Subwatershed corridors permit energy, material, species and gene flow among subwatersheds of the Credit River. These streams, generally 4^{th} or 5^{th} order or larger in size, have commonly been used in past subwatershed studies to form the backbone of local natural heritage systems (CVC 2003a, 2003b, 2007c). In urban areas, stream orders can change due to land use changes that alter stream hydrology. However, a visual examination ensured that the main tributaries selected through this methodology corresponded to a major catchment area of the Credit River (e.g., a subwatershed).

For the purposes of this analysis, subwatershed corridors were defined as the following:
- All habitat patches within or intersecting 100m on each side of all main tributaries of the Credit River (Table 11)

Valleylands of the Credit River and its main tributaries could not be included in mapping at this time as they were identified as a data gap. Valleylands (identified by crest of slope mapping) extend as a continuous feature in GIS mapping and frequently include smaller order streams. However an overlay of valleylands and Credit River and subwatershed corridors showed that the great majority of valleylands were included within the above corridor widths. Valleylands are also regulated by Credit Valley Conservation and form part of the Greenlands System of the Region of Peel (Regional Municipality of Peel 2005).

The Credit River and its main tributaries together form a network providing an important regional linkage among species, communities and subwatersheds of the Credit River

Watershed. This network will form the backbone of the Credit River Watershed's Natural Heritage System.

Habitat patches scoring a 'one' under the *Regional linkage* criteria are shown in Figure A25 (Appendix A) in green. These represent habitat patches that are particularly important for providing ecosystem functions related to regional connectivity. Habitat patches scoring a 'zero' under this component are shown in brown.

8.9 I) Provincial linkage: Niagara Escarpment, Oak Ridges Moraine, Greenbelt Natural Heritage System and the Lake Ontario Shoreline

Niagara Escarpment, Oak Ridges Moraine, and the Greenbelt Natural Heritage System

The Niagara Escarpment, Oak Ridges Moraine, Greenbelt Natural Heritage System and the Lake Ontario shoreline comprise the major provincial corridors in the Credit watershed, as they connect regions with distinct soils, climate, and vegetation and link the watershed to regional as well as provincial protected areas systems.

Provincial connectivity promotes large scale species movement within and beyond a landscape, permitting adaptation, gene flow or evolution. The Lake Ontario shoreline connects natural areas across Ontario, Quebec, and the United States. Structural connectivity permitting species movement at these scales enhances the overall resilience of species and ecosystem functions to disturbances such as disease, climate change, or urbanization (Forman 1995, OMNR 1999, 2000; Henson et al. 2005a).

Habitat patches that overlap with natural areas protected under provincial legislation (*Greenbelt Plan 2005, Oak Ridges Moraine Plan 2002,* and *Niagara Escarpment Plan 2005*) allow the Credit River Watershed's Natural Heritage System to link up with provincially important protected areas. This permits the migration of species across large areas of the province over space and time and contributes to the ecological and hydrological integrity of both provincial protected areas and the natural features within the watershed (OMMAH 2002).

For the purposes of this analysis, the following habitat patches were selected as contributing to provincial connectivity through overlap with provincial protected areas (Table 11):

- All habitat patches overlapping with areas designated as *Escarpment Natural Area* and *Escarpment Protected Area* within the Niagara Escarpment Plan Area;
- All habitat patches overlapping with natural features within the *Natural Core Areas*, *Natural Linkage Areas*, or *Countryside Area* within the Oak Ridges Moraine Plan Conservation Plan Area and
- All habitat patches overlapping with areas classified as "*Greenbelt Natural Heritage System*" within the Greenbelt Plan Area.

Lake Ontario shoreline
Natural features within 2km of the Lake Ontario shoreline (ranging from 2 to 10km distant from the shoreline) provide critical habitat during land and shore bird and butterfly migration (OMNR 2000). A study on Lake Erie found that attributes associated with migratory bird stopover sites included a diversity of natural and semi-natural habitats and proximity to the Great Lakes (Ewert et al. 2006). This study found that landbirds may be particularly concentrated along the shoreline to 0.4km and that relatively high numbers are found at least 1.7-5km inland from Great Lakes shorelines, particularly along wooded and brushy beach ridges and areas of high insect productivity. Another Lake Erie study found that nearly all migrant activity was concentrated within 10km of the lake's shoreline (Bonter et al. 2009). A study of migratory birds on the Lake Ontario shoreline in New York found that a combination of distance from shoreline and percent woody cover attracted the most birds (Strobl 2010). In this study, birds appeared to prefer habitat near the shore (0-2km) or farther away (32-75km) although bird presence is also mediated by the type and proximity of woody cover. There is considerable evidence that habitat on and near the Lake Ontario shoreline in the Toronto area is utilized by migratory birds (Dougan and Associates and North-South Environmental Inc. 2009). The City of Toronto's proximity to Lake Ontario is considered to make it a logical resting place for migratory species who have just crossed the lake from the south as well as those about to cross or fly around the lake on their route south (Dougan and Associates and North-South Environmental Inc. 2009).

Wildlife movement corridors are valuable in considering a natural heritage system as they allow species movement at larger scales, promoting genetic diversity (OMNR 1999, 2010). The Lake Ontario Biodiversity Conservation Strategy similarly identifies areas near Lake Ontario as important regional corridor. The Lake Ontario Biodiversity Conservation Strategy identifies natural features from line of wave action of Lake Ontario up to 2km inland as providing migratory stopover sites for land and shore birds, dune plant assemblages, piping plover, and bank swallow colonies (Lake Ontario Biodiversity Conservation Strategy Working Group 2009). The Region of Peel and Town of Caledon Study has identified areas within 2km of the Lake Ontario shoreline for protection for migratory species (North-South Environmental Inc. et al. 2009).

Natural features close to Lake Ontario promote north-south movement of species and east-west movement among shoreline areas and tributaries of Lake Ontario (this includes movements of non-migratory species). Hence the Lake Ontario shoreline is a critical provincial corridor. The shoreline of Lake Ontario also provides a linkage to natural areas in Quebec and farther south in the United States, from which species have the potential to move in response to climate change.

For the purposes of this analysis, all habitat patches lying within 2km of the Lake Ontario shoreline were considered important in providing provincial connectivity (Table 11).

Habitat patches scoring a 'one' under the *Provincial linkage* criterion are shown in Figure A26 (Appendix A) in green. These represent habitat patches that are particularly important for providing ecosystem functions related to provincial connectivity. Habitat patches scoring a ‘zero’ under this criterion are shown in brown.

Details of the GIS methodology used in the Landscape Scale Analysis can be found in Appendix B.

9. Assessment of the aquatic system of the Credit River Watershed

The aquatic system of the Credit River Watershed includes watercourses, lakes and ponds (CVC 1998). In the Ecological Land Classification system used by CVC and in this study, wetlands are considered part of the terrestrial system; however, a great number of wetlands in the watershed are hydrologically connected to streams or lakes (Figure A8, Appendix A) and play an important role in the functioning of the aquatic system. Valleylands are often considered the "backbone" of a watershed, performing important ecological functions because they usually contain watercourses (OMNR 2010). On-line ponds (definition, see Glossary) are associated with some negative ecosystem impacts including increase in water temperature of cold or cool water streams and impedance of sediment movement down the watercourse. Nevertheless these ponds provide habitat for more tolerant species and most importantly, form part of the stream continuum. Along with adjoining lands (valleylands and riparian zones), the aquatic system carries out many significant functions, including such as habitat for species, storage, release and conveyance of water and sediment for terrestrial and aquatic functions, nutrient cycling, erosion and sedimentation (OMNR 1999, 2010). A large number of terrestrial species also depend directly or indirectly on water for their life-cycles (CVC 2002a, 2002b, 2002c). Ecosystem goods and services associated with the aquatic system include flood moderation, sediment deposition, water purification and supply, groundwater recharge and discharge, fisheries, and recreation.

Smaller features such as headwater drainage features or swales can be difficult to map at the 1:10,000 scale due to difficulty in detection through air photo interpretation with some exceptions such as features on agricultural lands in the Peel Plain. Nevertheless these features as a whole contribute significantly to the healthy functioning of aquatic systems (Meyer et al. 2007, Nadeau and Rains 2007, Peterman et al. 2008). Assessment of the functional importance of specific headwater streams is generally conducted during smaller-scale studies (e.g., Environmental Impact Study). A draft set of scientific guidelines has been developed for assessing headwater features (TRCA and CVC 2009).

For the purposes of this analysis, aquatic features that were deemed important for ecosystem function at the watershed scale included permanent and intermittent streams, lakes and on-line ponds (see Glossary for definitions). These features are mapped in Figure A27 (Appendix A).

The aquatic system will be included in the Natural Heritage System for the Credit River Watershed as there is a need to complement the *Fisheries Act* in protecting the other natural resources of the aquatic system. The Natural Heritage System is not intended to limit existing uses of the aquatic system and recommended model policies will reflect this intention. The Credit River Fisheries Management Plan (OMNR and CVC 2002) provides detailed information and management guidelines for the watershed's aquatic system.

10. Mapping results of the Landscape Scale Analysis for the Credit River Watershed

Finally, habitat patches were mapped along with their scores (Figure A28, Appendix A).

Table 14 provides statistics on the number and area of habitat patches scoring between 0 and 9, and their contribution as a percent of total watershed area.

As part of a clustering analysis, habitat patch scores were overlaid with ecologically significant watershed features that were not used in the analysis. Over 75% of habitat patches scoring 7, 8 or 9 contained at least one significant feature, identified as an ESA, provincially significant Life Science ANSI, or PSW. All species at risk occurrences within the past 20 years were captured within habitat patches scoring 1 or more, and over 85% of occurrences were captured within habitat patches scoring 4 or more. Based on these results, habitat patches within the watershed were clustered into Core ecofunction, Highly Supporting ecofunction, Supporting ecofunction, and Contributing ecofunction patches (Table 14; Figure A29, Appendix A). The term ecofunction is used as an abbreviation for ecological function, and has been used elsewhere in a similar context (e.g., Diamond et al. 2002). Therefore features (habitat patches) that have been classified as Core ecofunction support or have the capacity to support a high number of ecological functions, based on this analysis.

Table 14: Number of habitat patches scoring 9, 8, 7, 6, 5, 4, 3, 2, 1, and 0, their area, and area as percent of watershed area.

Habitat patch category	Habitat patch score	Number of habitat patches	Area of habitat patches (ha)	Percent of watershed area
Core ecofunction	**9**	22	5951	6.3%
	8	72	9180	9.7%
	7	71	5259	5.5%
Highly supporting ecofunction	**6**	80	2992	3.2%
	5	86	1623	1.7%
	4	172	1871	2%
Supporting ecofunction	**3**	234	1298	1.4%
	2	302	1431	1.5%
	1	344	1104	1.2%
Contributing ecofunction	**0**	403	774	0.8%

Preliminary analyses using data from CVC's *Natural Areas Inventory* show that TEEM habitat patch scores are significantly correlated with the total number of plant species found in the patches and the total number of unique vegetation types (CVC *unpublished* *data*). That is, higher habitat patch scores are associated with greater numbers of plant species and unique vegetation types, validating the Landscape Scale Analysis approach. As additional data are obtained from the *Natural Areas Inventory*, they will be used to explore further relationships between landscape variables and site level data.

