Envirothon Study Guide

Non-point source (NPS) Pollution and Low Impact Development

2012

This Study Guide is to be used to help Envirothon teams prepare for the Ontario Envirothon Program.

FORESTS ONTARIO

Preface

This report was written by Nousheen Ahmed, Stephen Jeschke, Clarissa Jewell and Tyler Miller in partial fulfillment of the Credit for Product II course in the third year of the Ecosystem Management Technology Program 2011 at Sir Sandford Fleming College. This study guide was written for Kristina Quinlan of the Ontario Forestry Association.

This study guide focuses on nonpoint source pollution and low impact development, and ties these two issues to the core topics of aquatics, forests, soils and wildlife. The guide contains background information on these topics in addition to case studies, activities, references and a glossary. Also included in this package are informational videos designed to teach students about water quality issues and learn about different monitoring and identifying that can be used in the field.

The objective of this study guide is to provide Ontario Envirothon participants with information on the 2012 topic "Nonpoint Source Pollution and Low Impact Development". Activities, case studies and sample questions are highlighted throughout the study guide to ensure a comprehensive understanding of nonpoint source pollution and low impact development issues.

We would like to thank our faculty advisor, Sara Kelly, for her guidance and input throughout the course of this project. We would also like to thank Kristina Quinlan for her support as a mentor in creating this guide. We sincerely hope that this study guide will be of value to Ontario Envirothon students in the future.

Nousheen Ahmed, Stephen Jeschke, Clarissa Jewell and Tyler Miller

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1.0 Nonpoint Source Pollution (NPS) and Low Impact Development (LID)

This section will define, explain and give examples of nonpoint source (NPS) pollution and low impact development (LID).

At the end of this section, students should be able to do the following:

- Define NPS pollution and LID
- Identify how LID is used to manage NPS pollution
- Analyze the pros and cons of LID Best Management Practices (BMPs)
- Explain the impacts of land use on watersheds
- Explain the impacts urban sprawl has on NPS pollution and how LID can be used to reduce it
- Identify different types of LID practices and how they improve water quality
- Compare conventional stormwater management design versus LID

1.1 Introduction to NPS Pollution and LID

Nonpoint source (NPS) pollution is water pollution that accumulates over a widespread area and enters into water bodies, such as polluted runoff from agricultural areas entering a stream. **Stormwater** runoff from precipitation events picks up and carries natural and human-made pollutants, finally depositing them into streams, rivers, reservoirs and other bodies of water. Pollutants can come from all land uses (e.g. residential, agricultural, commercial, golf courses, industrial, etc.). NPS pollution can be contrasted with point source pollution, in which pollution entering a waterway can be traced to a single location such as industrial factories or sewage treatment plants.

Figure 1. Stormwater runoff can carry NPS pollution into waterways (Santa Fe, NM, 2011).

These pollutants include:

- Excess fertilizers, herbicides and insecticides from residential, agricultural and industrial areas
- Oil, grease and toxic chemicals from urban runoff and energy production
- Sediment from eroding stream banks and improperly managed construction sites, crops and forest lands
- Salt and acid from irrigation and mining
- Bacteria and nutrients from livestock, pet and wildlife wastes, and faulty septic systems
- Atmospheric deposition

NPS pollution negatively affects drinking water; fish and wildlife; animal and plant habitats; and can have serious environmental and human health impacts. Stormwater runoff is currently responsible for an estimated 60 percent of all water pollution, and millions of dollars are spent every year to restore and protect areas that are damaged by NPS pollutants.

One major effort that is used to combat the effects of NPS pollution is the increased use of **low impact development (LID)** practices. LID attempts to manage stormwater runoff at its source by increasing infiltration rates, **evapotranspiration** rates, and reuse of rainwater, thereby reducing how much water travels into streams, lakes and other water bodies. LID practices enhance natural systems and mimic the water cycle through the use of site design and planning techniques. These include things like preserving and recreating natural landscape features, minimizing the use of impervious sources like asphalt, and creating functional and appealing drainage areas like rain gardens that use runoff as a resource rather than a waste product. Through these combined practices, stormwater runoff in both urban and rural areas can be managed to have neutral or even positive effects on the environment.

Specifically LID aims to:

- Preserve open space and minimize land disturbance
- Protect natural systems and processes (drainage ways, vegetation, soils, wetlands)
- Re-examine the use and sizing of traditional infrastructure (lots, streets, curbs, gutters, sidewalks) and customize site design
- Incorporate natural site elements (wetlands, stream corridors, mature forests) as design elements
- Decentralize and micromanage stormwater at its source

There are many practices that have been used to adhere to these principles such as rain gardens, vegetated rooftops, rain barrels, bioretention facilities, and permeable pavements. By implementing LID principles and practices, water can be managed in a way that reduces the impact of built areas and promotes the natural movement of water within an ecosystem or watershed. LID practices have been successfully integrated into many municipal development codes and storm water management ordinances throughout Canada and around the world. With the implementation of these principals urban areas and other developments' impact on aquatic ecosystems can be reduced and managed to promote the natural function and splendour of the water systems being affected.

Figure 2. Rain gardens (left) and rain barrels (right) are LID practices that help manage stormwater by allowing it to drain into the ground close to wear it falls (campuslandscapeproject, 2011).

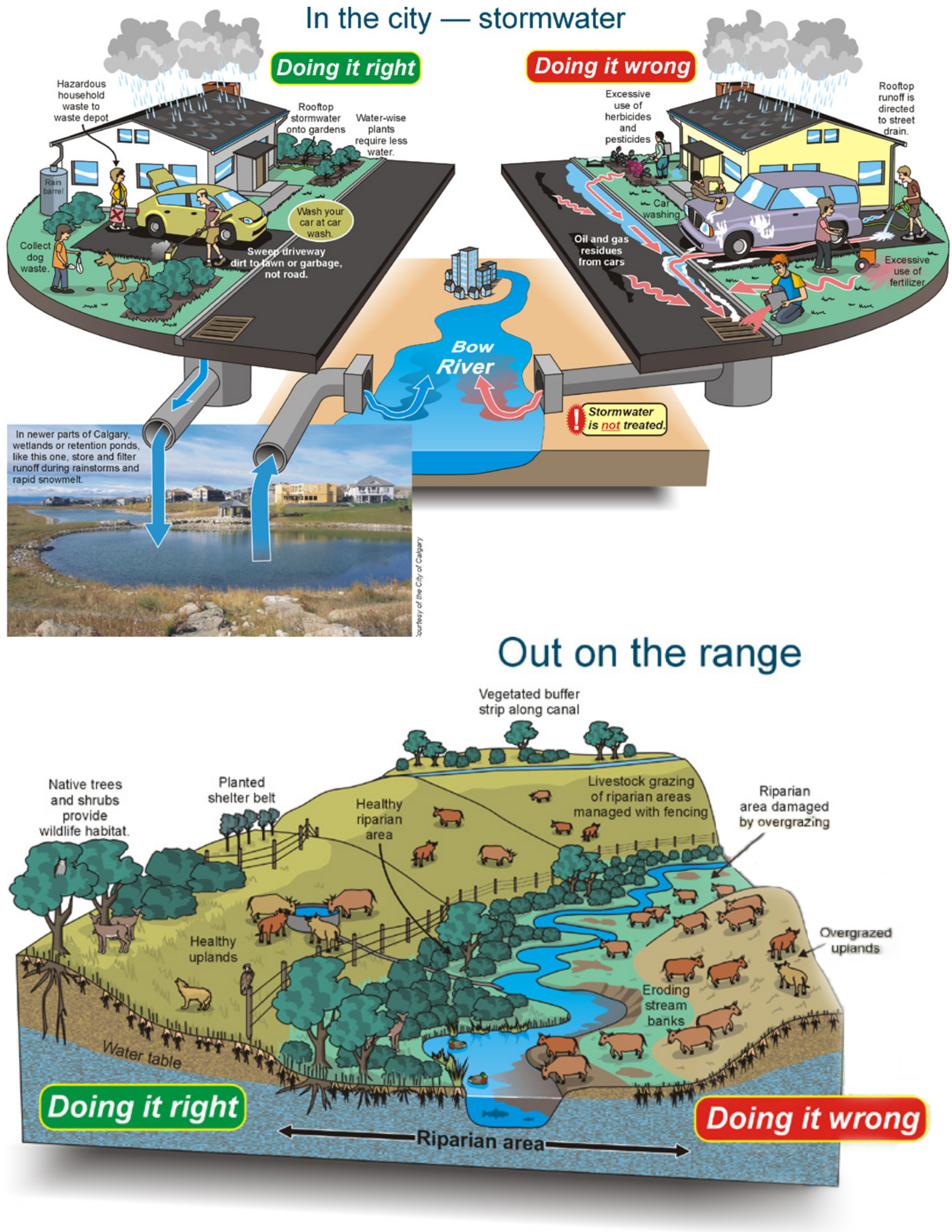

Figure 3. Managing NPS pollution in urban (above) and agricultural (below) areas through LID and BMPs (Natural Resources Canada, 2008a).

1.2 The Water Cycle and Watersheds

1.2.1 The Water Cycle

To better understand the problems with stormwater pollution, it is important to understand the water cycle, also known as the hydrologic cycle. In basic terms, the water cycle is the constant cycling of water from the sky to the ground and back again. The main components of the water cycle are precipitation; infiltration; evapotranspiration; surface and channel storage; and groundwater storage. As part of this cycle, wherever rainwater falls to the ground, or where snow or hail on the ground melt, that water may do one of several things: it may enter the ground directly, run across the surface and be gradually absorbed into the ground, or travel far enough to directly enter streams and water ways.

While the inner workings of the water cycle vary with precipitation patterns, soil types and other factors, the underlying principles remain the same. In a typical undeveloped area with natural ground cover such as forests or meadows, a large fraction of the water - suppose 50 percent - infiltrates the soil. Some of this water may remain in the soil near the surface, where it reappears in lakes and streams, while some of it may infiltrate deeper into the soil to replenish groundwater reserves. A significant share - perhaps 40 percent - of the water returns to the atmosphere through evapotranspiration. Only a small amount of the water - the remaining 10 percent - typically remains on the surface of land to run off into streams and other water bodies. Urbanization can dramatically alter this water cycle by increasing runoff and reducing infiltration, sometimes close to almost 0 percent. These changes can have profound impacts on water bodies.

1.2.2 Watersheds

A watershed is the area of land that catches rain and snow and drains or seeps it into streams, rivers, lakes, wetlands or groundwater. They encompass all of the water within an area, whether flowing or standing; the processes, factors and natural cycles that affect it; and all the organisms that live in and rely on the water for survival. The movement of water in a watershed is described by the water cycle.