Habitat patches scoring 7-9 are termed Core ecofunction patches. Occupying 21.5% of watershed area, these patches represent the highest quality patches in the watershed from a landscape perspective and on average contain over 200 species within each patch. These core patches are key to maintaining biodiversity and ecosystem function over the long term within the watershed, and should constitute a major component of the watershed Natural Heritage System. Patches scoring 4-6 are termed Highly Supporting ecofunction patches. Occupying 6.9% of watershed area, many of these patches contain ESAs, ANSIs, and PSWs and contribute to the ecological integrity of the Core patches. Patches scoring 1-3 are termed Supporting ecofunction patches and occupy 4.1% of total watershed area. Patches scoring 0 are termed Contributing ecofunction patches and occupy 0.8% of watershed area.

While Supporting and Contributing ecofunction patches account for a smaller percent of watershed area, they are most frequently found in the Lower Watershed, where natural cover is low due to the presence of urban and agricultural land uses. These patches are unique in that they are the last remaining natural areas on three specific physiographic regions of the watershed, namely the Peel Plain, Lake Iroquois Plain, and the South Slope. These patches play an important role in that they maintain or hold the potential to maintain some elements of Carolinian zone biodiversity. They also continue to provide some localized ecosystem functions that are of value due to the overall lack of natural cover in this zone. Their social value is high as they are surrounded by urbanization and provide opportunities for people to interact with and experience nature in areas where they live, work or play.

Table 15 provides statistics on the number and area of habitat patches contributing significantly to each criterion considered important for ecosystem function in the watershed. The largest number of habitat patches fall within the Valleylands and riparian areas criterion, reflecting past history of land use as tableland areas were the first to be converted to agriculture or urbanization. A relatively low number of habitat patches fell within the Successional areas criterion, because there are relatively few large successional areas within the watershed that are not fragmented by roads or other land uses.

Table 15: Number and area of habitat patches contributing significantly to ecosystem function.

	Criterion	Number of habitat patches	Area of habitat patches (ha)
A.	Woodlands	574	27,964
B.	Wetlands	456	23,669
C.	Successional areas	184	17,925
D.	Valleylands and riparian areas	962	28,358
E.	Habitat diversity	323	25,752
F.	Uncommon vegetation communities	468	23,637
G.	Ecological proximity	447	16,737
H.	Regional linkage	408	15,677
I.	Provincial linkage	697	25,501

Terrestrial and aquatic features were mapped for the Credit River Watershed as follows (Figure A30, Appendix A).

1. Habitat patches from the Landscape Scale Analysis; and
2. Important features of the aquatic system of the Credit River Watershed identifiable at the watershed scale – namely, permanent and intermittent streams, lakes and ponds.

Terrestrial and aquatic features important from a functional perspective as identified through the Landscape Scale Analysis may be considered part of an "Existing Natural Heritage System" for the watershed, as these areas do form part of the existing system of natural and semi-natural areas that is functioning at the current time. In that sense, the Natural Heritage System that will be developed for the Credit River Watershed may also be considered to be the "Target Natural Heritage System" as it will identify areas with the potential to be restored to a natural state. However, the term "Existing Natural Heritage System" has been found to be misleading during past communication, as it has sometimes been understood to mean that policies will be developed in relation to this system. To avoid this confusion, the assessment of existing natural features and functions has been termed the Landscape Scale Analysis throughout this document.

Habitat patches in urban and urbanizing areas are underrepresented and have lower scores in the Landscape Scale Analysis, because their size and isolation result in reduced biodiversity and ecological function. These low scores do not necessarily imply that the habitat patches have no value in terms of ecosystem function. The patches contribute to the local hydrologic cycle through infiltration, particularly in watersheds or subwatersheds with low natural cover. The patches may also support functions that can best be detected through site level study – for example, they may lie on a sensitive groundwater recharge area, or support particular species of conservation interest whether such species exist on site or utilize the site. In addition, urban natural areas serve an important social function through enhancement of human well being, educational opportunities, and access to local green spaces. The Landscape Scale Analysis for the watershed cannot capture all data useful for determining a particular site's functions as the analysis is limited to data that are available for the study area as a whole. Finally, patches with low scores in the LSA may hold potential to form a linkage or stepping stone habitat within a Natural Heritage System, or to be restored to natural cover, thereby increasing their capacity to provide some additional functionality to the system as a whole. The contribution of urban natural spaces to local ecological functions may be enhanced through development of a Natural Heritage System identifying areas for protection and enhancement at a smaller scale.

11. Landscape Scale Analysis results and existing protected areas

The habitat patches within the Credit River Watershed contain features and areas that receive some level of protection under existing legislation and those that do not currently receive protection. Features and areas that may have some level of protection include ESAs, ANSIs, PSWs, other wetlands, Greenbelt Natural Heritage System, portions of the Niagara Escarpment and Oak Ridges Moraine and regional or area municipal greenlands systems.

For comparison purposes, results from the Landscape Scale Analysis were overlaid with Species at Risk locations (1km x 1km squares or generalized locations, terrestrial and aquatic species) and with selected protected areas within the Credit River Watershed. Over 84% of Species at Risk generalized locations overlapped with the Core and Highly Supporting ecofunction habitats (habitat patches scoring 4-9 in the watershed Landscape Scale Analysis). A high proportion of Environmentally Significant Areas, provincial and regional Life Science ANSIs, and Provincially Significant Wetlands overlapped with Core and Highly Supporting ecofunction habitat patches (Figure A31, Appendix A).

Figure A32 (Appendix A) shows habitat patch groups from the Landscape Scale Analysis overlaid with areas designated as *Escarpment Natural Area* and *Escarpment Protected Area* within the Niagara Escarpment Plan, protected areas of the Oak Ridges Moraine Conservation Plan, and the Greenbelt Natural Heritage System. A high proportion of these protected areas overlap habitat patches identified as Core ecofunction habitats from the watershed Landscape Scale Analysis.

Figure A33 (Appendix A) shows habitat patch groups from the Landscape Scale Analysis overlaid with provincial, CVC, or NGO properties managed primarily for conservation. Again, a high proportion of these properties overlap with Core ecofunction habitats from the Landscape Scale Analysis.

Figure A34 (Appendix A) shows Core, Highly Supporting, Supporting, and Contributing ecofunction habitat patches from the Landscape Scale Analysis overlaid with all protected areas shown in Figures A31, A32, and A33. A significant number of the Core ecofunction patches from the Landscape Scale Analysis overlap with existing protected areas – nearly 22,000ha or 23% of watershed area. This is likely an underestimate because other protected areas (e.g., Peel's Greenlands System, Mississauga's Natural Areas System, Caledon's Environmental Policy Areas, protected areas within the Region of Halton, and others were not included due to differences in the definitions and level of 'protected' within and among the different systems. Also not included in the overlap calculation were hazard lands regulated by Conservation Authorities. The high degree of overlap indicates that some core ecofunction habitat patches as identified by the Landscape Scale Analysis are already protected through some form of legislation, policy or ownership, but others should be a focus for protection. The overlap also suggests that the Landscape Scale Analysis methodology is a relatively robust method for identifying important natural and semi-natural features on the landscape as it has identified important areas in terms of ecological function that have also been identified under other studies (e.g., ANSIs). Overlays can be conducted in future for any individual municipalities because each municipality would have a protected areas GIS layer that is consistent for its jurisdiction. As an example, an overlay was conducted for the Region of Peel's Greenlands System; 70% of the Region of Peel's Greenlands System overlapped with Core ecofunction habitat patches. The remaining area not overlapping the Peel Greenlands System includes successional habitat that forms part of these habitat patches.

The Landscape Scale Analysis for the Credit River Watershed is based upon sound scientific criteria and principles. Landscape Scale Analyses by their nature are scalable – they can be applied to any area of interest, depending on study goals and objectives – and they can cross municipal or watershed boundaries as long as data are available. For example, the criteria used for the watershed Landscape Scale Analysis can also be used to assess habitat patches within urban areas. Credit Valley Conservation is currently working with the City of Mississauga and associated Conservation Authorities (Toronto and Region Conservation Authority, Halton Region Conservation Authority) to conduct a Landscape Scale Analysis of the natural and semi-natural features within the City boundary. The Analysis offers opportunities to enhance the City's existing Natural Areas System by identifying semi-natural areas that with appropriate restoration or enhancement can contribute strongly to the ecological functioning of the City's ecosystems. The Analysis is also capable of assessing Open Space (e.g., parks) and Agriculture areas for their relative ability to improve ecological functioning of the City's natural ecosystems. These types of analyses can further help municipalities identify priority areas for restoration or stewardship activities (within the context of existing uses where applicable).

12. Future work

This report represents Phase 1 and 2 of TEEM. Background information on the watershed's features and biophysical components has been presented, and a Landscape Scale Analysis conducted that assesses existing natural and semi-natural features that currently support biodiversity and ecosystem function within the Credit River Watershed. Although CVC has not developed policies associated with the Landscape Scale Analysis, this analysis will inform the process of identifying a Natural Heritage System for the Credit River Watershed. Future work could include a similar Landscape Scale Analysis of the aquatic system of the watershed to identify relatively high functioning areas of the aquatic system and those in need of restoration or stewardship. The results of the Landscape Scale Analysis have been communicated to stakeholders through four consultation sessions (Wianecki 2009) and to the public through numerous presentations.

Phase 3 of the TEEM project will focus developing a methodology for the Natural Heritage System for the Credit River Watershed, focusing on protecting, restoring and enhancing the functioning of the watershed's ecosystems.

Phase 4 of TEEM will focus on refining the methodology the Natural Heritage System for the watershed and developing recommended model (sample) policies. During this phase, other scenarios such as increased development, aggregate extraction, or agriculture will be examined to guide development of a system that will have improved resilience to current and future urban growth. Regional connectivity and east-west connections will be enhanced through identification of key connections and bottlenecks in consultation with neighbouring Conservation Authorities and MNR. Pre-settlement vegetation data and results from other watershed studies may help guide restoration – for example it may identify areas which could be restored or rehabilitated to wetlands or to open (savannah or prairie) habitat. Additional management recommendations might arise from an analysis of roads in relation to movement of species that are particularly sensitive to roads or their impacts. This phase will also include development of recommended model policies for the watershed Natural Heritage System, and development of indicators and targets related to monitoring progress towards achieving the goals and objectives for the Natural Heritage System.

Stakeholder input will continue to be sought during Phase 3 and Phase 4 of Natural Heritage System development. Outreach throughout the process will keep the general public informed of this CVC initiative.

Following development of the Credit River Watershed Natural Heritage System, CVC will engage municipal planning authorities to emphasize the effectiveness of existing natural heritage related policies and provide technical information to assist in updating existing natural heritage system protection strategies within the context of watershed health.

This Landscape Scale Analysis presents the rationale and approach to assessing existing natural and semi-natural areas of the watershed for purposes of natural heritage planning, based on current science and information. As data for the watershed improve and the science around these analyses advances, the Landscape Scale Analysis should be updated and improved. It is recommended that the Landscape Scale Analysis be rerun every 5-10 years to determine how site quality in the watershed is changing. Landscape Scale Analysis shapefiles and the Analysis results will be kept as current as possible based on CVC's Ecological Land Classification updates.

13. References

2DegreesC. 2007. Climate change: impacts and adaptations for terrestrial and aquatic ecosystems and species in the Credit Valley. Final report, September 10, 2007. 82p.

Agriculture and Agri-Food Canada. 2003. 2002-2003 Canadian honey situation and trends. Available online at http://www4.agr.gc.ca/resources/prod/doc/horticulture/honey_e.pdf Accessed 2 February 2009.

Andren, H. 1994. Effects of habitat fragmentation on birds and mammals in landscapes with different proportions of suitable habitat: A review. Oikos 71(3):355-366.

Askins, R.A. and M.J. Philbrick. 1987. Effect of changes in regional forest abundance on the decline and recovery of a forest bird community. *Wilson Bulletin* 99:7-21.

Askins, R.A. 2000. Restoring North America's birds. Yale University Press, New Haven, Connecticut.

Austen, M.J.W. and M.S.W. Bradstreet. 1996. The effects of fragmentation on forest birds and plants in southern Ontario: Recommendations for woodland conservation and restoration. Long Point Bird Observatory. Port Rowan, Ontario. 43 p.

Austen, M.J.W., C.M. Francis, D.M. Burke and M.S. Bradstreet. 2001. Landscape context and fragmentation effects on forest birds in southern Ontario. *Condor* 103:704-714.

Batáry, P. and A. Báldi. 2004. Evidence of an edge effect on avian nest success. *Conservation Biology* 18:389-400.

Bay, M.D. 1996. Breeding Birds in Early Successional Oldfields: the Effect of Area on Community Structure. Proceedings of the Oklahoma Academy of Science 76:67-73.

Beacon Environmental and LSRCA (Lake Simcoe Region Conservation Authority). 2007. Natural Heritage System for the Lake Simcoe Watershed. Prepared for the Lake Simcoe Region Conservation Authority and the Lake Simcoe Environmental Management Strategy. 142 p. plus appendices.

Belisle, M. and A. Desrochers. 2002. Gap-crossing decisions by forest birds: an empirical basis for parameterizing spatially-explicit, individual-based models. *Landscape Ecology* 17:219-231.

Bennett, A.F. 2003. Linkages in the Landscape: The Role of Corridors and Connectivity in Wildlife Conservation. IUCN, Gland, Switzerland and Cambridge, UK. xiv + 254 p.

Berger G., P. Holger, H. Kächele, S. Andreas, and J. Hoffmann. 2003. Nature protection in agricultural landscapes by setting aside unproductive areas and ecotones within arable fields ("Infield Nature Protection Spots"). Journal for Nature Conservation 11:221-233.

Bird Studies Canada, Federation of Ontario Naturalists, Canadian Wildlife Service, Ontario Ministry of Natural Resources, and Ontario Field Ornithologists. 2004. Ontario Breeding Bird Atlas Database. Port Rowan, Ontario: Bird Studies Canada.

Bonter, D.N., S.A. Gauthreaux, and T.N. Donovan. 2009. Characteristics of important stopover locations for migrating birds: remote sensing with radar in the Great Lakes Basin. *Conservation Biology* 23:440-448.

Booth, D.B. 2000. *Forest Cover, Impervious-Surface Area, and the Mitigation of Urbanization Impacts in King County, Washington*. Prepared for King County Water and Land Resources Division. Seattle, Washington. 18 pp.

Booth, D.B., D. Hartley, and R. Jackson. 2002. Forest cover, impervious-surface area, and the mitigation of stormwater impacts. *Journal of the American Water Resources Association* 38:835-845.

Brennan, L.A. and W.P. Kuvlesky, Jr. 2005. North American grassland birds: an unfolding conservation crisis? *Journal of Wildlife Management* 69:1-13.

Breshears, D.D., 2007. Drought-induced vegetation mortality and associated ecosystem responses: examples from semiarid woodlands and forests. In: *Understanding Multiple Environmental Stresses*. National Academy Press, Washington, D.C., pp. 89–95.

Burke, D.M. and E. Nol. 1998. Influence of food abundance, nest-site habitat, and forest fragmentation on breeding ovenbirds. *Auk* 115:96–104.

Burke, D.M. and E. Nol. 2000. Landscape and fragment size effects on reproductive success of forest-breeding birds in Ontario. *Ecological Applications* 10:1749-1761.

Burne, M.R. and C.R. Griffin. 2005. Habitat associations of pool-breeding amphibians in eastern Massachusetts, USA. *Wetlands Ecology and Management* 13:247-259.

CCSP (Climate Change Science Program) 2009: *Thresholds of Climate Change in Ecosystems.* A report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research [Fagre, D.B., C.W. Charles, C.D. Allen, C. Birkeland, F.S. Chapin III, P.M. Groffman, G.R. Guntenspergen, A.K. Knapp, A.D.

Chen, J., S.C. Saunders, T.R. Crow, R.J. Naiman, K.D. Brosofske, G.D. Mroz, B.L. Brookshire and J.F. Franklin. 1999. Microclimate in forest ecosystem and landscape ecology. *BioScience* 49:288–297.

McGuire, P.J. Mulholland, D.P.C. Peters, D.D. Roby, and George Sugihara]. U.S. Geological Survey, Reston, VA, 156 pp.

Canadian Urban Institute. 2006. Nature Count$: valuing southern Ontario's natural heritage. Prepared by the Canadian Urban Institute for the Natural Spaces Leadership Alliance.

Cardinale, B.J., M.A. Palmer and S.L. Collins. 2002. Species diversity enhances ecosystem functioning through interspecific facilitation. *Nature* 415:426-429.

Castelle, A.J., A.W. Johnson and C. Conolly. 1994. Wetland and stream buffer size requirements - A Review. *Journal of Environmental Quality* 23:878-882.

Cataraqui Region Conservation Authority. 2006. Central Cataraqui Region Natural Heritage Study. Final draft report June 2006. Available online at http://www.cataraquiregion.on.ca/management/ccrnaturalheritagestudyjune2006.pdf Accessed 29 January 2009.

Chapman, L.J. and Putnam, D.F. 2007. Physiography of southern Ontario. Ontario Geological Survey, Miscellaneous Release--Data 228. ISBN 978-1-4249-5158-1.

Chase, V., L. Deming, and F. Latawiec. 1995 revised 1997. Buffers for wetlands and surface waters. A guidebook for New Hampshire municipalities. University of New Hampshire Cooperative Extension. 82p.

Chen, J., S.C. Saunders, T.R. Crow, R.J. Naiman, K.D. Brosofske, G.D. Mroz, B.L. Brookshire, and J.F. Franklin. 1999. Microclimate in forest ecosystem and landscape ecology. *Bioscience* 49:288-297.

Chichilnisky, G. and G. Heal. 1998. Economic returns from the biosphere. *Nature* 391: 629-630.

Christensen, N.L., A.M. Bartuska, J.H. Brown, S. Carpenter, C. D'Antonio, R. Francis, J.F. Franklin, J.A. MacMahon, R.F. Noss, D.J. Parsons, C.H. Peterson, M.G. Turner, and R.G. Woodmansee. 1996. The report of the Ecological Society of America Committee on the scientific basis for ecosystem management. *Ecological Applications* 6:665-691.

Chu, C., N.E. Jones, N.E. Mandrak, A.R. Piggott and C.K. Minns. 2008. The influence of air temperature, groundwater discharge and climate change on the thermal diversity of stream fishes in southern Ontario watersheds. *Canadian Journal of Fisheries and Aquatic Science* 65:297-308.

City of Brampton. 2008. Official Plan. Available online at http://www.city.brampton.on.ca/official_plan/pdfs/officialplan358-2006.pdf Accessed 26 January 2009.

City of Hamilton. 2005. Discussion Paper #4a: Review of Significant Woodland Criteria Technical Discussion Paper. 17p.

City of Hamilton. 2006. Rural Official Plan. 109p. Available online at http://www.myhamilton.ca/myhamilton/CityandGovernment/CityDepartments/PlanningEcDev/LongRangePlanning/OfficialPlan/HamiltonNewOfficialPlan/Rural-Hamilton-Official-Plan.htm Accessed 31 January 2009.

City of London. 2006. City of London: Guideline Document for the Evaluation of Ecologically Significant Woodlands. City of London. London. 12p.

City of Mississauga. 2005. Mississauga Plan. Available online at http://www.mississauga.ca/portal/residents/mississaugaplan Accessed 27 January 2009.

City of Mississauga. 2006. Natural Areas Survey – 2006 update.

Colombo, S.J., M.L. Cherry, C. Graham, S. Greifenhagen, R.S. McAlpine, C.S. Papadopol, W.C. Parker, T. Scarr, M.T. Ter-Mikaelian, and M.D. Flannigan. 1998. The impacts of climate change on Ontario's forests. Queen's Printer for Ontario.

Colombo, S.J., D.W. McKenney, K.M. Lawrence, and P.A. Gray. 2007. Climate change projections for Ontario: practical information for policymakers and planners.

Costanza, R., R. d'Arge, R.S. de Groot, S. Farber, M. Grasso, B. Hannon, K. Limburg, S. Naeem, R.V. O'Neill, J. Paruelo, R.G. Raskin, P. Sutton, and M. van den Belt. 1997. The value of the world's ecosystem services and natural capital. *Nature* 387:253-260.

Crawford, J.A. and R.D. Semlitsch. 2007. Estimation of core terrestrial habitat for stream-breeding salamanders and delineation of riparian buffers for protection of biodiversity. *Conservation Biology* 21:152-158.

Cuffney, T.F., R.A. Brightbill, J.T. May, and I.R. Waite. 2010. Responses of benthic macroinvertebrates to environmental changes associated with urbanization in nine metropolitan areas. *Ecological Applications* 20:1384-1401.

CVC (Credit Valley Conservation).1998. Credit Watershed Natural Heritage Project detailed methodology: identifying, mapping, and collecting field data at watershed and subwatershed scales. Version 3, April 1998. 137p.

CVC (Credit Valley Conservation). 2002a. Birds of the Credit River Watershed.

CVC (Credit Valley Conservation). 2002b. Mammals of the Credit River Watershed.

CVC (Credit Valley Conservation). 2002c. Reptiles and amphibians of the Credit River Watershed.

CVC (Credit Valley Conservation), Schroeter and Associates, Environmental Water Resources Group, Aquafor Beech Ltd., Jacques Whitford Environmental Ltd. 2002d. Silver Creek Subwatershed Study Characterization Report.

CVC (Credit Valley Conservation). 2003a. Caledon Creek and Credit River Subwatershed Study - Subwatershed 16 & 18 (October 2003). Available online at http://www.creditvalleyca.ca/bulletin/resources.htm Accessed 28 January 2009.

CVC (Credit Valley Conservation). 2003b. Silver Creek Subwatershed Study - Subwatershed 11 Updated November 2003. Available online at http://www.creditvalleyca.ca/bulletin/resources.htm Accessed 28 January 2009.

CVC (Credit Valley Conservation) and University of Guelph. 2003. Mapping pre-settlement vegetation from surveyors' records.

CVC (Credit Valley Conservation). 2004. Greenlands Securement Strategy. 44p.

CVC (Credit Valley Conservation). 2005. Credit Valley Conservation Watershed Report Card. A detailed summary on the ecosystem health of the Credit River Watershed. 24p. Available online at http://www.creditvalleyca.ca/bulletin/downloads/WRCard-Detailed.pdf Accessed 28 April 2009.

CVC (Credit Valley Conservation). 2006a. Terrestrial Ecosystem Enhancement Model (TEEM). Background document and terms of reference. February 2006.

CVC (Credit Valley Conservation). 2006b. Credit Valley Conservation Strategic Plan 2006.

CVC (Credit Valley Conservation). 2007a. Interim Watershed Characterization Report for the Credit River Watershed. 28 February 2007.