Some watersheds cross provincial, federal, and even international borders such as the Great Lakes Basin. Watersheds come in all shapes and sizes. Some are millions of square miles, others are just a few acres. Just as creeks drain into rivers, watersheds are nearly always part of a larger watershed or basin. Every stream, tributary or river has an associated watershed.

Figure 4. The three primary watersheds in Ontario are the Great Lakes, Hudson Bay and the Nelson River (Ontario Ministry of Natural Resources, 2009).

Three different scales of a water ecosystem include:

- The bioregion, which is an area of particular physical characteristics that supports certain types of organisms. Ontario has three terrestrial bioregions:

Mixed Wood Plains, the Boreal Shield and the Hudson Plains
- The watershed, for example the Great Lakes watershed
- The watershed sub–basin or sub-watershed (land area drained by a single tributary), for example the Ottawa River

There are three primary watersheds in the province of Ontario:

- The Great Lakes draining to the Great Lake system into the St. Lawrence
- Hudson Bay draining north to Hudson Bay
- The Nelson River draining west to Manitoba

Watersheds are comprised of a number of different land types, such as uplands, riparian areas, wetlands, streams and lakes. The most common of these land use types found across all watersheds are the uplands, which is many areas cover 99 percent of the total watershed area. All of the precipitation that falls on a watershed area that is not evaporated is stored in the soil, and over time moves down the slopes through a network of drainage pathways, both underground and on the surface.

In healthy watersheds, vegetation and wetland areas intercept and slow the flow of water, removing sediment and filtering water as it enters the soil and percolates into the groundwater. This water then eventually makes its way into water bodies at the base of watersheds. In unhealthy systems, water is not able to soak into the ground and quickly travels over the surface, entering water bodies directly without being filtered and often causing erosion to stream banks.

Human activities and development can negatively impact watersheds and their processes. Improperly managed timber harvesting can cause erosion and dump sediment into streams. Agricultural activities can impact water quality through excess use of chemicals like pesticides and fertilizers from crops, and through harmful bacteria from animal wastes. Rural development and human recreational activities can result in the degradation of riparian areas, which destabilizes stream banks and affects animal habitats. Though individually each person may have minimal impacts on a watershed, the cumulative effects can have severe and profound effects on the overall system. As humans place higher and higher demands on watersheds, more effort will be needed to help reduce these harmful impacts to preserve watershed functioning for all.

1.3 Impacts of Land Use and Urban Sprawl on NPS Pollution

There are many different ways that human development and land use can have adverse effects on local waterways. Some of these impacts are lowered groundwater availability; increased flooding; reduced water quality; and increased habitat loss and economic impact.

1.3.1 Lowered Groundwater Availability

When impervious surfaces interfere with water's ability to move into the ground, groundwater thus becomes less available. Groundwater is important for drinking water and municipal use, and is also important for stream flow during periods of dry weather. Without groundwater to sustain themselves, streams may run shallow or disappear entirely until water levels are replenished.

1.3.2 Flooding

Increasing the amount of impervious surface area allows for larger amounts of stormwater to travel at higher speeds along the ground's surface. This can cause erosion along the entire distance the water travels, especially where it enters into water bodies. Flooding damages ecosystems like wetlands that normally act as water buffers that control water levels and filter sediments and contaminants in the water. Flooding also causes property damage.

1.3.3 Water Quality Decline

Stormwater runoff carries pollutants like pathogens, nutrients, sediments, toxins and debris into waterways (see Section 2.5). The amount of these pollutants in runoff is directly related to the percentage of impervious cover in a watershed. In severe cases this can lead to streams that are completely sterile, incapable of supporting life.

1.3.4 Habitat Loss and Economic Impact

Drought, flooding, erosion and water quality decline can all degrade riparian and aquatic habitats. Without these habitats, the plants and organisms that live in them might not be able to survive, or to survive at suboptimal levels.

Humans, in losing these ecosystems, might face economic impacts through loss of recreation, tourism and business opportunities, along with all the other impacts.

1.4 Costs and Benefits of LID

LID can be applied to new developments, urban retrofits, and redevelopment/ revitalization projects at many scales. At a small scale, LID techniques can be used to better handle rainfall for a single family lot through rain barrels and rain gardens. At a larger scale, proper site design in combination with many landscaping and infiltration techniques distributed throughout a subdivision or development will cumulatively improve water quality and reduce runoff.

Specific benefits of LID in urban areas include:

- Improved aesthetics
- Expanded recreational opportunities
- Increased property values due to the desirability of the lots and their proximity to open space
- Increased total number of units developed
- Increased marketing potential and faster sales
- Reduced runoff volumes and pollutant loadings to downstream waters
- Reduced incidences of combined sewer overflows
- Improved habitat
- Aesthetic amenities
- Improved quality of life

As water becomes an ever-increasing issue nationwide, managing our stormwater properly is not only a green technology, it becomes a necessity. Through the use of LID strategies, properly managing stormwater is something all of us can do.

Conventional development practices and approaches to stormwater management typically involve hard infrastructure such as curbs, gutters and piping. These practices often clear all trees and valuable topsoil from a site and re-grade it so that all water ends up in one large detention. The resulting problems include loss of recharge, increased water temperature, decreased water quality and higher runoff volumes.

LID-based designs, in contrast, are designed to use natural drainage features or engineered swales and vegetated contours for runoff conveyance and treatment. The LID approach protects the natural ability of the site to capture precipitation, keep it clean and allow it to recharge the local water table.

In terms of costs, LID techniques can reduce the amount of materials needed for paving roads and driveways and for installing curbs and gutters. Other LID techniques can eliminate or reduce the need for curbs and gutters outright, thereby reducing infrastructure costs. Also, by infiltrating or evaporating runoff, LID techniques can reduce the size and cost of flood-control structures. In some circumstances, however, LID techniques might result in higher costs due to more expensive plant material, site preparation, soil amendments, installation of under drains and connections to municipal stormwater systems and increased project management costs. Other considerations include land required to implement a management practice and differences in maintenance requirements. Finally, in some circumstances LID practices can offset the costs associated with regulatory requirements for stormwater control (see Table 1).

Table 1. Cost Comparisons Between Conventional and LID Approaches (U.S. Environmental Protection Agency, 2007).

Project	Conventional Development Cost	LID Cost	Cost Difference	Percent Difference
2nd Avenue SEA Street	$868,803	$651,548	$217,255	25%
Auburn Hills	$2,360,385	$1,598,989	$761,396	32%
Bellingham City Hall	$27,600	$5,600	$22,000	80%
Bellingham Bloedel Donovan Park	$52,800	$12,800	$40,000	76%
Gap Creek	$4,620,600	$3,942,100	$678,500	15%
Garden Valley	$324,400	$260,700	$63,700	20%
Kensington Estates	$765,700	$1,502,900	–$737,200	-96%
Laurel Springs	$1,654,021	$1,149,552	$504,469	30%
Mill Creekc	$12,510	$9,099	$3,411	27%
Somerset	$2,456,843	$1,671,461	$785,382	32%
Tellabs Corporate Campus	$3,162,160	$2,700,650	$461,510	15%

1.5 Types of LID Practices

There are a number of different types of LID practices. Some examples that will be discussed in depth here are green roofs, rain barrels and cisterns, and permeable pavements.

Ten Common LID Practices

1. Rain Gardens and Bioretention
2. Rooftop Gardens
3. Sidewalk Storage
4. Vegetated Swales, Buffers, and Strips; Tree Preservation
5. Roof Leader Disconnection
6. Rain Barrels and Cisterns
7. Permeable Pavers
8. Soil Amendments
9. Impervious Surface Reduction and Disconnection
10. Pollution Prevention and Good Housekeeping

(Natural Resources Defense Council, 1999)

1.5.1 Green Roofs

Green roofs are extremely beneficial for urban settings in runoff control. They help prevent non point source pollution by filtering out, absorbing or detaining rainfall. Rain water that would normally flow into storm drains and then into rivers is now absorbed by vegetation and soil on the roof, thus reducing the amount of water and chemicals from entering into aquatic ecosystems. Green roofs are built with a lightweight soil media, a drainage layer, and then a high quality impermeable membrane that is designed to protect the building structure. Plants that are picked to grow on green roofs are those that can handle dry, high temperature condition on top of buildings. The plants also have to be able to withstand high winds during storms. Green roofs provide stormwater management benefits by making use of biological, physical, and chemical processes found in plant and soil complexes, which prevent airborne pollutants entering water systems.

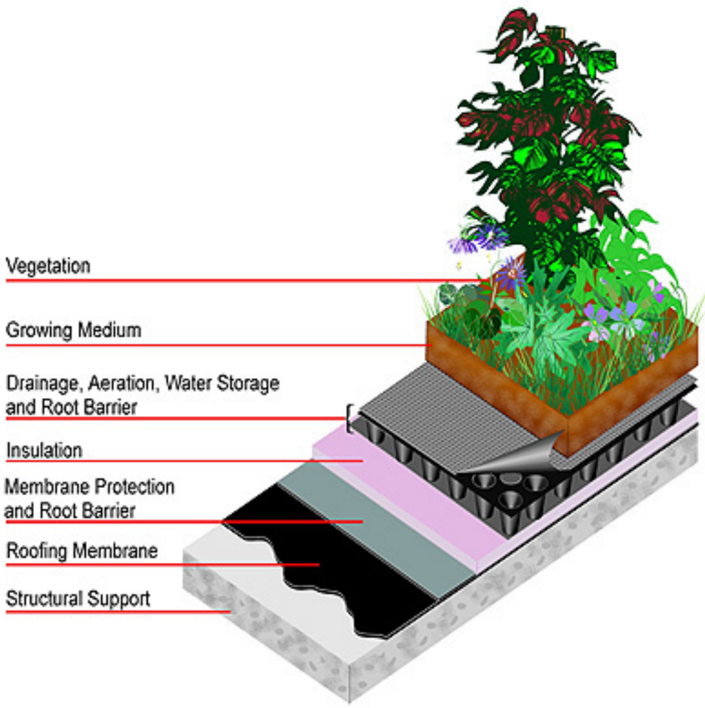

Figure 5. Deconstruction of a green roof (Low Impact Development Center, Inc., 2007).

Other ways in which green roofs are beneficial is that they reduce carbon dioxide in cities, and reduce air conditioning demands in summer and heating demands in winter.

There are two major types of green roofs: intensive or active, and extensive or passive.

Intensive green roofs have deep growing mediums, which allows for a wide range of landscape design options and more room for plants to grow. These types of green roofs can even support trees, and often incorporate recreational use with features like benches, shallow pools and fountains.

Extensive green roofs have shallow growing mediums, often just 1½ to 6" thick; are more self-sustaining; and require less maintenance than intensive green roofs. Because they are lighter, they require less structural support and are less expensive than intensive systems. They are typically seeded with grasses, which are able to spring back between long periods without rain.

Figure 6. The Manulife Centre in Toronto is over 25 years old and has trees that are over 3 stories high (City of Toronto, 2011a).

Figure 7. The Mountain Equipment Co-op green roof was built in 1998, and uses a shallow garden medium (City of Toronto, 2011a).

1.5.2 Rain Barrels and Cisterns

Rain barrels are a very effective way for houses and commercial sites like green houses, to manage rain runoff from roofs. Rain barrels are low in cost and are easy to maintain. There are three basic parts to a rain barrel system: (1) a catchment area, like the roof of a house or building; (2) a conveyance system, such as gutters on a house; and (3) the storage area, which would be the barrel itself. Rain that collects on roofs of buildings or that sits in rain barrels is said to collect microbiological contaminations as well as increases in pH, turbidity, metal and organic levels. However, a study using cisterns and rain large rain barrels for water uses other than drinking found that there were minimal levels of microbiological contaminations and trace metals found in rain barrels. The study's authors concluded that there is minimal risk associated for non-drinking purposes such as watering gardens, laundry and toilet flushing. The use of rain barrels provides an excellent way to reduce the amount of municipal water used for watering gardens and lawns. In this way the collection of rainwater can be used productively and efficiently instead of collecting sediments and pollutants before entering into aquatic ecosystems.

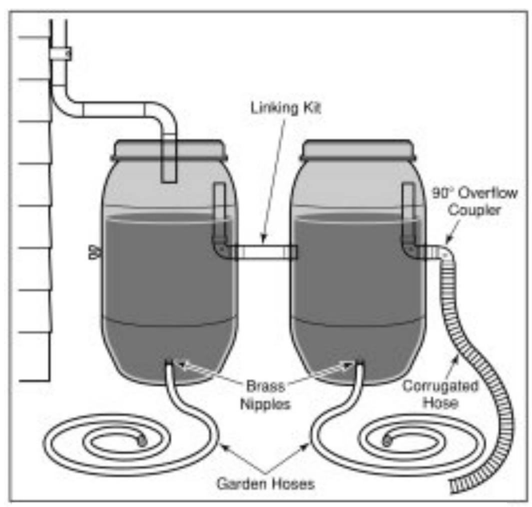

Figure 8. Typical manufactured urban rain barrel design with added accessories. (Low Impact Development Center, Inc., 2007).

Cisterns are very similar to rain barrels except that they are much larger and hold more water, and they can be adapted for more uses. By adapting cisterns to pump water for laundry and toilet use, this will let homeowners reduce their municipal water bills.

1.5.3 Permeable Pavements

Figure 9. Permeable pavement (BuildingGreen, 2007).

Most of the urban world is covered by pavement and concrete in the form of roads and parking lots. This pavement is considered impermeable and does not allow water to flow through it. Leaving water to flow to its lowest point usually results in it ending up in drains that in turn end up in waterways. Use of permeable materials, however, can allow water to drain into the ground at the source. It can also eliminate problems with standing water, provide groundwater recharge, control erosion of streambeds and riverbanks, as well as facilitate pollutant removal.

There are a variety of different types of permeable surfaces, most of which are grouped into three main types: modular interlocking concrete block pavement; porous asphalt and concrete; and plastic grid systems. Modular interlocking concrete blocks consist of concrete blocks that interlock with each other and let water permeate into a reservoir through inter-block or intra-lock voids. These voids can be filled with gravel, soil or grass. Porous asphalt or concrete is standard asphalt or concrete with the finer aggregates are removed, which allows water to flow through the pavement. Plastic grid systems are plastic interlocking bricks with spaces in the middle that allows them be filled with gravel or planted with grass.

The implementation of permeable surfaces has beneficial impacts on the environment by reducing runoff volume, and thus lowering erosion by stormwater and lowering sediment loading. They also help to reduce the amount of pollution that would normally be picked up by stormwater runoff from roads or other sources such as salts, total suspended solids, total phosphorus, and total nitrogen.

1.6 LEED© Certification and LID

LEED© stands for Leadership in Energy and Environmental Design, and is an internationally accepted, third-party certification program that recognizes green building practices. This certification verifies that buildings are designed and built using LID strategies to promote environmentally sustainable practices. Performance is measured with respect to five different categories: sustainable development, water efficiency, energy efficiency, materials selection and indoor environmental quality. An additional category not recognized under these five encompasses innovation, building expertise, exemplary

Figure 10. LEED© Gold Certification (Cadillac Fairview Corporation, 2010).

performance and other measures.

The LEED rating system was originally begun in 1998 by the U.S. Green Building Council, and has since expanded to encompass more than 30 member countries. The Canadian rating system is adapted from the U.S. system and is tailored to Canadian climates, construction practices and regulations. Certification is based on a total point score using established criteria based on LEED's five overall principles, and is divided into four levels: certified, silver, gold and platinum.

LEED certification helps both the public and private sector to promote:

- Promote awareness of environmental stewardship issues
- Use innovation to improve efficiency and reduce costs
- Validate and recognize achievement
- Be recognized as committed to environmental and human health issues

Figure 11. The George and Kathy Dembroski Centre for Horticulture at the Toronto Botanical Garden is LEED silver certified (TBG, 2011).

1.7 Case Study: Real life Applications of LID

Urbanization, and all the features that come hand in hand with it (e.g. impervious pavements, storm sewers, etc), have a huge impact on the environment and increase the incidence of NPS pollution. LID provides an alternative solution to these issues. The first time that LID was officially recognized as an alternative means to dealing with stormwater and preserving the original hydrology of an area was in 1999 in Prince George's County, Maryland, U.S.A. Here, they used manmade landscaping features to deal with the effects of precipitation events in the form of porous pavements, stormwater ponds and rain gardens. This was the first large-scale application of LID in a modern North American urban community.

The effectiveness of LID against traditional development methods was tested in Connecticut, when two subdivisions were built side-by-side. One was built using LID principles, while the other was a regularly built subdivision. The LID-built subdivision responded more effectively to precipitation events and measured less runoff on site. In the LID site they tried to mimic the pre-existing hydrological conditions before the site was developed, and they did this by using grassed swales and bioretention gardens. It was found that the conventional site experienced 47 percent more runoff, and that there was more

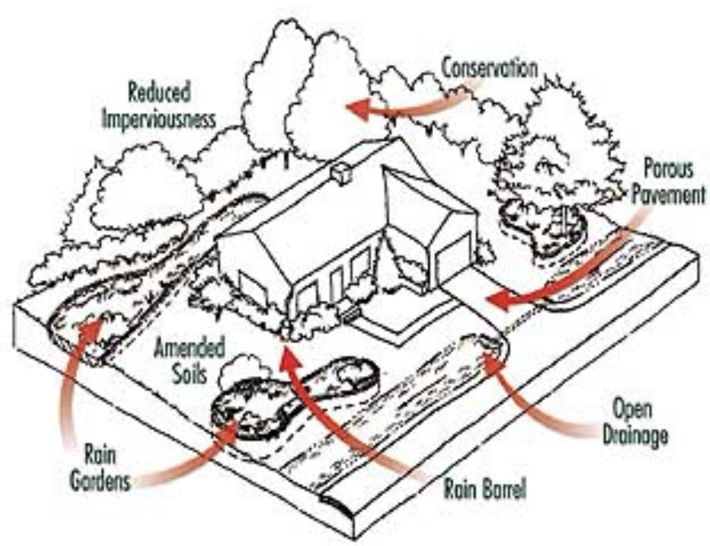

Figure 12. Low impact development on a single family home. (Wulkan, 2001).

nutrient loading in the surrounding watershed originating from the conventional site.

Case Study Questions

1. What are some of the contaminants that can be diminished by the use of LID practices in an urban residential development?
2. Can you think of an example of LID in your area? Describe it and explain how it works.
3. Do you think that LID is more or less expensive than conventional building practices? Why are why not?

1.8 Activity: What Does "Parts Per Million" Mean?

Adapted from Project WILD

The goal of this activity is to have students understand that even small amounts of contaminants can have a detrimental effect on aquatic ecosystems. Sometimes pollutants are in a quantity that is so small that detection is next to impossible without extensive testing. You may not be able to see or smell contaminants, but that does not mean that they are not there. LID practices should be able to impede even the smallest amount of toxins introduced by NPS pollution.

Methods

Students are asked to research what types of chemical pollutants may be contained in the runoff water in the area where they live, and the impacts these may have on the environment.

Background information

Depending on the area where you live, different pollutants may be more common than others. The types of pollutants found in a given area are determined by the activities that take place in that area. These can be industrial, agricultural or residential activities. Below are some substances and their "toxic" concentration levels in water:

Table 2. Toxic concentrations of chemicals commonly found in drinking water (U.S. EPA, 2010)

Substance	Concentration, ppb	Substance	Concentration, ppb
Arsenic	50	Nitrate	10 000
Barium	1 000	Selenium	10
Cadmium	10	Endrin	0.2
Mercury	2	2,4-d (herbicide)	100

Sometimes just a small amount can harm human health or the health of an ecosystem. Aquatic ecosystems are particularly vulnerable. But what exactly does parts per million (ppm), or parts per billion (ppb) really mean?

Recommended Materials (per group)

One stir stick, two containers of tap water (one for rinsing, one for diluting), food colouring, one eyedropper, ten clear containers, white paper.

Procedure

1. Line up 10 clear containers in a row and place a piece of white paper underneath each, labelled 1 through 10.
2. Place 10 drops of food colouring into the first container.
3. Take 1 drop of food colouring from Container 1, and transfer that to Container 2. Rinse the eyedropper well.
4. Add 9 drops of water to Container 2, and stir.
5. Transfer 1 drop of the solution from Container 2 into Container 3. Rinse the eyedropper well. Add 9 drops of water to Container 3, and stir.
6. Transfer 1 drop of the solution from Container 3 into Container 4. Rinse the eyedropper. Add 9 drops of water to Container 4, and stir.
7. Continue in the same method until all the containers are filled with solution.

Activity Questions

1. If the solution in Container 1 is 1 part food colouring to 10 parts water, what is the concentration of the each successive container?
2. Which container is the first one holding colourless liquid, and what is the concentration of that liquid?
3. What would remain in each container if the water were removed?
4. Explain the important to be aware of trace chemicals and the importance of using equipment to measure them.

1.9 Review Questions

1. Define NPS pollution.
2. Define LID.
3. Explain the impacts of land use on watersheds.
4. Identify how LID practices mimic the water cycle to manage stormwater.
5. Compare conventional stormwater management practices and LID practices, identifying the limitations of each.
6. Describe at least three different types of LID practices and explain why they are effective in reducing NPS pollution.
7. Provide examples of ways in which individuals and communities can do to implement LID practices in their area.