CVC (Credit Valley Conservation). 2007b. Credit River Water Management Strategy Update – Making it Work. May 2007. Available online at http://www.creditvalleyca.ca/bulletin/downloads/CRWMSU-detailedreport.pdf accessed 26 Nov 2008).

CVC (Credit Valley Conservation). 2007c. East Credit Subwatershed Study - Subwatershed 13. Finalized November 2007. Available online at http://www.creditvalleyca.ca/bulletin/resources.htm Accessed 28 January 2009.

CVC (Credit Valley Conservation). 2008. Credit Valley Conservation Draft Integrated Water Budget Report. November 2008.

CVC (Credit Valley Conservation). 2009. Credit Valley Conservation: An Invasive Species Strategy (Draft).

CVC (Credit Valley Conservation). 2010. Monitoring wetland integrity within the Credit River Watershed. Chapter 3: Wetland vegetation 2005-2009. Credit Valley Conservation ix+102p.

CWP (Centre for Watershed Protection). 2003. Impacts of impervious cover on aquatic systems. 142p.

CWP (Centre for Watershed Protection). 2005. Urban watershed forestry manual: methods for increasing forest cover in a watershed. 94p. plus appendices.

CWP (Centre for Watershed Protection). 2006. Direct and indirect impacts of urbanization on wetland quality. 81p.

CWP (Centre for Watershed Protection). 2007. The importance of protecting vulnerable streams and wetlands at the local level. 48p.

CWS (Canadian Wildlife Service). 2007. Area-sensitive forest birds in urban areas.

Daily, G.C. (Ed.), 1997. Nature's Services: Societal Dependence on Natural Ecosystems. Island Press, Washington, DC.

Daily, G.C., T. Soderquist, S. Aniyar, K. Arrow, P. Dasgupta, P.R. Ehrlich, C. Folke, A.M. Jansson, B.O. Jansson, N. Kautsky, S. Levin, J. Lubchenco, K.G. Maler, S. David, D. Starrett, D. Tilman, and B. Walker. 2000. The value of nature and the nature of value. *Science* 289:395–396.

Damschen, E.I., N.M. Haddad, J.L. Horrock, J.J. Tewksbury, and D.J. Levey. 2006. Corridors increase plant species richness at large scales. *Science* 313:1284-1286.

Debinski, D.M., C. Ray, and E.H. Saveraid. 2001. Species diversity and the scale of the landscape mosaic: Do scales of movement and patch size affect diversity? Biological Conservation 98:179-190.

de Groot, R.S., M.A. Wilson, and R.M.J. Boumans. 2002. A typology for the classification, description and valuation of ecosystem functions, goods and services. *Ecological Economics* 41:393-408.

Diamond, M., J. Dougan, N. Helferty, E. Hodge, P. Niblett, M. Rose and S. Rowe. 2002. Natural Heritage Systems in urbanizing settings: sustainable practices for the Oak Ridges Moraine. Prepared on behalf of the Save the Rouge Valley System Inc. and the City of Toronto. 109p.

Dougan and Associates. 2003. Natural Areas Inventory: Town of Fort Erie Settlement Areas. (Volume 1 of 2). Final Draft March 2003. 78p.

Dougan and Associates. 2005. Region of Waterloo Environmentally Sensitive Landscapes (ESLs) Study Discussion Paper. Final Report August 2005. 66p.

Dougan and Associates 2009. Guelph Natural Heritage Strategy. Phase 2: Terrestrial Inventory & Natural Heritage System. Volume 1. Final report March 2009. 102p.

DSS Management Consultants Inc. 2008. The Credit River Watershed: Social, economic and environmental services provided to the watershed community. Valuation of Angling. Final report January 2008. 52p.

DSS Management Consultants Inc. 2008. The Credit River Watershed: Social, economic and environmental services provided to the watershed community. The impact of natural features on property values. Final report March 2009. 40p.

Ducks Unlimited Canada. 2010. Southern Ontario wetland conversion analysis. Final report March 2010. Ducks Unlimited Canada. 51p.

Duffy, J.E. 2009. Why biodiversity is important to the functioning of real-world ecosystems. *Frontiers in Ecology and the Environment* 7:437-444.

Dunford, W. and K. Freemark. 2004. Matrix matters: effects of surrounding land uses on forest birds near Ottawa, Canada. *Landscape Ecology* 20:497-511.

DuWors, E., M. Villeneuve, and F. Filion, 1999. The Importance of Nature to Canadians: Survey Highlights. Environmental Economics Branch, Environment Canada, Ottawa.

ECO (Environmental Commissioner of Ontario). 2000. The protection of Ontario's groundwater and intensive farming. Special report to the Legislative Assembly of Ontario. 27 July 2000. 14p.

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

Endangered Species Act. 2007. Available online at http://www.e-laws.gov.on.ca/html/statutes/english/elaws_statutes_07e06_e.htm Accessed 29 January 2009.

Environment Canada. 2004. How much habitat is enough? A framework for guiding habitat rehabilitation in Great Lakes Areas of Concern. 2nd edition. Canadian Wildlife Service. 88p.

Environment Canada. 2007. Area-sensitive forest birds in urban areas. Canadian Wildlife Service. 58p.

Environmental Law Institute. 2003. Conservation thresholds for land use planners. Environmental Law Institute, Washington, DC. 64p.

Ewert, D.N., G.J. Soulliere, R.D. Macleod, M.C. Shieldcastle, P.G. Rodewald, E. Fujimura, J. Shieldcastle, and R.J. Gates. 2006. Migratory bird stopover site attributes in the western Lake Erie basin. Final report to The George Gund Foundation.

Federal Provincial Task Force on the Importance of Nature to Canadians. 1999. The importance of nature to Canadians: the economic significance of nature-related activities. Environment Canada.

Fahrig, L. 1997. Relative effects of habitat loss and fragmentation on population extinction. *Journal of Wildlife Management* 61:603-610.

Fahrig, L. 1998. When does fragmentation of breeding habitat affect population survival? *Ecological Modelling* 105:273-292.

Fahrig, L. 2001. How much habitat is enough? *Biological Conservation* 100:65-74.

Fahrig, L. 2002. Effect of habitat fragmentation on the extinction threshold: a synthesis. *Ecological Applications* 12:346-353.

Faulkner, S. 2004. Urbanization impacts on the structure and function of forested wetlands. *Urban Ecosystems* 7:89-106.

Findlay, C.S. and J. Houlahan. 1997. Anthropogenic correlates of species richness in southeastern Ontario wetlands. *Conservation Biology* 11:1000-1009.

Forman, R.T.T. 1995. Land mosaics: the ecology of landscapes and regions. Cambridge University Press, Cambridge, England. 632p.

Forman, R.T.T. 2000. Estimate of the area affected ecologically by the road system in the United States. *Conservation Biology* 14:31-35.

Forman, R.T.T. and M. Godron. 1986. Landscape ecology. Wiley, New York.

Forman, R.T.T., D. Sperling, J.A. Bissonette, A.P. Clevenger, C.D. Cutshall, V.H. Dale, L. Fahrig, R. France, C.R. Goldman, K. Heanue, J.A. Jones, F.J. Swanson, T. Turrentine and T.C. Winter. 2003. Road Ecology: Science and solutions. Island Press, Washington. 481p.

Friesen, L., M.D. Cadman and R.J. MacKay. 1999. Nesting success of neotropical migrant songbirds in a highly fragmented landscape. *Conservation Biology* 13:338-346.

Friesen, L.E., V.E. Wyatt and M.D. Cadman. 1999. Pairing success of Wood Thrushes in a fragmented agricultural landscape. *Wilson Bulletin* 111:279-281.
Fuller, T.K. and S. DeStefano. 2003. Relative importance of early-successional forests and shrubland habitats to mammals in the northeastern United States. *Forest Ecology and Management* 185:75-79.

Gabor, T.S., A.K. North, L.C.M. Ross, H.R. Murkin, J.S. Anderson, and M.A. Turner. 2001. Beyond the pipe: The importance of wetlands & upland conservation practices in watershed management: Functions and values for water quality and quantity. Ducks Unlimited Canada.

Gartner-Lee Ltd. 2002. Final report: Rationale and methodology for determining significant woodlands in the Regional Municipality of Halton. Prepared for the Regional Municipality of Halton.

Gibbs, J.P. and W.G. Shriver. 2005. Can road mortality limit populations of pool-breeding amphibians? *Wetlands Ecology and Management* 13:281-289.

Gilbert-Norton, L., R. Wilson, J.R. Stevens, and K.H. Beard. 2010. A meta-analytic review of corridor effectiveness. *Conservation Biology* 24:660-668.

Goetz, S.J., R.K. Wright, A.J. Smith, E. Zinecker, and E. Schaub. 2003. IKONOS imagery for resource management: tree cover, impervious surfaces, and riparian buffer analyses in the mid-Atlantic region. *Remote Sensing of Environment* 88:195-208.

Golet, F.H., Y. Wang, J.D. Merrow, and W.R. DeRagon. 2001. Relationship between habitat and landscape features and the avian community of red maple swamps in southern Rhode Island. *Wilson Bulletin* 113:217-227.

Government of Canada. *Species at Risk Act.* Available online at http://laws.justice.gc.ca/en/s-15.3/text.html Accessed 31 January 2009.

Government of Ontario. *Clean Water Act.* Available online at http://www.e-laws.gov.on.ca/html/statutes/english/elaws_statutes_06c22_e.htm Accessed 29 January 2009.

Government of Ontario. *Conservation Authorities Act.* Available online at http://www.e-laws.gov.on.ca/html/statutes/english/elaws_statutes_90c27_e.htm Accessed 31 January 2009.

Government of Ontario. *Endangered Species Act.* Available online at http://www.e-laws.gov.on.ca/html/statutes/english/elaws_statutes_07e06_e.htm Accessed 31 January 2009.

Government of Ontario. *Places to Grow Act.* Available online at http://www.e-laws.gov.on.ca/html/statutes/english/elaws_statutes_05p13_e.htm Accessed 31 January 2009.

Government of Ontario. *Planning Act.* Available online at http://www.e-laws.gov.on.ca/html/statutes/english/elaws_statutes_90p13_e.htm Accessed 31 January 2009.

Gregory, S.V., F.J. Swanson, W.A. McKee, and K.W. Cummins. 1991. An ecosystem perspective of riparian zones. *Bioscience* 41:540-555.

Guerry, A.D., and M.L. Hunter Jr. 2002. Amphibian distributions in a landscape of forests and agriculture: An examination of landscape composition and configuration. *Conservation Biology* 16:745-754.

Gunderson, L. 1999. Resilience, flexibility and adaptive management - antidotes for spurious certitude? *Conservation Ecology* 3(1): 7. Available online at http://www.ecologyandsociety.org/vol3/iss1/art7/ Accessed 29 January 2009.

Gunderson, L.H. 2000. Ecological resilience in theory and application. *Annual Review of Ecology and Systematics* 31:425-439.

Gutzwiller, K.J. (ed.) 2002. Applying landscape ecology in biological conservation. Springer-Verlag, New York, New York. 518p.

Haddad, N.M., G.M. Crutsinger, K. Gross, J. Haarstad, J.M.H. Knopps and D. Tilman. 2009. Plant species loss decreases arthropod diversity and shifts trophic structure. *Ecology Letters* 12:1029-1039.

Halpin, P.N. 1997. Global climate change and natural-area protection: management responses and research directions. *Ecological Applications* 7:828-843.