Figure 13. Managing NPS pollution through the use of bioswales (Richards, 2009).

2.0 Aquatic Ecosystems

This section will discuss how NPS pollution and LID affect local aquatic ecosystems, such as lakes, rivers and streams. There will be a focus on the different types of aquatic pollutants and also on different types of **bioindicators** used to monitor pollution.

At the end of this section, students should be able to do the following:

- Define aquatic NPS pollution
- Explain how LID impacts aquatic ecosystems
- List and describe different types of NPS pollution
- Discuss bioindicators as a means of monitoring aquatic ecosystem health

2.1 Introduction to Aquatics

Covering over 70% of the Earth's surface, water is the world's most precious natural resource. Canada is one of the top water-rich nations, trailing only after Brazil, Russia and China. On its own, Ontario holds a quarter of a million lakes, rivers and streams. These lakes are globally significant ecosystems that support numerous coastal wetland habitats, some with internationally rare animals and vegetation communities. The five Great Lakes, four of which have borders with Ontario, hold one-fifth of the world's fresh surface water and are the world's largest continuous body of fresh water. Ontario also holds about 6% of the world wetlands and from one-quarter to one-third of Canada's overall wetlands.

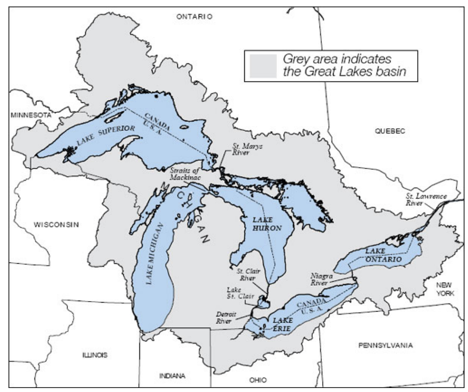

Figure 14. The Great Lakes Basin. Four of the five Great Lakes are found in Ontario (U.S. Department of Interior, 2007).

Scientists working in the field of aquatics are becoming increasingly concerned about pollution that ends up in aquatic ecosystems. Aquatic pollution can occur when an **aquatic ecosystem** is harmfully affected by the addition of large amounts of material into the system. Examples of this include phosphorus loading, sediment loading, and road runoff such as oil, salt and garbage. One mechanism through which this pollution can happen is NPS pollution.

2.2 What is Aquatic NPS Pollution?

Aquatic NPS pollution occurs when rainfall or snowmelt water travels over the ground collecting any natural or man-made pollutants in its path and deposits them into streams, rivers, lakes, wetlands, and coastal waters. Some of the primary causes of NPS pollution are crop farming, livestock farming, timber harvesting, new developments, and roads and

Figure 15. Farmland NPS pollution (Dorworth *et al.*, 2007).

building construction.

2.3 How is LID Related to Aquatic Ecosystems?

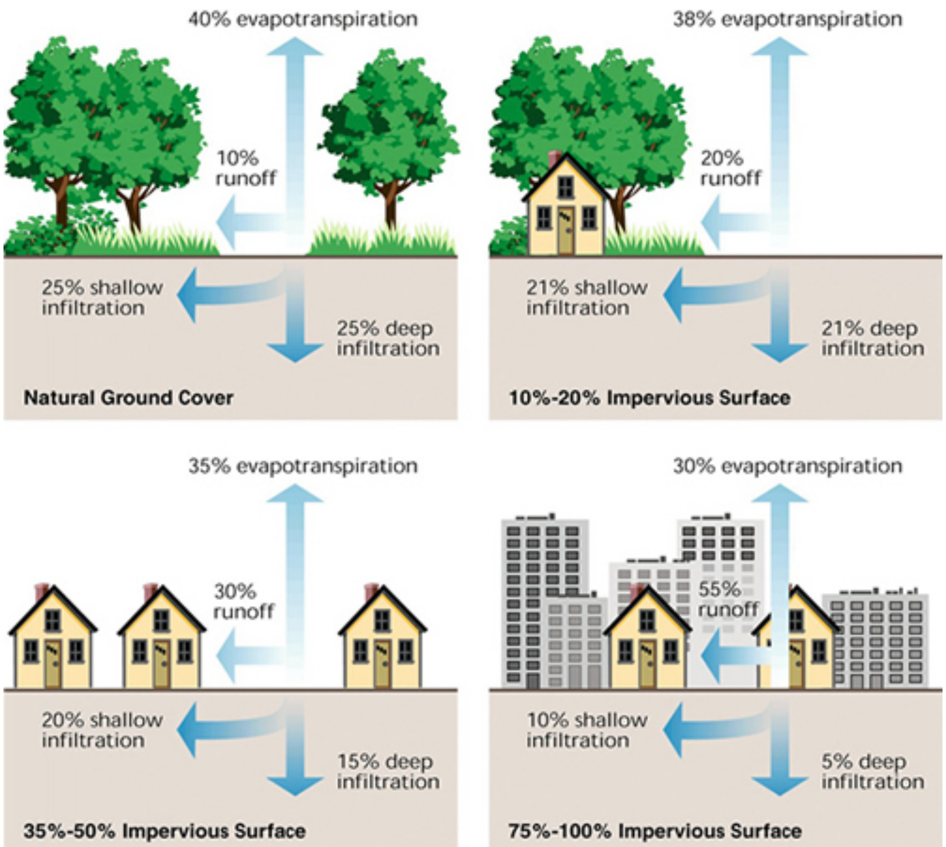

Figure 16. Relationship between impervious cover and surface runoff. As little as 10% impervious cover in a watershed can result in stream degradation (FISRWG, 1998).

LID is the land development or re-development of urban cities and towns that works with nature to manage the quantity and quality of stormwater. It employs principles of preserving and recreating natural landscape features, as well as minimizing the amount of impervious surfaces, to create a functional and appealing drainage site that will use stormwater as a resource rather than a waste product. The implementation of these principles will allow for less polluted water and more clean water to enter into aquatic ecosystems. Thus, low impact development can reduce the amount of pollution that could potentially harm an aquatic ecosystem or the wildlife that inhabit and use that aquatic ecosystem.

2.4 How Does NPS Pollution Affect Aquatic Ecosystems?

NPS pollution can affect aquatic ecosystem in many different ways. The most common ways in which NPS pollution can affect aquatic ecosystems is through the addition of pathogens, oxygen depleting substances, nutrients, sediments and toxins such as chemicals. These five main categories will be further discussed below. There are numerous problems connected with nonpoint source pollution, the most common being damage to aquatic ecosystems and animals living there, reduced aesthetics of lakes and rivers, economic losses to commercial and recreational fishing, cost of restoration of affected aquatic ecosystems, and lastly degraded drinking water and potential human health risks. Some other effects that are not as prominent include reduced water-based recreational activities, tourism opportunities, and real estate values for waterfront properties.

2.5 Types of NPS pollution in aquatic ecosystems

<u>2.5.1 Pathogens</u>

Pathogens are **microorganisms**, bacteria, viruses and protozoa that cause waterborne illnesses. Pathogens most commonly come from human sewage: from leaking or ageing municipal sewage systems, residential sewage systems and overflows from sewage treatment plants. Another source of pathogens is manure from farm livestock and wild animal scat. One of the most famous examples of a waterborne pathogen in Ontario is the E. coli outbreak in Walkerton. The American Society for Microbiology estimates that it is possible that about 90,000 cases of illness and 90 deaths occur annually in Canada as a result of waterborne diseases.

2.5.2 Oxygen Depleting Substances and Nutrients

When organic matter such as manure from farms or sewage from septic systems breaks down in water, bacteria consume the waste and use up dissolved oxygen in the water. If there is enough **effluent** in the water the bacteria may consume so much oxygen that levels may drop to dangerous levels in which fish become stressed and may die. Eventually there will be no more oxygen left in the water, and anaerobic decomposition will begin and produce gases such as hydrogen sulphide (which is toxic to many organisms). Another way for oxygen to be depleted is if phosphorus and nitrogen are introduced into an aquatic ecosystem from sources such as fertilizer from farmers' fields, industrial emissions and household wastewater (see Table 3). This loading of phosphorus and nitrogen then results in the exponential growth of aquatic plants like **macrophytes** and algae, and when they die off their decomposers then consumes large amounts of dissolved oxygen, dropping it to dangerous levels for fish and other organisms in the water.

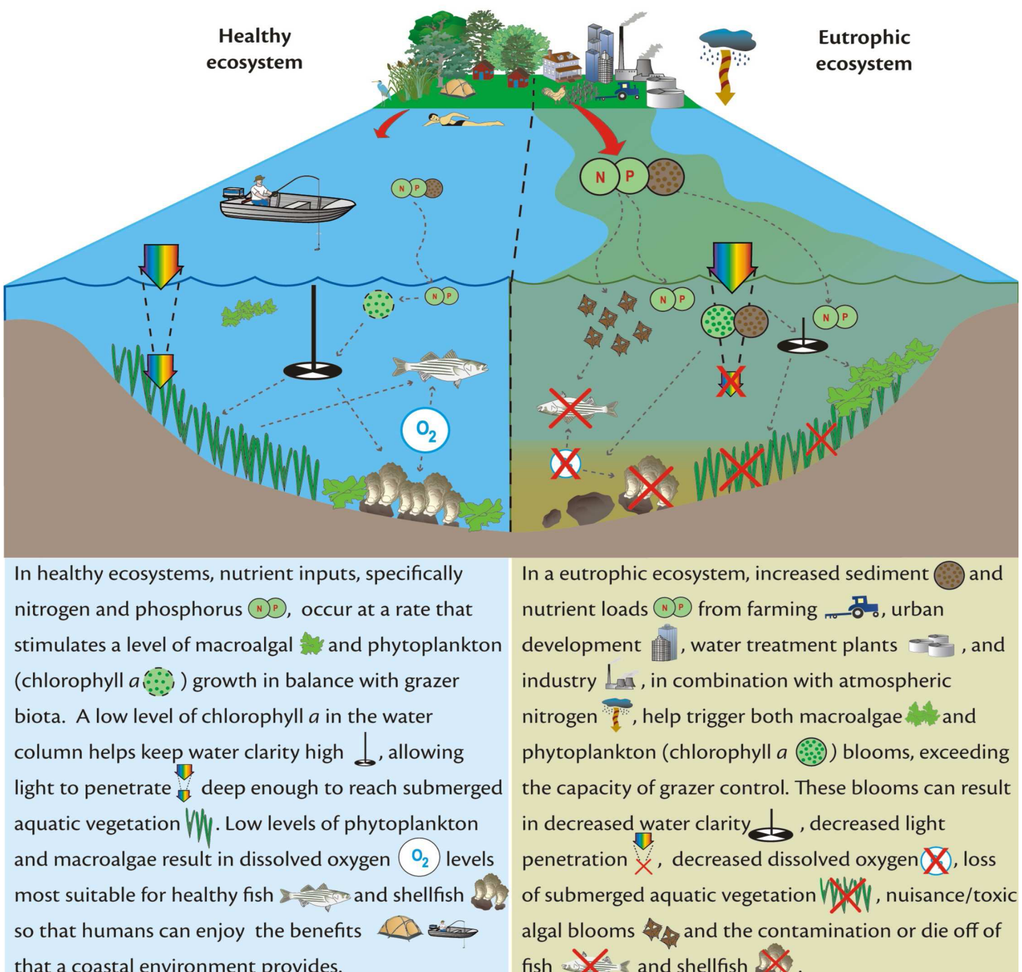

Figure 17. Conceptual diagram comparing a healthy ecosystem with a eutrophic one (NOAA, 2011).

Table 3. Comparison of P and N loading to Canadian surface and ground waters from various sources, (British Columbia Ministry of the Environment, 1999)

Nutrient Source	Nitrogen (10^3 t/yr)	Phosphorus (10^3 t/yr)
Municipal wastewater treatment plants	80.3	5.6
Municipal Sewers	11.8	2.3
Septic systems	15.4	1.9
Industry[1]	1.8	2.0
Agriculture[2] (residual in the field after crop harvest)	293	55
Aquaculture	2.3	0.5
Atmospheric deposition to water	182 (NO_3- and NH_4+ only)	N/A

2.5.3 Sediments

Sediments are soil particles that are suspended in water, which make water appear muddy and cloudy. This allows for less light to penetrate the surface of the water, light needed to allow plants to perform **photosynthesis**. It also injures or kills fish by damaging their gills, covering spawning areas and smothering fish eggs. Fish growth is also negatively affected by sediment loading over longer periods of time by lack of feeding, because fish cannot detect food as quickly as in a clearer, non-cloudy water. Growth might also be inhibited because fish are stressed and have a higher **metabolic** demand. Fish populations could also be impacted as fish become more stressed due to the sudden habitat change, and as they become more stressed their resistance to diseases falls and they become more vulnerable. Other organisms that are affected by sediment loading are **periphyton**, which with increased sediments in the water do not have enough light to perform photosynthesis, so their populations drop. This drop in periphyton populations will then case a drop in the populations of the **macroinvertebrates** that feed on them.

2.5.4 Toxins

Toxic chemicals can enter into aquatic ecosystems from a number of sources such as from industrial runoff, agricultural runoff and even from homes. Chemicals can cause problems with the taste, odour, and colour of water. Animals such as fish and macroinvertebrates are subject to reduced fertility, deformities, immune system damage, tumours and even death. Many of these chemicals can be harmful to humans in small amounts. Toxins such as ammonia, nitrate, metals, polychlorinated phenols (PCPs), Polychlorinated biphenyls (PCBs), and pesticides are examples of toxins that can adversely affect aquatic ecosystems.

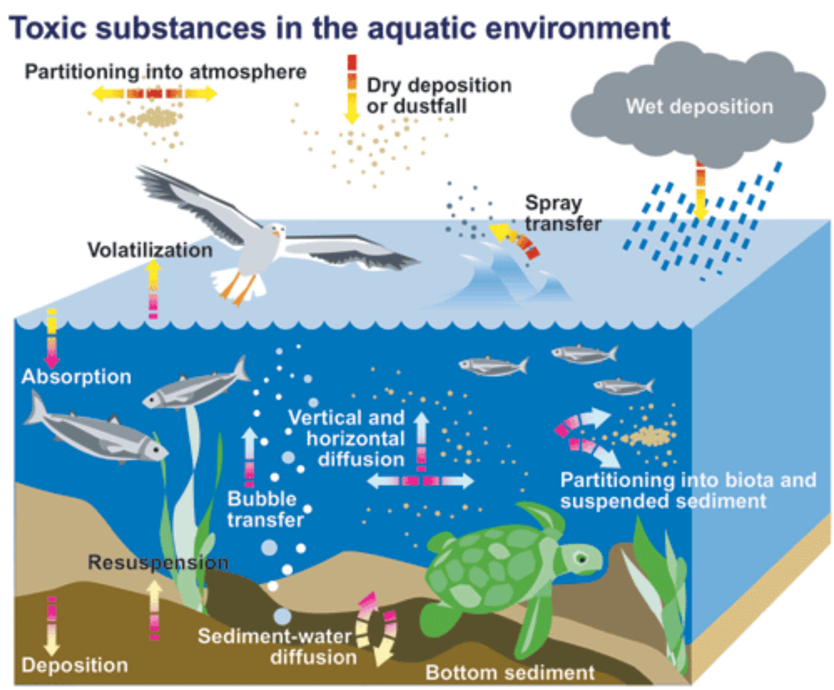

Figure 18. Toxic substances in the aquatic environment (Environment Canada, 2010).

Table 4. Sources of Polluted Runoff (Dorworth *et al*., 2007)

	Farm Land	Managed Green Space (e.g. golf courses, parks)	Commercial & Industrial	Residential
Nutrients	Fertilizers	Fertilizers	Acid rain, automotive exhaust	Fertilizers, septic system effluent
Pathogens	Domestic & wild animal waste	Pet & wild animal waste	Malfunctioning/ overloaded septic systems and lagoons	Malfunctioning septic systems, pet waste
Sediments	Erosion from fields, stream bank erosion	Erosion from unprotected exposed areas	Construction sites, roadside erosion, road salts and sand	Construction sites, road salts and sand, erosion from lawns and gardens
Toxic Contaminants	Pesticides	Pesticides	Industrial pollutions, automotive emissions & fluids	Household products, pesticides
Debris	Litter, illegal dumping	Litter, illegal dumping	Litter, illegal dumping	Litter, illegal dumping
Thermal	Removal of streamside vegetation	Shallow water impoundments, removal of streamside vegetation	Heated runoff, removal of streamside vegetation, impoundments	Heated runoff, removal of streamside vegetation, impoundments

2.6 Measuring Aquatic NPS Pollution and LID

Biological indicator species are an excellent way to determine the conditions of the stream, lake, river or wetland that they were found in. They are a species or group of species whose function, population or health can be used to determine the ecosystem's integrity. Examples of biological indicators are fish, macroinvertebrates, periphyton and macrophytes. Such species are good indicators because of the way in which they respond to pollution, such as with population increase or decrease, given their tolerance or sensitivity to specific changes in environmental conditions such as nutrient loading, decreased light, and presence of toxins, metals, herbicides and salt contaminants.

2.6.1 Fish

For many years fish have been used to determine whether waters are clean or polluted, or to determine whether waters are improving or getting worse. Knowing that fish are living in the different types of water is simply not enough we must know what kinds of fish, the population size of each species and the relative health of the that population. Fish can be excellent indicators of water pollution because they:

- Live in the water all of their life
- Differ in their tolerance to amount and types of pollution
- Are easy to collect with the right equipment
- Live for several years
- Are easy to identify in the field

2.6.2 Macroinvertebrates

Macroinvertebrates or benthos are large, bottom-dwelling organisms such as worms, crustaceans, caddis fly larva, may fly larva, etc. They are excellent indicators of river, lake and stream health. The reason that benthos are so widely used in determining the health of aquatic ecosystems is because they:

- Live in the water for all or most of their life
- Stay in areas suitable for their survival
- Are easy to collect
- Are easy to identify in a laboratory
- Often live for more than one year
- Have limited mobility

Another reason for using macroinvertebrates as an indicator species is because of the way each individual species tolerate differing amounts and types of pollution that can be found in the water. This allows us to look at what species of macroinvertebrate is in a given aquatic ecosystem, and then determine the quality of the water by using various models. In Ontario, the Ontario Ministry of the Environment and Environment Canada came together to create the Ontario Benthos Biomonitoring Network (OBBN). This network allows for aquatic ecosystems to be evaluated using shallow water benthos and the reference condition approach. The reference condition approach gathers samples from minimally impacted rivers, lakes and streams to determine the normal range of variation for a range of indices that summarize the different benthos found in the site.

One model used to determine water quality using macroinvertebrates is the Hilsenhoff Index. Dr. William Hilsenhoff of the University of Wisconsin-Madison developed it in 1977. He originally developed this index to determine low dissolved oxygen caused by organic loading in streams and rivers. Later in 1979, the Wisconsin Department of Natural Resources began to use the Hilsenhoff Biotic Index (HBI) to measure water quality in streams and rivers as part of a number of nonpoint source pollution monitoring programs. Dr. Hilsenhoff then expanded the index by developing a range of biotic index values ranging from 1 to 10 for water quality and degree of organic pollution (see Table 5).

Table 5. Water quality classifications for the Hilsenhoff Biotic Index (HBI) (Shepard, 1997).

Bi Value	**Water Quality**	**Degree of Organic Pollution**
0.00-3.50	Excellent	No apparent organic pollution
3.51-4.50	Very Good	Slight organic pollution
4.51-5.50	Good	Some organic pollution
5.51-6.50	Fair	Fairly significant organic pollution
6.51-7.50	Fairly Poor	Significant organic pollution
7.51-8.50	Poor	Very significant organic pollution
8.51-10.00	Very Poor	Severe organic pollution

2.6.3. Periphyton

Periphyton are **benthic** algae that grow attached to rocks, bedrock or larger plants. Periphyton are considered primary producers and are very sensitive to environmental changes in waterways, and because they are bottom-dwelling algae this makes them more sensitive to changes from physical and chemical disturbances. Others reasons that make periphyton good indicators are:

- A naturally high number of species
- A rapid response time to both exposure and recovery
- Identification to a species level by experienced biologists
- Ease of sampling, requiring few people
- Tolerance or sensitivity to specific changes in environmental condition are known for many species

Figure 19. Periphyton are important for water absorption and nitrogen fixation. (Bromilow, 2008)

2.6.4 Macrophytes

Macrophytes are aquatic plants that grow in or near water. They can be floating such as the White Pond Lily or Water Shield, submergent (underwater) like Milfoil or Common Bladderwort, or emergent (growing out of the water) such as Water Arum and Arrow Head. Aquatic plants are essential to aquatic ecosystems because they provide food and cover for fish and substrate for macroinvertebrates, but most importantly they provide oxygen for water. A lack of macrophytes in an aquatic system could result in a reduced population of fish and waterfowl. It could also indicate water quality problems such as excessive **turbidity**, herbicides, or **salinization.** An excess of macrophytes can indicate high nutrient levels and can interfere with lake processes and recreational activities, as well as detract from the overall aesthetics of the water body.

Figure 20. Common Bladderwort (Bromilow, 2008).