Hames, R.S., K.V. Rosenberg, J.D. Lowe and A.A. Dhondt. 2001. Site reoccupation in fragmented landscapes: Testing predictions of metapopulation theory. *Journal of Animal Ecology* 70:182-190.

Hannon, L.E. and T.D. Sisk. 2009. Hedgerows in an agri-natural landscape: potential habitat value for native bees. *Biological Conservation* 142:2140-2154.

Hansen, A.J., R.P. Nielson, V.H. Dale, C.H. Flather, L.R. Iverson, D.J. Currie, S. Shafer, R. Cook, and P.J. Bartlein. 2001. Global change in forests: responses of species, communities, and biomes. *BioScience* 51:765-779.

Hargis, C.D., J.A. Bissonette, and J.L. David. 1998. The behavior of landscape metrics commonly used in the study of habitat fragmentation. *Landscape Ecology* 13:167-186.

Hargrave, C.W. 2009. Effects of fish species richness and assemblage composition on stream ecosystem function. *Ecology of Freshwater Fish* 18:24-32.

Hartley, M.J. and M.L. Hunter, Jr. 1998. A meta-analysis of forest cover, edge effects, and artificial nest predation rates. *Conservation Biology* 12:465-469.

Hels, T. and E. Buchwald. 2001. The effect of road kills on amphibian populations. *Biological Conservation* 99:331-340.

Henson, B.L., K.E. Brodribb, and J.L. Riley. 2005a. Great Lakes Conservation Blueprint for terrestrial biodiversity. Volume 1. Nature Conservancy of Canada. 156p.

Henson, B.L. and K.E. Brodribb. 2005b. Great Lakes Conservation Blueprint for terrestrial biodiversity. Volume 2. Ecodistrict summaries. Nature Conservancy of Canada. 344p.

Herkert, J.R. 1994. The effects of habitat fragmentation on midwestern grassland bird communities. *Ecological Applications* 4:461-71.

Herrmann H.L., K.J. Babbitt, M.J. Baber, and R.G. Congalton. 2005. Effects of landscape characteristics on amphibian distribution in a forest-dominated landscape. *Biological Conservation* 123:139-149.

Hilty, J.A., W.Z. Lidicker Jr., and A.M. Merenlender. 2006. Corridor ecology. The science and practice of linking landscapes for biodiversity conservation. Island Press. 323p.

Hodges, M.F., Jr., and D.G. Krementz. 1996. Neotropical migratory breeding bird communities in riparian forests of different widths along the Altamaha river, Georgia. *Wilson Bulletin* 108:496-506.

Holling, C.S. 1973. Resilience and stability of ecological systems. *Annual Review of Ecology and Systematics* 4:1-23.

Honnay, O., K. Verheyen, J. Butaye, H. Jacquemyn, B. Bossuyt, and M. Hermy. 2002. Possible effects of habitat fragmentation and climate change on the range of forest plant species. *Ecology Letters* 5:525-530.

Hooper, D.U., F.S. Chapin III, J.J. Ewel, A. Hector, P. Inchausti, S. Lavorel, J.H. Lawton, D.M. Lodge, M. Loreau, S. Naeem, B. Schmid, H. Setala, A.J. Symstad, J. Vandermeer, and D.A. Wardle. 2005. Effects of biodiversity on ecosystem functioning: a consensus of current knowledge. *Ecological Monographs* 75:3-35.

Jalava, J.V., J.L. Riley, D.G. Cuddy, and W.J. Crins. 1996. A proposed revision to Ecological Site District boundaries in Site Regions 6 and 7 (Unpublished draft). Natural Heritage Information Centre, Peterborough, Ontario.

Johnston, C.A., N.E. Detenbeck, and G.J. Niemi. 1990. The cumulative effects of wetlands on stream water quality and quantity. A landscape approach. *Biogeochemistry* 10:105-141.

Johnston, C.A. 1994. Cumulative impacts to wetlands. *Wetlands* 14:49-55.

Karraker, N.E., J.P. Gibbs, and J.R. Vonesh. 2008. Impacts of road deicing salt on the demography of vernal pool-breeding amphibians. *Ecological Applications* 18:724-734.

Kareiva, P. 1994. Diversity begets productivity. *Nature* 368:686-687.

Kennedy, M. and J. Wilson. 2009. Natural Credit: Estimating the value of natural capital in the Credit River Watershed. The Pembina Institute and Credit Valley Conservation. 64p.

Kerr, J.T. 2001. Butterfly species richness patterns in Canada: energy, heterogeneity, and the potential consequences of climate change. *Conservation Ecology* 5:10 [online] URL: http://www.consecol.org/vol5/iss1/art10.

Kremen, C. 2005. Managing ecosystem services: what do we need to know about their ecology? *Ecology Letters* 8:468-479.

Lake Ontario Biodiversity Conservation Strategy Working Group. 2009. The beautiful lake. A binational biodiversity conservation strategy for Lake Ontario. Final report April 2009 updated July 2009.

Lantz, V., P. Boxall, M. Kennedy and J. Wilson. 2010. Valuing wetlands in southern Ontario's Credit River Watershed: A contingent valuation analysis. June 2010. The Pembina Institute and Credit Valley Conservation. 33p.

Larson, B.M, J.L. Riley, E.A. Snell and H.G. Godschalk. 1999. The woodland heritage of southern Ontario: a study of ecological change, distribution and significance. Federation of Ontario Naturalists, Don Mills, Ontario. 262 p.

Lee, H.T., W.D. Bakowsky, J. Riley, J. Bowles, M. Puddister, P. Uhlig, and S. McMurray. 1998. Ecological Land Classification for Southern Ontario: First Approximation and its Application. Ontario Ministry of Natural Resources, Southcentral Science Section, Science Development and Transfer Branch. SCSS Field Guide FG-02. 225p.

Lee J.T., S.J. Woddy, and S. Thompson. 2001. Targeting sites for conservation: Using a patch-based ranking scheme to assess conservation potential. *Journal of Environmental Management* 61:367-380.

Lee, M., L. Fahrig, K. Freemark, and D.J. Currie. 2002. Importance of patch scale vs landscape scale on selected forest birds. *Oikos* 96:110-118.

Lee, P., C. Smyth, and S. Boutin. 2004. Quantitative review of riparian buffer width guidelines from Canada and the United States. *Journal of Environmental Management* 70:165-180.

Leitao, A.B. and J. Ahern. 2002. Applying landscape ecological concepts and metrics in sustainable landscape planning. *Landscape and urban planning* 59:65-93.

Levey, D.J., B.M. Bolker, J.J. Tewksbury, S. Sargent, and N.M. Haddad. 2005a. Effects of landscape corridors on seed dispersal by birds. *Science* 309:146-148.

Levey, D.J., B.M. Bolker, J.J. Tewksbury, S. Sargent, and N.M. Haddad. 2005b. Response to Proches et al. 2005. *Science* 310:782-783.

Lindenmayer, D.B., R.B. Cunningham, C.F. Donnelly, H. Nix and B.D. Lindenmayer. 2002. Effects of forest fragmentation on bird assemblages in a novel landscape context. *Ecological Applications* 72:1-18.

Lindenmayer, D.B. and J.F. Franklin. 2002. Conserving forest biodiversity: A comprehensive multiscaled approach. Island Press, Washington, DC. 368p.

Loreau, M., S. Naeem, P. Inchausti, J. Bengtsson, J.P. Grime, A. Hector, D.U. Hooper, M.A. Huston, D. Raffaelli, B. Schmid, D. Tilman, D.A. Wardle. 2001. Biodiversity and ecosystem functioning: current knowledge and future challenges. *Science* 294:804-808.

Lower Trent Conservation. 2001. Natural Heritage Report: Municipality of Campbellford/Seymour/Percy/Hastings, City of Quinte West, and City of Belleville. 33p. plus appendices.

MacArthur, R.H. and E.O. Wilson. 1967. The theory of island biogeography. Princeton University Press, Princeton.

Macdonald, S.E., B. Eaton, C.S. Machtans, C. Paszkowski, S. Hannon, and S. Boutin. 2006. Is forest close to lakes ecologically unique? Analysis of vegetation, small mammals, amphibians and songbirds. *Forest Ecology and Management* 223:1-17.

Machtans, C.S., M.-J. Villard, and S.J. Hannon. 1996. Use of riparian buffer strips as movement corridors by forest birds. *Conservation Biology* 10:1366-1379.

Mancke, R.G. and T.A. Gavin. 2000. Breeding bird density in woodlots: Effects of depth and buildings at the edges. *Ecological Applications* 10:598-611.

Marzluff, J.M. and K. Ewing. 2001. Restoration of fragmented landscapes for the conservation of birds: A general framework and specific recommendations for urbanizing landscapes. *Restoration Ecology* 9:280-292.

Mayer, P.M., S.K. Reynolds, M.D. McCutchen, and T.J. Canfield. 2005. Riparian buffer width, vegetative cover, and nitrogen removal effectiveness: A review of current science and regulations. EPA/600/R-05/118. Cincinnati, OH, U.S. Environmental Protection Agency.

Mazerolle, M.J. 2004. Amphibian road mortality in response to nightly variations in traffic intensity. *Herpetologica* 60:45-53.

McGarigal, K. and B.J. Marks. 1995. FRAGSTATS: spatial pattern analysis program for quantifying landscape structure. Gen. Tech. Rep. PNW-GTR-351. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 122p.

McGarigal, K. and W.C. McComb. 1995. Relationships between landscape structure and breeding birds in the Oregon Coast Range. *Ecological Monographs* 65:235-260.

McNeil, J. and C. Vava. 2006. Oakville's urban forest: our solution to our pollution. Town of Oakville, Parks and Open Space Department, Forestry Section.

Meyer, C.L., T.D. Sisk and W.W. Covington. 2001. Microclimatic changes induced by ecological restoration of Ponderosa pine forests in northern Arizona. *Restoration Ecology* 9:443-452.

Meyer, J.L., D.L. Strayer, J.B. Wallace, S.L. Eggert, G.S. Helfman, and N.E. Leonard. 2007. The contribution of headwater streams to biodiversity in river networks. *Journal of the American Water Resources Association* 43:86-103.

Millennium Ecosystem Assessment. 2005. Ecosystems and Human Well-being: Synthesis. Island Press, Washington, DC.

Milne, R.J. and L.P. Bennett. 2007. Biodiversity and ecological value of conservation lands in agricultural landscapes of southern Ontario, Canada. *Landscape Ecology* 22:657-670.

Mitsch, W.J. and J.G. Gosselink. 2000. The value of wetlands: importance of scale and landscape setting. *Ecological Economics* 35:25-33.

MOE (Ontario Ministry of the Environment). 2005. Transboundary air pollution in Ontario. Available online at http://www.ene.gov.on.ca/envision/techdocs/5158e_1.pdf Accessed 15 April 2009. 7p.

MOE (Ontario Ministry of the Environment). 2006. Draft Watershed Characterization, Guidance Module October 2006.

Mooney, H.A. and E.E. Cleland. 2001. The evolutionary impact of invasive species. *Proceedings of the National Academy of Sciences* 98:5446-5451.

Mortberg, U.M. 2001. Resident bird species in urban forest remnants: landscape and habitat perspectives. *Landscape Ecology* 16:193-203.

MPIR (Ministry for Public Infrastructure and Renewal, now renamed Ministry of Energy and Infrastructure). 2006. Places to Grow. Growth Plan for the Greater Golden Horseshoe. Queen's Printer for Ontario.