Macrophytes are excellent indicator species because they:

- Respond to nutrients, light, toxic contaminants, metals, herbicides, turbidity, water level change, and salt
- Are easily sampled through transects or aerial photography
- Do not require laboratory analysis
- Are easily used for calculating simple abundance metrics
- Are integrators of environmental condition

2.7 Case Study: Green Roofs in Toronto

A green roof is a roof on a building that has been partially or completely converted to grow vegetation. One of the purposes of having a green roof is to mitigate the volume of runoff and the amount of toxins that can be collected by stormwater as it flows into aquatic ecosystems. Other reasons for building a green roof is to reduce the amount of carbon dioxide in the atmosphere, as well they act insulation in the winter and cool the building down in the summer lastly they also help to lower what is known as the **urban heat island**. There are two main types of green roofs. The first type is the intensive roof, which has more soil and can support a more diverse plant population however this makes the roof heavier requiring reinforcement of the roof. Because there is more plant life it also means that more care is needed in order to take care of the plants. The second type is an extensive roof that is the opposite of the intensive. The extensive type has a light layer of soil and has less vegetation, which requires no reinforcement of the roof and less care than the intensive roof.

In May of 2009 Toronto, Ontario created the Eco-Roof Incentive Program. This is designed to promote the use and creation of green roofs in Toronto. These green roofs would be constructed on commercial, industrial, and institutional buildings. The original purpose of this program is to reduce the impact that the business community has on climate change, however these roofs also help to reduce the amount of stormwater entering sewers and water ways. The Eco-Roof Incentive Program has approved over 50 applications for funding to build green roofs creating a total area of green roofs of 90,000 square meters.

The Toronto and Region Conservation Authority conducted a study called Evaluation of Green Roofs for Runoff Retention, Runoff Quality, and Leachability. This three-year study looks at the quantity and quality of runoff from an extensive green roof on a multiple story building at York University in Toronto. The study compared this building's green roof to a neighbouring roof and took samples of runoff water from both to determine changes in quality and quantity. The study showed that compared to this neighbouring building, the green roof retained 63% more water over 18 months excluding the winter months which were not tested. Water samples from both roofs were taken from 21 rain events and were assessed for general water chemistry such as pH, total suspended solids, metals, nutrients and bacteria. These parameters were tested in runoff water and found that they were lower for all except for calcium, magnesium and total phosphorus which can be found naturally in soils to help grow plants.

This study found that the implementation of green roofs reduces the amount of runoff water entering into aquatic ecosystems. It will also help to reduce the amount of toxins picked up by rainwater that would normally collect on a normal roof surface or from the atmosphere. With the soil and vegetation of a green roof the toxins are now filtered from the water reducing amounts entering aquatic ecosystem.

<u>Case Study Questions</u>

1. What functions do green roofs have?
2. What are the two types of green roofs? Why would you choose one design over the other?
3. Why are green roofs especially useful in urban areas?

2.8 Activity: Benthic Macroinvertebrates - Canaries of the Water

When mining was in its early years miners used to take canaries into coalmines. This was done because canaries are more sensitive than humans to the presence of dangerous gases in the air. Canaries would become uncomfortable or even die in the presence of natural gas this would tell the miners if it was safe to work or not.

Background

In aquatic ecosystems like lakes and rivers the presence or absence of certain organisms are called indicator species, like benthic macroinvertebrates. This presence or absence can tell you much about the quality of the water that you're studying. These creatures then create a biotic index. Water that contains a large and varied population is usually a healthy system, while systems with a low population and small range in species can indicate an unhealthy system. One way in which a systems health can drop is through NPS pollution entering and contaminating the water.

Recommended Materials

1. Rubber boots or hip waders
2. Personal floatation device (PFD) if necessary
3. Water quality test kit
4. Nets
5. Basin to hold BMIs (preferably white)
6. Meter stick
7. BMI identification and tally sheet and pencil
8. Tweezers
9. Container with tight fitting lid
10. Hand lens
11. Field guides

Procedure

1. Select a sample site. Try to find a small fairly shallow stream.
2. Approach the site from downstream, as to not disturb the site too much. Go through the site and collect any organisms that you see and place them carefully into the white container.
3. Now that you have collected some organisms try to identify them by using the ID books. Conduct a tally to see how many different species there are in your collection. Be sure to return the organisms back to the water where they were found.
4. Now that you have looked at the organisms take out the water quality kit and follow the instructions and determine the pH and temperature of the water as well as the air temperature. Record the test results on your sheet of paper.

This activity should be repeated in different areas or streams to show the differences in how organisms can differ in different habitats. This activity allows you to see what pollutions and changes in water chemistry can do to the organisms that live in the water.

<u>Activity Questions</u>

1. What can the presence or absence of aquatic organisms tells us about an ecosystem?
2. Are there any inferences you can make relating the types of organisms you gather and the abiotic qualities of your water sample?
3. List other types of bioindicators that might be used to evaluate aquatic health.

2.9 Review Questions

1. Define aquatic NPS pollution.
2. Explain how LID impacts aquatic ecosystems.
3. List and describe different types of NPS pollution.
4. Give examples of different bioindicators that can be used to evaluate NPS pollution in an aquatic system.
5. Discuss bioindicators as a means of monitoring aquatic ecosystem health.

Figure 21. Water pollution (All Skull Consciousness, 2010).

3.0 Forests

This section will discuss forestry concepts and practices, and their relation to NPS pollution and LID. There will be a specific focus on riparian zones, explaining what they are, what they do and how you can protect and enhance them in your area.

At the end of this section, students should be able to do the following:

- Describe Ontario's four forest regions
- Explain the effects of forests on NPS pollution
- Define a riparian zone
- Describe the importance of riparian zones
- Discuss positive and negative effects that forestry practices can have on NPS pollution
- Give examples of Better Management Practices and describe plant composition in riparian zones

3.1 Introduction to Forests

Ontario contains roughly 2% of the world's forests, totalling 70 million hectares. Forests are the most common land class in Ontario, covering two-thirds of the province.
They are divided into four regions:

Hudson Bay Lowlands

- Most northerly part of the province, subarctic barrens
- Contains 20% of Ontario's forest
- Generally made up of stunted tamarack and black spruce

Figure 22. Hudson Bay Lowlands (Government of Ontario, 2011).

Boreal Forest

- Ontario's largest forested region containing 58% of Ontario's forest
- Extends from Hudson Bay Lowlands south to Great Lakes-St Lawrence Forest
- Main conifer trees are black and white spruce, jack pine, balsam fir, tamarack and eastern white cedar; main deciduous trees are poplars and white birch

Figure 23. Boreal Forest (Government of Ontario, 2011).

Great Lakes-St. Lawrence Forest

- Second largest forest region containing 19% of Ontario's forest
- Transitional zone between coniferous boreal forest in the north and deciduous forest in the south

Figure 24. Great Lakes-St. Lawrence Forest (Government of Ontario, 2011).

- Coniferous trees include eastern white pine, red pine, eastern hemlock and white cedar; deciduous species include yellow birch, sugar and red maple, basswood and red oak. Also contains boreal conifers such as black and white spruce, jack pine, aspen and white birch

Deciduous Forest

- Most diverse of all forest regions, but also the smallest and most threatened
- Similar composition to Great Lakes-St. Lawrence forest, but also contains black walnut, butternut, tulip, magnolia, black gum, many types of oaks, hickories, sassafras and red-bud species and other Carolinian species
- Largely cleared with dense human populations, containing over 90% of Ontario's 13 million residents

Figure 25. Deciduous Forest (Government of Ontario, 2011).

3.2 Forestry and NPS Pollution

Forest activities can cause significant water quality issues if not properly managed. Sources of nonpoint source pollution associated with forestry include removal of streamside vegetation, road construction and use, timber harvesting and mechanical preparation for tree planting.

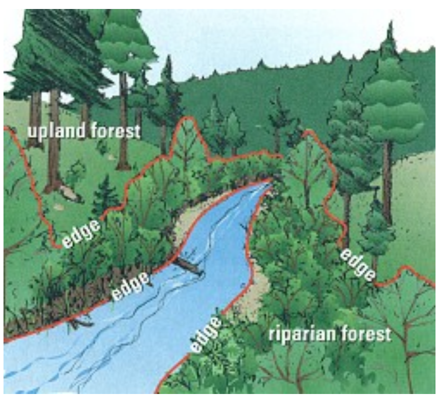

Figure 26. Riparian zone diagram (Red River Regional Council, 2006).

The removal of vegetation in **riparian zones** can lead to soil erosion, which impacts local waterways. It also reduces stream bank shading, which regulates water temperature. These changes can have negative impacts for aquatic and terrestrial species by limiting sources of food, shade and shelter.

Road construction and use are the primary source of NPS pollution on forested lands, accounting for up to 90% of the total sediment from forestry operations. Sediment is the most common pollutant from forest harvests. Activities from harvesting timber loosen soil, which is then carried to streams and lakes. Sediment decreases water quality for fish and other aquatic animals and plants. Even if water appears clear, some sediment remains in the water column.

Timber harvesting and mechanical preparations for planting leave large open spaces and bare ground exposed, also leading to soil erosion that pollutes streams and watercourses.

3.3 Managing for NPS Pollution in Forestry Activities

To limit water quality impacts caused by forestry, forest managers can develop and use different pre-harvest management plans. These plans clearly identify the area to be harvested; locate special areas of protection, such as wetlands and riparian areas; plan for the proper timing of forestry activities; describe management measures for road layout, design, construction and maintenance; and discuss harvesting methods and **forest regeneration**.

Identifying the area to be harvested and conducting site surveys can help identify areas that need special consideration during forestry operations. Sensitive landscapes include areas that have steep slopes, greater potential for landslides, sensitive rock formations, high precipitation levels, snowpack, or special ecological functions such as those provided by streamside vegetation. Activities in these areas have a high chance of affecting water quality. Planning for proper timing of forest operations can have a significant impact on water quality. Rainy seasons, fish migration and spawning sites and other events should be avoided.

Figure 27. Forestry activities can cause soil erosion and degrade riparian and forest ecosystems (Connect, Create, Inspire, 2010).

3.4 Riparian Ecosystems and their Importance

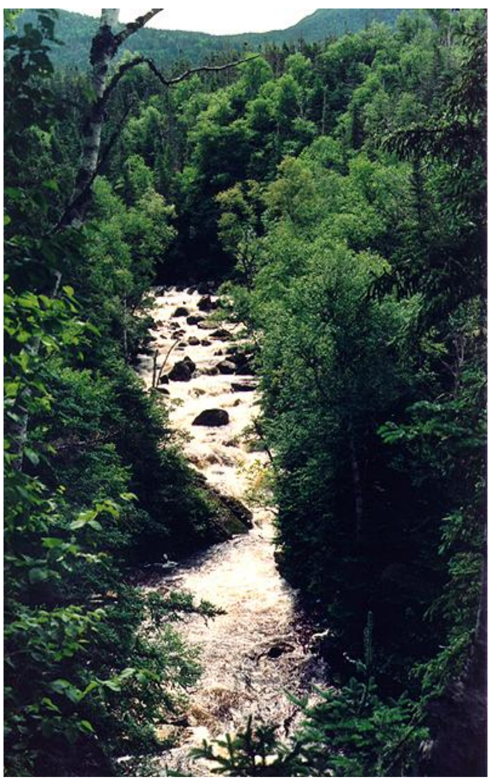

Figure 28. Stream located in Gros Morne National Park, NFLD (Churchill, 1990).