Nadeau, T-L. and M.C. Rains. 2007. Hydrological connectivity between headwater streams and downstream waters: how science can inform policy. *Journal of the American Water Resources Association* 43:118-133.

Naiman, R.J. and H. Decamps. 1997. The ecology of interfaces: Riparian zones. *Annual Review of Ecology and Systematics* 28:621-658.

Naiman, R.J., H. Decamps and M. Pollock. 1993. The role of riparian corridors in maintaining regional diversity. *Ecological Applications* 3:209-212.

NEC (Niagara Escarpment Commission). 2010. The Niagara Escarpment Plan. Office Consolidation March 11, 2010. Queen's Printer for Ontario. 136p. Available online at http://www.escarpment.org/_files/file.php?fileid=fileAvYFlCnDlv&filename=file_NEP_Consolidation_March_11_2010.pdf Accessed 25 November 2010.

NHIC (Natural Heritage Information Centre). 2002. Big Picture 2002. Available online at http://nhic.mnr.gov.on.ca/MNR/nhic/projects/BP/bigpict_2002_main.cfm Accessed 29 January 2009.

North-South Environmental Inc. 2009. Natural Heritage System definition and implementation. Sustainable Halton Report 3.02. Final Draft April 2009. 62p.

North-South Environmental Inc., Dougan and Associates, and Sorensen Gravely Lowes 2009. Peel-Caledon Significant Woodlands and Significant Wildlife Habitat Study. Final Report June 2009. Ontario: Region of Peel and Town of Caledon. Available online at http://www.region.peel.on.ca/planning/officialplan/woodlands-and-wetlands-discussion-paper.htm accessed 15 January 2009.

Noss, R.F. and L.D. Harris. 1986. Nodes, networks and MUMS: Preserving biodiversity at all scales. *Environmental Management* 10:299-309.

NVCA (Nottawasaga Valley Conservation Authority). 2004. Town of New Tecumseth Natural Resource Management Plan: background review and Natural Heritage Model. Nottawasaga Valley Conservation Authority. 49p.

Olewiler, N. 2004. The value of natural capital in settled areas of Canada. Published by Ducks Unlimited Canada and the Nature Conservancy of Canada.

OMMAH (Ontario Ministry of Municipal Affairs and Housing). 1996, amended in 1997. Provincial Policy Statement. Available online at http://www.mah.gov.on.ca/Page216.aspx Accessed 28 June 2010.

OMMAH (Ontario Ministry of Municipal Affairs and Housing). 2002. Oak Ridges Moraine Conservation Plan. Queen's Printer for Ontario. 82p.

OMMAH (Ontario Ministry of Municipal Affairs and Housing). 2004a. Oak Ridges Moraine Conservation Plan Technical Papers Series. 1. Identification of key natural heritage features. Available online at http://www.mah.gov.on.ca/AssetFactory.aspx?did=4886 Accessed 4 May 2010.

OMMAH (Ontario Ministry of Municipal Affairs and Housing). 2004b. Oak Ridges Moraine Conservation Plan Technical Papers Series. 3. Supporting connectivity. Available online at http://www.mah.gov.on.ca/AssetFactory.aspx?did=4888 Accessed 28 January 2009.

OMMAH (Ontario Ministry of Municipal Affairs and Housing). 2004c. Oak Ridges Moraine Conservation Plan Technical Papers Series. 7. Identification and protection of Significant Woodlands. Available online at http://www.mah.gov.on.ca/AssetFactory.aspx?did=4892 Accessed 28 January 2009.

OMMAH (Ontario Ministry of Municipal Affairs and Housing). 2005a. Provincial Policy Statement. Queen's Printer for Ontario. 37p. Available online at http://www.mah.gov.on.ca/Page1485.aspx Accessed 21 June 2010.

OMMAH (Ontario Ministry of Municipal Affairs and Housing). 2005b. Greenbelt Plan. Queen's Printer for Ontario. 57p. Available online at http://www.mah.gov.on.ca/Page189.aspx#greenbelt Accessed 28 January 2009.

OMNR (Ontario Ministry of Natural Resources).1988. Implementation Strategy: Areas of Natural and Scientific Interest.

OMNR (Ontario Ministry of Natural Resources).1991. A Natural Heritage Framework: A Strategy for the Protection and Management of Natural Heritage in the Greater Toronto Area. November 1991, GTA Branch.

OMNR (Ontario Ministry of Natural Resources).1993. Ontario Wetland Evaluation System, Southern Manual (3rd Edition). 101 pp + Appendices.

OMNR (Ontario Ministry of Natural Resources). 1999. Natural Heritage Reference Manual. For Policy 2.3 of the Provincial Policy Statement - Ontario Ministry of Natural Resources – June 1999. Available online at http://www.mnr.gov.on.ca/249080.pdf Accessed 14 April 2009.

OMNR (Ontario Ministry of Natural Resources). 2000. Significant Wildlife Habitat Technical Guide. 151p.

OMNR (Ministry of Natural Resources) and CVC (Credit Valley Conservation). 2002. A cooperative management planning initiative for the Credit River Fishery. Queen's Printer for Ontario. 180p.

OMNR (Ontario Ministry of Natural Resources). 2004. A Natural Heritage System for the Oak Ridges Moraine – Cores and Linkages. OMNR, Aurora District, Peterborough District and Midhurst District, May 2004. Draft document.

OMNR (Ontario Ministry of Natural Resources). 2005a. *Ontario Biodiversity Strategy*. Available online at http://www.obs-sbo.ca/ Accessed 31 January 2009.

OMNR (Ontario Ministry of Natural Resources). 2005b. Seaton Lands/Duffins Rouge Agricultural Preserve Natural Heritage System. 29 pp.

OMNR (Ontario Ministry of Natural Resources). 2008a. Identification and Confirmation Procedure for Areas of Natural and Scientific Interest. Available online at http://ontarioparks.com/english/planning_pdf/ansi/ansi_procedure.pdf Accessed 12 April 2009.

OMNR (Ontario Ministry of Natural Resources). 2008b. Technical paper 2: Technical definitions and criteria for Significant Woodlands in the Natural Heritage System of the Protected Countryside Area of the Greenbelt Plan (2005). Draft September 16, 2008.

OMNR (Ontario Ministry of Natural Resources). 2010. Natural Heritage Reference Manual for Natural Heritage Policies of the Provincial Policy Statement, 2005. Second edition. Toronto: Queen's Printer for Ontario. 248p.

OMNRSTU (Ontario Ministry of Natural Resources, Science and Technology Unit). 1996. Southern Region Ecological Land Classification: Community Catalogue.

OMNR (Ontario Ministry of Natural Resources) and CVC (Credit Valley Conservation). 2002. Credit River Fisheries Management Plan. A Cooperative Planning Initiative for the Credit River Fishery. Volume 2, Appendix A: Issues, Strategies, and Tactics. Queen's Printer for Ontario.

Ontario Nature. 2004. Suggested conservation guidelines for the identification of significant woodlands in southern Ontario. Ontario Nature, 193p.

Ontario Parks 2001. Study of the economic and social benefits of the nine Ontario Living Legacy Signature Sites. Unpublished discussion paper.

Ontario Parks. 2002. The economic impact of Ontario Parks: a summary report for fiscal 2000-01. Unpublished discussion paper.

Ott, K. 2003. The case for strong sustainability. In: Ott, K. & P. Thapa, eds. *Greifswald's Environmental Ethics.* Greifswald: Steinbecker Verlag Ulrich Rose. Available online at http://umwethik.botanik.uni-greifswald.de/booklet/8_strong_sustainability.pdf Accessed 26 November 2010.

Packett, D.L. and J.B. Dunning, Jr. 2009. Stopover habitat selection by migrant landbirds in a fragmented forest-agricultural landscape. *The Auk* 126:579-589.

Palomino, D. and C.S. Carrascal. 2007. Threshold distances to nearby cities and roads influence the bird community of a mosaic landscape. *Biological Conservation* 140:100-109.

Peterman, W.E., J.A. Crawford and R.D. Semlitsch. 2008. Productivity and significance of headwater streams: population structure and biomass of the black-bellied salamander (*Desmognathus quadramaculatus*). *Freshwater Biology* 53:347-357.

Petit, S., L. Griffiths, S.S. Smart, G.M. Smith, R.C. Stuart, and S.M. Wright. 2004. Effects of area and isolation of woodland patches on herbaceous plant species richness across Great Britain. *Landscape Ecology* 19:463-471

Pearce, C.M., M.B. Green, and M.R. Baldwin. 2007. Developing habitat models for waterbirds in urban wetlands: a log-linear approach. *Urban Ecosystems* 10:239-254.

Randhir, T. and P. Ekness. 2009. Urbanization effects on watershed habitat potential: a multivariate assessment of thresholds and interactions. *Ecohydrology* 2:88-101.

Region of Waterloo. 2006. Region of Waterloo Official Plan. September 2006 consolidation. Chapter 4, Natural Habitat Network. 56p.

Regional Municipality of Peel. 2005. Region of Peel Official Plan Office Consolidation November 2005.

Regional Municipality of Peel. 2008. *Natural Heritage Policy Review Discussion Paper* prepared by Sorensen Gravely Lowes, North-South Environmental Inc. and Dougan & Associates in association with the Region of Peel. Brampton, Ontario: Regional Municipality of Peel, October 2008. Available online at http://www.region.peel.on.ca/planning/officialplan/nat-heritage-discussion-paper.htm Accessed 2 February 2009.

Regional Municipality of Peel. http://www.peelregion.ca/health/smog/index.htm Accessed 12 March 2009.

Ries, L., R.J. Fletcher Jr., J. Battin, and T.D. Sisk. 2004. Ecological responses to habitat edges: mechanisms, models, and variability explained. *Annual Review of Ecology and Systematics* 35:491-522.

Ritters, K.H., R.V. O'Neill, C.T. Hunsaker, J.D. Wickham, D.H. Yankee, S.P. Timmins, K.B. Jones, and B.L. Jackson. 1995. A factor analysis of landscape pattern and structure metrics. *Landscape Ecology* 10: 23-40.

Riley, J.L. and P. Mohr. 1994. The Natural Heritage of Southern Ontario's Settled Landscapes. A Review of Conservation and Restoration Ecology for Land-Use and Landscape Planning. Science and Technology Transfer, Technical Report TR-001. Ontario Ministry of Natural Resources, Southern Region, Aurora, Ontario. 78 p.

Roe, J.H. and A. Georges. 2007. Heterogeneous wetland complexes, buffer zones, and travel corridors: landscape management for freshwater reptiles. *Biological Conservation* 135:67-76.

Rosenburg, K.V., J.D. Lowe, and A.A. Dhondt. 1999. Effects of forest fragmentation on breeding tanagers: a continental perspective. *Conservation Biology* 13:568-583.

Rowe, J.S. 1972. Forest Regions of Canada. Canadian Forestry Service. Pub. No. 1300.

Rowsell, M. 2003. Woodland Valuation System: methods and rationale for assigning woodland value at the patch scale for consideration in planning and conservation in Eastern Ontario. Version 2.0. Eastern Ontario Model Forest. 80p.

Roy, A.H., B.J. Freeman, and M.C. Freeman. 2007. Riparian influences on stream fish assemblage structure in urbanizing streams. *Landscape Ecology* 22:385-402.

Sandin, L. and R.K. Johnson. 2004. Local, landscape and regional factors structuring benthic macroinvertebrate assemblages in Swedish streams. *Landscape Ecology* 19:501-514.

Saunders, D.A., R.J. Hobbs, and C.R. Margules. 1991. Biological consequences of ecosystem fragmentation: a review. *Conservation Biology* 5:18-32.

Schueler, T.R. 1994. The importance of imperviousness. *Watershed Protection Techniques* 1: 100-111.

Semlitsch, R.D. 1998. Biological delineation of terrestrial buffer zones for pond-breeding salamanders. *Conservation Biology* 12:1113-1119.

Semlitsch, R.D. and J.R. Bodie. 1998. Are small, isolated wetlands expendable? *Conservation Biology* 12:1129-1133.

Semlitsch, R.D. and J.R. Bodie. 2003. Biological criteria for buffer zones around wetlands and riparian habitats for amphibians and reptiles. *Conservation Biology* 17:1219-1228.

Scheffer, M., S.R. Carpenter, J. Foley, C. Folke, and B.H. Walker. 2001. Catastrophic shifts in ecosystems. *Nature* 413:591-696.

Shafer, C.L. 1995. Values and shortcomings of small reserves. *Bioscience* 45:80-88.

Snell, E. 1987. Wetland distribution and conversion in southern Ontario. Inland Waters and Lands Directorate, Environment Canada. Working paper #48. 61p.

Snodgrass, J.W., M.J. Komoroski, A.L. Bryan, Jr. and J. Burger. 2000. Relationships among isolated wetland size, hydroperiod, and amphibian species richness: Implications for wetland regulations. *Conservation Biology* 14:414-419.

Society for Ecological Restoration International Science & Policy Working Group. 2004. The SER International Primer on Ecological Restoration. www.ser.org & Tucson: Society for Ecological Restoration International. 15p.

Spackman, S.C., and J.W. Hughes. 1995. Assessment of minimum stream corridor width for biological conservation: Species richness and distribution along mid-order streams in Vermont, U.S.A. *Biological Conservation* 71:325-332.

Srivastava, D.S. and T. Bell. 2009. Reducing horizontal and vertical diversity in a foodweb triggers extinctions and impacts functions. *Ecology Letters* 12:1016-1028.

Srivastava, D.S. and M. Vellend. 2005. Biodiversity-ecosystem function research: is it relevant to conservation? *Annual Review of Ecology and Systematics* 36:267-294.

Stanfield, L.W. and B.W. Kilgour. 2006. Effects of percent impervious cover on fish and benthos assemblages and instream habitats in Lake Ontario tributaries. *American Fisheries Society Symposium* 48:577-599.

Steedman, R.J. 1987. Comparative analysis of stream degradation and rehabilitation in the Toronto area. Ph.D. Thesis, University of Toronto. 172 pp.

Strasberg, J.L. 2006. Roads and genetic connectivity. *Nature* 440:875-876.

Strobl, E.E. 2010. Vegetation characterization for the Lake Ontario stopover project. A thesis submitted in partial fulfillment of the requirements for the degree of Masters of Science in Environmental Science at The Rochester Institute of Technology. 84p.

Sweeney, B.W., T.L. Bott, J.K. Jackson, L.A. Kaplan, J.D. Newbold, L.J. Standley, W.C. Hession, and R.J. Horwitz. 2004. Riparian deforestation, stream narrowing, and loss of stream ecosystem services. *Proceedings of the National Academy of Sciences* 101:14132-14137.

Tabacchi, E., D.L. Correll, R. Hauer, G. Pinay, A.-M. Planty-Tabacchi, and R.C. Wissmar. 1998. Development, maintenance, and role of riparian vegetation in the river landscape. *Freshwater Biology* 40:497-516.

Tate, D.P. 1998. Assessment of the ecological integrity of forest bird communities – a draft methodology and a field test in the Severn Sound Area of Concern. Severn Sound RAP Technical Report. Canadian Wildlife Service. Ontario Region.

Taylor, P.D., L. Fahrig, K. Henein, and G. Merriam. 1993. Connectivity is a vital element of landscape structure. *Oikos* 68:571-573.

Tewksbury, J.J., D.J. Levey, N.M. Haddad, S. Sargent, J.L. Orrock, A. Weldon, B.J. Danielson, J. Brinkerhoff, E.I. Damschen, and P. Townsend. 2002. Corridors affect plants, animals, and their interactions in fragmented landscapes. *Proceedings of the National Academy of Sciences* 99:12923-12926.

The Land Ethic Group. 2006. Natural Heritage Strategy for the Raisin Region Conservation Authority. Final version January 2006. Available online at http://www.rrca.on.ca/watershed-planning/national-heritage-strategy.html Accessed 29 January 2009.

Tilman, D. 1999. Global environmental impacts of agricultural expansion: the need for sustainable and efficient practices. *Proceedings of the National Academy of Sciences* 96:5995-6000.

TRCA (Toronto and Region Conservation Authority). 2007. Terrestrial Natural Heritage System Strategy.

TRCA (Toronto and Region Conservation Authority) and CVC (Credit Valley Conservation). 2009. Evaluation, Classification and Management of Headwater Drainage Features: Interim Guidelines Updated March 2009.

Trombulak, S.C. and C.A. Frissell. 2000. Review of ecological effects of roads on terrestrial and aquatic communities. *Conservation Biology* 14:18-30.

Trzcinski, M.K., L. Fahrig and G. Merriam. 1999. Independent effects of forest cover and fragmentation on the distribution of forest breeding birds. *Ecological Applications* 9:586-593.

UTRCA (Upper Thames River Conservation Authority). 2003. The Middlesex Natural Heritage Study: A Natural Heritage Study to identify significant woodland patches in Middlesex County. July 2003. Available online at http://www.thamesriver.on.ca/MNHS/images/MNHS_Report_S1-3.pdf Accessed 29 January 2009.

UTRCA (Upper Thames River Conservation Authority) and County of Oxford. 2006. Oxford Natural Heritage Study. Available online at http://www.thamesriver.on.ca/ONHS/ONHS.htm Accessed 29 January 2009.

Van Geert, A., F. Van Rossum, and L. Triest. 2010. Do linear landscape elements in farmland act as biological corridors for pollen dispersal? *Journal of Ecology* 98:178-187.

Vannote, R.L., G.W. Minshall, K.W. Cummins, J.R. Seddell, and C.E. Cushing. 1980. The River Continuum Concept. *Canadian Journal of Fisheries and Aquatic Sciences* 37:130-137.

Varrin, R., J. Bowman, and P.A. Gray. 2007. The known and potential effects of climate change on biodiversity in Ontario's terrestrial ecosystems: case studies and recommendations for adaptation. Ontario Ministry of Natural Resources. 47p.

Villard M.A. 1998. On forest-interior species, edge avoidance, area sensitivity, and dogmas in avian conservation. *Auk* 115:801–805.

Villard, M.-A., M.K. Trzcinski, and G. Merriam. 1999. Fragmentation effects on forest birds: relative influence of woodland cover and configuration on landscape occupancy. *Conservation Biology* 13:774-783.

Walsh, C.J., A.H. Roy, J.W. Feminella, P.D. Cottingham, P.M. Groffman, and R.P. Morgan II. 2005. The urban stream syndrome: current knowledge and the search for a cure. *Journal of the North American Benthological Society* 24:706-723.

Waterfront Regeneration Trust. 1995. Lake Ontario Greenway Strategy. Waterfront Regeneration Trust. 215p.

Wehling, S. and M. Diekmann. 2009. Importance of hedgerows as habitat corridors for forest plants in agricultural landscapes. *Biological Conservation* 142:2522-2530.

Wenger, S. 1999. A review of the scientific literature on riparian buffer width, extent, and vegetation. Institute of Ecology, University of Georgia. 59p.

Wianecki, K. 2009. Towards a Natural Heritage System for the Credit River Watershed – Compendium report from a series of focused dialogues across the watershed. 38p.

Wichert, G.A., K.E. Brodribb, B.L. Henson, and C. Phair. 2005. Great Lakes Conservation Blueprint for aquatic biodiversity. Volume I. Nature Conservancy of Canada. 86p.

Wilson, S. 2008. Ontario's Wealth Canada's Future: Appreciating the value of the Greenbelts eco-services." Report prepared for the David Suzuki Foundation.

Wilson, M. and J.G. Imhof. 1998. Literature review: an overview of the state of science. Riparian zone workshop. Grand River Conservation Authority, Cambridge Ontario, Canada.

Zar, J.H. 1999. Biostatistical Analysis. Prentice-Hall, Inc. 663p. plus appendices.

Zhang, X., X. Liu, M. Zhang, and R.A. Dahlgren. 2010. A review of vegetated buffers and a meta-analysis of their mitigation efficiency in reducing nonpoint source pollution. *Journal of Environmental Quality* 39:76-84.

14. Glossary

Active Aggregate: Areas that are currently being excavated (see aggregate extraction). CVC 1998.

Aggregate Extraction: All resource extraction pits or quarries. These areas are subdivided into active and inactive aggregate extraction areas. (CVC 1998).

Agricultural Areas: These are lands that are utilized for food production and other products such as Christmas tree plantations, nurseries, and so forth. Agricultural areas are divided into two sub-categories: Intensive Agricultural and Non-intensive Agricultural. CVC 1998.

Aquatic system: The aquatic system includes shallow or deep standing or flowing waters with little or no emergent vegetation (Lee et al. 1998). The aquatic system mapped in CVC includes watercourses (stream orders 1 and higher), lakes and ponds (CVC 1998).

Areas of Natural and Scientific Interest (ANSI): Areas of land and water containing natural landscapes or features which have been identified as having life science or earth science values related to protection, scientific study, or education (OMMAH 2005a).

Bog (Community Class): Peatlands often covered in Sphagnum. Bogs are often raised and therefore, nutrient poor. Tree cover is less than 25%. CVC 1998.

Community series: See *ELC community series*

Community type: A group of similar vegetation stands that share common characteristics of vegetation, structure, and soils (Lee et al. 1998).

Coniferous Swamps (Community Series): Wetland communities with greater than 75 percent coniferous canopy cover. CVC 1998.

Coniferous Forest or Plantation (Community Series): A community with greater than 75% coniferous composition. CVC 1998.

Cultural communities (Community Class; also referred to as semi-natural in the text): Open and treed areas where previous land use practices have significantly influenced the resulting substrate and vegetation. Tree canopy cover is less than 60% and contains a higher percentage of non-native species than natural communities. CVC 1998.

Cultural Meadow (Community Series): Cultural Community where tree cover is less than 25% as a result of human disturbance. Graminoids and forbs dominate the area. CVC 1998.

Cultural Thicket (Community Series): Cultural Communities that have greater than 25% shrub species and tree cover is less than 25% as a result of human disturbance. CVC 1998.

Cultural Savannah (Community Series): Cultural Communities where tree cover is between 25% and 35%. Vegetation is stratified with scattered or clumped trees and dominated by graminoids and forbs. CVC 1998.

Cultural Woodland (Community Series): Cultural Communities where tree cover is between 35% and 60%. Vegetation is stratified with scattered or clumped trees and dominated by graminoids and forbs. CVC 1998.

Deciduous Forest or Plantation (Community Series): A community with greater than 75% deciduous composition. CVC 1998.

Deciduous Swamps (Community Series): Wetland community with greater than 75 percent deciduous canopy cover. CVC 1998.

Dominant Form: The vegetation form that is considered to have the greatest influence on the community. It is usually the tallest form with the greatest amount of canopy cover and/or biomass (CVC 1998).