Riparian zones link aquatic ecosystems with the surrounding landscape. They cover ravine slopes, banks, shores and wetlands. They are generally more fragile than most upland woodlands, often with sloping lands, on shallow or erodible soils, and are directly adjacent to surface waters. Riparian flora and fauna are often distinctly different than those found in adjacent communities because of the water-rich soils found in riparian zones. Healthy riparian zones provide a number of ecosystem services and are often important habitats for wildlife.

Riparian zones provide the same benefits of wetlands in that they protect soil and water quality and provide habitat and woodland products. Riparian woodlands perform these functions more effectively than other woodland types assuming they are extensive in size, contiguous in shape, and are relatively undisturbed.

Aside from forestry and logging, riparian zones are also threatened by other factors such as overgrazing, agriculture, building dams and human development.

Riparian zones provide a number of different functions and services:

Stream bank and streambed protection

- Tree roots hold soil, reducing erosion and sedimentation without interfering with natural channel process (meandering and bank shaping)
- Trees improve the efficiency of sediment transport in the channel by narrowing it
- Trees and branches in streams form riffles, pools and meanders that improve aquatic habitat

Water quality

- Trees and **understory vegetation** filter sediment and other contaminants from runoff
- Root growth and organic matter addition increase **infiltration rates**
- Woodland plant absorb nutrients before they reach surface waters
- High organic matter levels and diverse soil life help to biologically and chemically alter contaminants into living tissue or less harmful forms

Fish and wildlife habitat

- Surface waters shaded by riparian forests provide cool and cold fish habitats
- Leaves and other organic debris feed aquatic insects as part of the food chain in aquatic environments
- Fallen trees and branches provide cover for fish and other aquatic animals
- Riparian woodlands provide habitat needs – space, cover, food and water – for most mammals, birds, reptiles, amphibians and insects that live in ontario

Other environmental functions

- Riparian woodlands are excellent for conserving soil, with buffers, **berms** and **strip-cropping** able to reduce runoff and control erosion
- Trees and shrubs are efficient for fixing carbon (co_2) from the atmosphere to form wood and organic soil matter, and prevent dissolved nitrate (no_3) from turning into nitrous oxide (n_2o), a harmful greenhouse gas

3.5 Characteristics of Healthy and Unhealthy Riparian Ecosystems

Characteristics of healthy riparian areas differ according to the landscape they are found in. Grassy vegetation holds together stream banks formed from sediments, while trees and shrubs dominate on the steep, rocky banks of more rapidly moving and narrower headwaters. In all cases water-tolerant or water-loving plants are more effective at holding soil than plants that are more adapted to upland conditions, because they have deeper and stronger root systems.

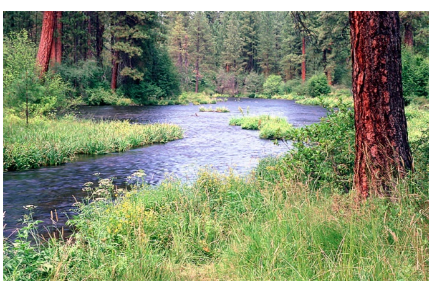

Figure 29. Healthy riparian system (Hutmacher, 2010).

Healthy riparian areas generally exhibit certain similarities:

- thick growth of vegetation that covers stream banks and provides shade over the stream
- surrounding land remains wet most of the year, except where streams cut through rocky terrain
- stream banks are more vertical than flattened out
- stream levels vary only moderately throughout the year

- stream water is relatively clear but contains leaves, twigs or logs that create pools and other habitat for fish and other aquatic organisms
- a diversity of fish, aquatic life, mammals, birds and other wildlife

Degraded riparian areas have some or all of the following characteristics:

Figure 30. Unhealthy riparian system (Soil-Science.info, 2009).

- patchy of scrubby plant growth with bare ground
- vegetation dominated by upland plants or weeds
- soil that is compacted, shows **rills** or **gullies**
- stream banks that are eroded, severely undercut or sloughing
- streams that flood in spring and become dry in summer
- stream water that is muddy or murky and may contain toxic levels or nutrients or contaminants
- few mammal or birds living or feeding
- limited numbers and diversity of fish and other species

3.6 Best Management Practices for Riparian Zones and Forests

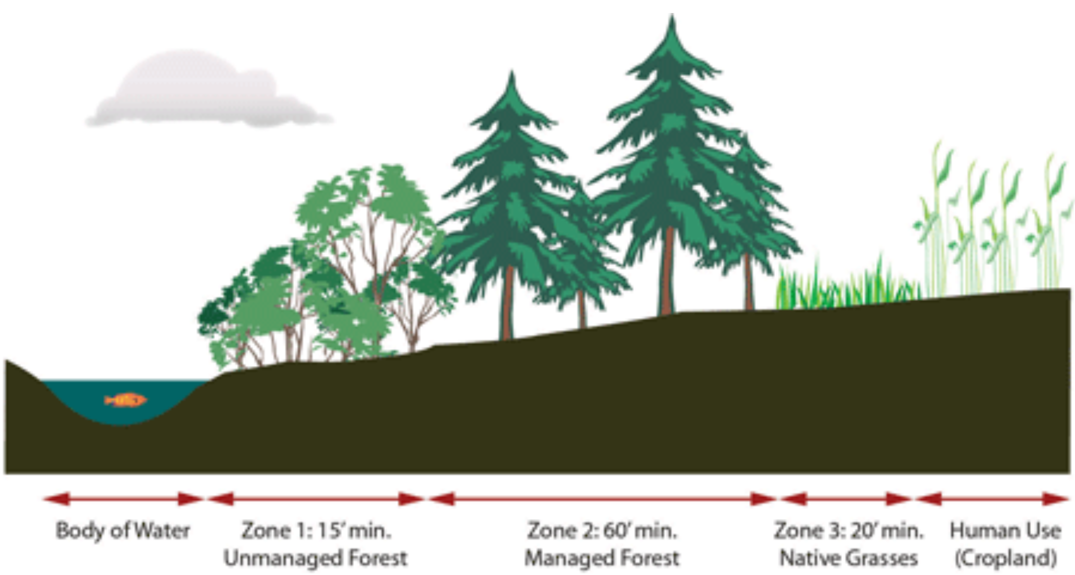

Figure 31. Treed buffer design. Zone widths according to U.S.D.A. guidelines (Virginia Outdoors Foundation, 2007).

Not all riparian forests need management; in many cases the best strategy is to leave these areas alone. At the very least, establishing no-harvest zones adjacent to watercourses can lead to ecosystem protection. When active management is needed, best management practices (BMPs) are available to help people establish buffered zones to protect and enhance riparian areas. In a treed buffer design, three different zones are established to buffer the distance between aquatic ecosystems and upland development. Zone 1 provides vegetation that shades the water and stabilizes the banks. Zone 2 provides distance between streams and upland development, while soils and vegetation help to filter sediments and promote infiltration and sediment storage. Zone 3 filters runoff from development areas such as cropland and urban areas and prevents encroachment.

When planning and managing riparian zones, a variety of factors must be considered. For example, different vegetation types are better suited for different desired functions (Table 6). It is also important to match species appropriately to the surrounding landscape, taking into account factors such as soil composition and pH, moisture regime, temperature and cover type (e.g., trees species in different woodland cover types; Table 7).

Table 6. Relative Effectiveness of Riparian Types by Function. Adapted from Tjaden and Weber (1998) IN Lane (2008).

	Vegetation Type		
Function	**Grasses and Forbs**	**Shrubs**	**Trees**
Bank/Shore Stability	Low/Medium	Medium/High	High
Filtration of Sediment	High	Low/Medium	High
Filtration of Soil-bound Nutrients, Bacteria and Pesticides	High	Low/Medium	High
Retention of Soluble Nutrients, Bacteria and Pesticides	Low	Low	Medium
Water Storage	Low	Medium	High
Flood Protection	Low	Medium	High
Fish Habitat	Low	Medium	High
Wildlife Habitat	Medium	Medium	Medium
Forest Habitat	Low	Medium	High
Greenhouse Gas Reduction/Carbon Sequestration	Low	Medium	High
Nitrate Uptake	Low	Low	Medium/High
Phosphorus	High	Low/Medium	High
Economic Products	Medium	Low	High
Visual Diversity	Low	Medium	High

Table 7. Four Riparian Woodland Cover types (Lane, 2007).

Type	**Description**	**Dominant Tree Species**
Upland Hardwoods	• similar to non-riparian hardwood forests • suited to selection management • prone to erosion on steep slopes	• Sugar Maple, Beech, Hickory, Ash, Oak, Black Cherry (south) • Poplar-Birch (north)
Upland Mixwoods	• Diverse habitats important to numerous wildlife • Selection management is most suitable • Difficult to keep mixwood components on some sites	• Hemlock-White Pine-Sugar Maple; White Pine-White Spruce (south) • White Birch-Poplar-White Spruce (north)
Lowland Hardwoods	• Level to hummocky topography • Temporary pools hold floodwaters, thereby reducing flooding and **windthrow**	• Silver Maple; Soft Maple-Green Ash; Bur Oak-Shagbark Hickory-White Ash (south) • Black Ash; Balsam Poplar-White Birch (north)
Lowland Mixedwoods	• Located in floodplains and beside riparian woods • Organic surface layer is common • Minimal understory vegetation prone to flooding and windthrow	• Cedar-Tamarack-Balsam Fir-Birch-Poplar (north and south) • Red Maple-Hemlock-White Pine-Yellow Birch (south)

3.7 Case Study: Oak Ridges Moraine

Figure 32. Oak Ridges Moraine, shown in green. The City of Toronto is shown in orange; the Greater Toronto Area in yellow (York Region, 2006).

The Oak Ridges Moraine is one of the most significant landforms in Ontario, rising 300 m above Lake Ontario and stretching 160 km from the Niagara Escarpment in the west to the headwaters of the Trent River in the east (Natural Resources Canada, 2008). About 65% of it lies within the Greater Toronto Area (GTA). The moraine sands and gravel for a layer that is almost 200 m thick and act like a sponge, absorbing water from rain and snow and storing it in aquifers. The moraine is able to do this because its surface material is more permeable than the surrounding, less permeable till plains. The presence of kettle lakes also helps to capture water. This water is then filtered and slowly released into streams, rivers and lakes. The springs from which these filtered waters emerge are the headwaters for over 60% of the watersheds in the GTA.