Ecofunction: Serves as an abbreviation for 'ecological function'. This term is adopted by CVC to refer to relative habitat patch quality in terms of its ecological function at the landscape scale within the CVC jurisdiction based on the Landscape Scale Analysis. For example, a Core ecofunction habitat patch is a feature that provides or has the capacity to provide a high number of ecological functions relative to other patches in the watershed.

Ecological functions: The natural processes, products or services that living and non-living environments provide or perform within or between species, ecosystems and landscapes, including hydrological functions and biological, physical, chemical and socio-economic interactions (OMMAH 2002, OMMAH 2005a).

Ecological Restoration: Ecological restoration is the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed (Society for Ecological Restoration International Science and Policy Working Group 2004).

Ecosystem: An ecosystem consists of a dynamic set of living organisms (plants, animals, and microorganisms) together with the non-living components of their environment, related processes, and humans (OMNR 1999).

ELC community series: An ELC community series is a relatively homogeneous area identified by the type of cover (open, treed, or shrub) as well as plant form (deciduous, coniferous, or mixed) that is characteristic of the area. It is a unit that is normally visible and consistently recognizable on an air-photo or a combination of maps, air-photo interpretation and other remote sensing techniques. Community Series are the lowest level in the ELC classification that can be identified without a site visit (Lee et al. 1998). The ELC community series classification breaks down communities into sub types such as deciduous forest, coniferous swamp, cultural meadow, cultural thicket, etc. The ELC community series characterized in this analysis include coniferous, deciduous and mixed forests; bog, coniferous swamp, deciduous swamp, fen, marsh, mixed swamp, thicket swamp; coniferous plantation, deciduous plantation, mixed plantation; cultural woodland; and cultural meadow, cultural savannah or cultural thicket.

Fen (Community Class): Peatlands characterized by surface layers of poorly decomposed peat usually dominated by sedges and have low oxygen saturation and mineral supply is limited. Tree cover is less than 25%. CVC 1998.

Fish Habitat: is defined as the spawning grounds and nursery, rearing, food supply, and migration areas on which fish depend, directly or indirectly, in order to carry out their life functions (Federal *Fisheries Act*, 1985). This Act defines fish as shellfish, crustaceans, marine animals, any parts of shellfish, crustaceans, or marine mammals, and the eggs, sperm, spawn larvae, spat and juvenile stages of fish, shellfish, crustaceans and marine animals.

Forest (Community Class): A complex ecosystem with greater than 60% canopy cover comprised of continuous grouping of trees, shrubs and ground vegetation and immediate environmental conditions on which they depend. CVC 1998.

Groundwater Discharge: Groundwater discharge is the process of upward movement of groundwater as a result of hydraulic pressures, which results in groundwater reaching the surface. Groundwater discharge is typically noted as seepage into wetlands and watercourses. Springs are the visible discharge points at the surface. CVC 1998.

Groundwater feature: Refers to water-related features in the earth's subsurface, including recharge/discharge areas, water tables, aquifers and unsaturated zones that can be defined by surface and subsurface hydrogeologic investigations. (OMMAH 2005a).

Groundwater Recharge: Groundwater recharge is the process of water, usually from precipitation, moving downward through permeable soil and rock layers into an aquifer (i.e. a water bearing soil or rock formation). High recharge rates occur in areas of high permeable soils and rocks (e.g., sand and gravel and fractured bedrock) while low recharge rates may occur in low permeable soils (e.g., clays)(Gartner Lee, 1997). CVC 1998.

Habitat patch: A habitat patch is defined as a contiguous area, boundaries delineated by another land use type or a 30m gap on a 1:10,000 scale air photo (CVC 1998). It includes natural and semi-natural communities.

Inactive Aggregate: Areas that have been recently revegetated to an abandoned field or wetland stage. CVC 1998.

Intensive Agriculture: Intensive agriculture includes cultivated fields producing crops in varying degrees (e.g., corn and wheat). This includes specialty agriculture, which consists of orchards, market gardens, Christmas tree plantations, and nurseries. CVC 1998.

Intermittent streams: Water flows for an extended period of time because of a connection with seasonally high groundwater tables; or seasonally extended contributions from wetlands or other surface storage areas. CVC 1998.

Lake: An extensive body of water lying in a depression that is 2 ha. in size or greater. A lake can be completely enclosed by land or can have either or both an in-flowing or out-flowing stream. A lake can also be created by interrupting the normal flow of a watercourse with a dam. CVC 1998.

Landscape: A mosaic where the mix of local ecosystems or land uses is repeated in similar form over a kilometres-wide area (Forman 1995).

Landscape Scale Analysis: The characterization and analysis of ecosystem features and functions at the landscape scale, using GIS mapping, a systems approach, and well-established principles of landscape ecology and conservation biology, to ensure integration of the features and functions within the region of interest with those in the broader landscape.

Manicured Open Space: Dominated by gardens, parkland, and lawn areas. For example, cemeteries, golf courses, urban parks, ski hills, and residential/industrial open space with a minimum size of 2 hectares. CVC 1998.

Marsh (Community Class): Open wetland areas where tree and shrub coverage is less than 25%. CVC 1998.

Mixed Forest or Plantation (Community Series): A community with a mixture of deciduous and coniferous trees with neither less than 25% of the total tree cover. CVC 1998.

Mixed Swamps (Community Series): Wetland communities with a mixture of deciduous and coniferous trees with neither less than 25% of the total canopy cover. CVC 1998.

Natural Heritage System: A system made up of natural heritage features and areas, linked by natural corridors which are necessary to maintain biological and geological diversity, natural functions, viable populations of indigenous species and ecosystems. These systems can include lands that have been restored and areas with the potential to be restored to a natural state. (OMMAH 2005a).

Non-Intensive Agriculture: Non-intensive agriculture includes fields dominated with herbaceous vegetation and grasses with an understory of similar material in a state of decay. Includes pasture/grazing areas. Weedy hay and/or pasture cover more than 50% of the area. Associated with extensive or unconfined grazing of livestock and minimal evidence of recent cultivation. CVC 1998.

On-line pond: A pond with a stream flowing into and/or out of the pond.

Off-line pond: A pond without any stream flow into or out of the pond.

Permanent streams: Contain continuously flowing water most years (e.g., baseflow conditions are supported by year round groundwater and/or wetland/surface storage areas). CVC 1998.

Plantation (Community Class): A cultivated area, usually dominated by commercially valuable species. Tree species are usually even-aged, planted in linear rows and have little or no shrub or ground vegetation. In CVC methodology, plantations that are immature, and that may therefore not have 60% canopy cover, are still mapped as plantation. The definition of plantation excludes plantations that are managed for the production of fruits, nuts, Christmas trees or nursery stock. CVC 1998.

Pond: an area of still water between 0.5 and 2 ha. in size lying in a natural or man-made depression. Can be completely enclosed by land or can have either or both an in-flowing or out-flowing stream. A pond can also be created by interrupting the normal flow of a watercourse with a dam. CVC 1998.

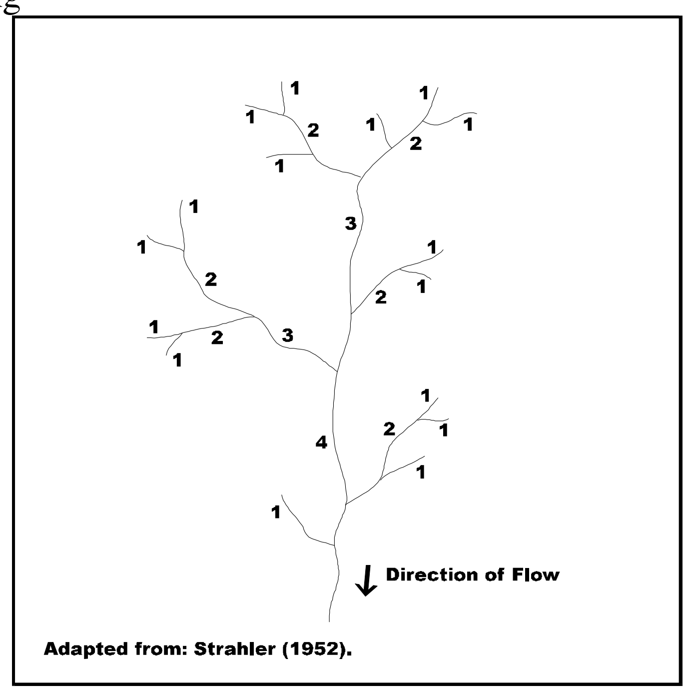
Restore: See *Ecological Restoration.*

Semi-natural: Modified by human influence but retaining many natural features (Merriam-Webster dictionary, www.merriam-webster.com Accessed 25 Nov 2010). The term “semi-natural” is intended to convey the same meaning to non-technical users as “cultural” in the context of communities as defined under the Ecological Land Classification (Lee et al. 1998).

Shrub: Woody vegetation usually consisting of a number of stems from the ground or small branches near the ground.

Stream order: A hierarchical classification system for dendritic streams to indicate their stream size and flow characteristics (see figure below).

Stream Ordering



Successional area: Successional areas are defined as areas that have experienced human influence in the past and that are succeeding or have the potential to succeed to a natural state. These areas correspond to the Cultural Meadow (CUM), Cultural Savannah (CUS) and Cultural Thicket (CUT) ELC communities.

Surface Water feature: Refers to water-related features on the earth's surface, including headwaters, rivers, stream channels, inland lakes, seepage areas, recharge/discharge areas, springs, wetlands, and associated riparian lands that can be defined by their soil moisture, soil type, vegetation or topographic characteristics. (OMMAH 2005a).

Swamp (Community Class): Treed wetland areas where tree or shrub cover is greater than 25%. CVC 1998.

Thicket Swamps (Community Series): A wetland community that is dominated by shrub species. CVC 1998.

Tree: A perennial woody species usually consisting of one stem that grows to at least 4.5 m.

Urban Areas: Urban related uses including continuous ribbon development. Interpreted from air photos by number of roof tops, and groupings of 5 or more residential units equaling 2 or more hectares (i.e. the presence of pavement, buildings and structures). Single rural residential lots are not included as Urban Area unless part of a group of 5 or more units (OMAF, 1982). CVC 1998.

Watercourse: A watercourse is constituted when there is sufficient continuous or intermittent flow of water to form and maintain a defined channel of a permanent, yet dynamic nature. Therefore, ephemeral streams or swales will not be defined as watercourses (CVC 1998).

Watershed: The area of land drained by a river and its tributaries (OMMAH 2005a). For the purposes of this study, 'watershed' refers to the area under CVC jurisdiction.

Wetlands: Lands that are seasonally or permanently covered by shallow water, as well as lands where the water table is close to or at the surface. In either case the presence of abundant water has caused the formation of hydric soils and has favoured the dominance of either hydrophytic plants or water tolerant plants. The four major types of wetlands are swamps, marshes, bogs and fens. (OMMAH 2005a).

Wet Meadows: Lands that are periodically "soaked" or "wet", and are currently being used for agricultural purposes (i.e. grazing). These lands, by definition under the Ontario Wetland Evaluation System, are not considered to be wetlands.

Woodlands: Treed areas that provide environmental and economic benefits such as erosion prevention, water retention, provision of habitat, recreation and the sustainable harvest of woodland products. Woodlands include treed areas, woodlots, or forested areas and vary in their level of significance. (OMMAH 2005a).