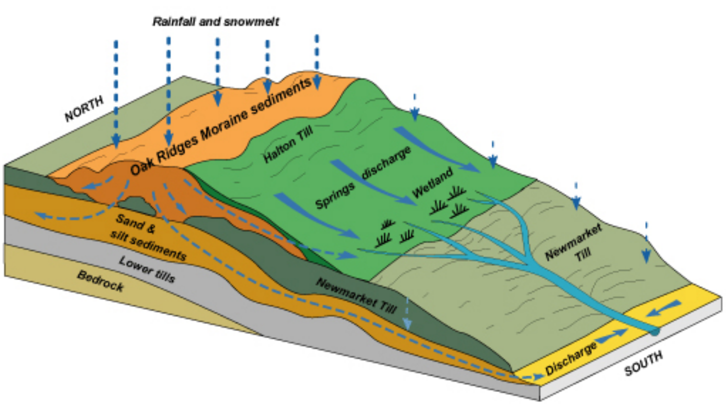

Figure 33. Oak Ridges Moraine Water Flow (Natural Resources Canada, 2008)

Almost 28% of the Oak Ridges Moraine is forested, compared to less than 5% of the GTA. It contains a wide diversity of habitats and is home to many different species of significant flora and fauna. It is crucial to protect these areas, as they provide much needed habitat for birds and other wildlife. They also act as lungs for the GTA, filtering out greenhouse gases and toxins from the air. The moraine also contains thousands of wetlands, including kettle lakes and rare kettle bogs, and has drier upland areas that support prairie habitats and species.

Removing these important habitats along the moraine and the paving over these features will reduce the amount of water that will make it into underground aquifers, impair the moraine's ability to filter and store water, and destroy habitat that supports hundreds of plant and animal species. Recognizing the moraine's overall significance, the Government of Ontario passed legislation in 2001 to protect this important ecosystem.

Case Study Questions

1. Why is the Oak Ridges Moraine an integral feature of southern Ontario?
2. Why is it necessary for legislation to pass laws to protect it?
3. What might have happened if development had not been prohibited on the moraine?
4. Which watershed do you live in? Where does your drinking water come from?

3.8 Activity: Food Webs in Riparian Ecosystems
Adapted from Project WILD

Detangling the relationships between food webs and ecosystems can help to give you an idea about how different ecosystems work and what sort of abiotic and biotic factors they need to sustain themselves. Trees, shrubs, grasses and other plants help to regulate riparian areas and provide critical habitat for aquatic and terrestrial animal species. What happens when these chains and processes get interrupted?

Method

Students will create a variety of representations of the plants and animals that live in riparian habitats.

Background

Riparian areas are important and valuable in many ways, including as ecologies for whole communities of life. They are the green ribbons of life found on the edges of watercourses such as streams, rivers, lakes and ponds. They provide space, shelter and food for the plant and animal species found there, and act as important corridors for animals to move from one area to another.

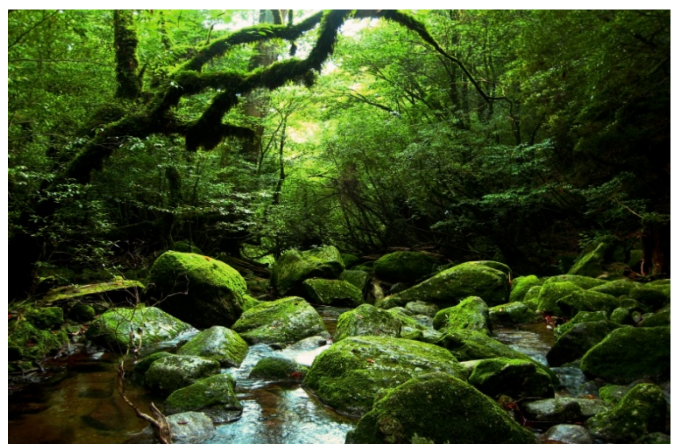

Figure 34. A riparian system. What kind of animals might live there? (Haftelm, 2008).

Each plant and animal in a riparian ecosystem has an important role or **niche**. An animal's niche includes its preferences for food, shelter and space. If niche refers to an animal's "occupation", then it's habitat can be thought of its "address". This activity focuses on the different animal and plants found in riparian ecosystems and their respective niches within this system.

Recommended Materials

A variety of art materials, nature magazines for photos (optional), books or references about riparian habitats (optional).

Procedure

1. In the classroom, identify a local stream or standing water body and have students generate a list of all of the plants and animals that might live in this ecosystem.
2. Assist students in verifying that the plants and animals they've come up with for their lists actually do live in the region and might live in this area. Use references to help decide.
3. Once the list is verified, have each student choose an animal and have them create an art form representation of their given creature. Advise them that what they create must be durable to be displayed outdoors and have a hook, string, or other support to attach to branches or be placed on the ground.
4. Have the students gather more information about their animal and its habits and life cycle. Students should be able to explain their organism's role within the ecosystem or its "niche" – what this organism depends on, and which other organisms depend on it. Include terms such as predator, prey, producer, herbivore, carnivore, omnivore, decomposer, and food web.
5. Visit the riparian site with the students and have them bring their art pieces. Select a common area from which all areas of the site are visible, and designate this site a discussion area. Emphasize safety and regard for not significantly disturbing the habitat.
6. Have the students disperse and place their "animals" where they think their animal would live in the system. Keep a focus on what plants are found in this riparian habitat and how they help shape the area. After they are placed, have students return to the discussion area.
7. Ask each student in turn to explain their animal's characteristics, habitat and niche in a short summary. Students should also explain why they placed their animal where they did, and what vegetation characteristics influenced their choices.
8. Once each student has discussed their animal, gather the students into a discussion about the concepts of niches, habitats, and the interrelatedness of organisms in a system. Have students identify and discuss the characteristics of riparian habitats.
9. Ask students to consider how changes to the riparian zone might alter ecosystem function and impact their given animal. Here are some example changes:
    - Draining areas to expand areas for farmland
    - Removing shade-producing trees and shrubs
    - Introducing **exotic species**
    - Clear-cutting a slope above the stream, increasing runoff
    - Removing organic and other debris in the stream
    - Straightening or **channelization** of the stream, increasing the speed flow
    - Disturbing spawning beds by introducing livestock or people wading through streams
    - Planting vegetative cover on a previously bare slope above the stream
    - Regulating uses of the riparian area to control soil compaction and erosion
10. Visually illustrate how these impacts play out by having students remove animals that would be severely impacted by changes, such as removing aquatic species such as fish and insects in response to severe water pollution. Discuss how those removals affect other species.
11. Have students work in small teams and investigate the area for evidence of actual animal life in the area. List and quantify any species observed. Have students compare how their findings compare with their original ideas of what they might find.
12. Have students summarize what they have learned about niche, habitat and riparian environments. Have the students gather their art and return to the classroom.

Extensions

Figure 35. Restoration efforts to riparian systems (Halsted, 2005).

1. Investigate what kind of repairs can be done to riparian ecosystems that have been severely degraded. See if there are groups in your area working to restore riparian habitats in your community. Explore the possibility of joining in one of these restoration efforts. Consult wildlife and conservation groups for information.

Activity Questions

1. Identify and describe the habitat and niche of the following organisms: raccoon, frog, fish, heron, mosquito.
2. Name three other animals that are common in riparian systems in your area, and explain their niche.
3. Describe two positive and two negative things that could impact a riparian system.
4. A large strand of trees in a riparian area is being evaluated for its economic potential. What values would you ask the owners to consider before they came to a conclusion about whether to cut the trees?

2.9 Review Questions

1. What are Ontario's four forest zones? Describe their characteristics.
2. What forestry practices can negatively impact water quality? How can these impacts be mitigated?
3. What is a riparian zone?
4. Why are riparian zones important? Describe ecosystem services riparian zones provide.
5. List five major threats to riparian zones.
6. Define Best Management Practices and describe their relation to low impact development.

4.0 Soils

This section will define soil concepts and theory. There will be a focus on how NPS pollution and LID relate with soils.

At the end of this section, students should be able to do the following:

- Discuss soil profile and identify the three major soil textures classes
- Explain how NPS pollution and LID practices tie in with soils
- Discuss features that shape soil erosion

4.1 Introduction to Soils

Without soil there would be no life. Soil provides a home for many animals and fungi, as well as a place for plants to anchor themselves. But what exactly is soil?

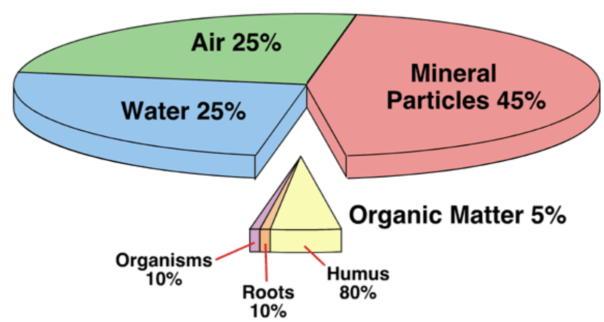

Figure 36. The components of soil (Pidwirny and Jones, 2010).

Soil is composed of two main ingredients, **inorganic** and **organic**, with a few extra bits like air, water and organisms thrown into the mix . It is composed of different layers, called **horizons**. Each horizon has different properties, and a different composition of organic and inorganic soil.

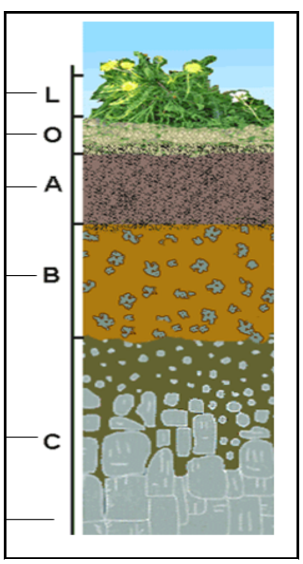

Figure 37. Soil Horizons (Radboud University Nijmegen, 2010).

The inorganic portion forms the majority of soil composition at approximately 45%. This provides the structure for the soil. It's made up of different sizes of weathered mineral matter, as well as pore spaces between these particles. The pore spaces are very important for the retention and percolation (downward movement) of water, and they also ensure the presence of gases in the soil. Inorganic soil (also called 'mineral soil') is mainly found in the C Horizon.

The organic portion of the soil is formed from decomposing organic matter, such as dead plants and trees, faeces, and fallen leaves. It only makes up approximately 5% of soil. This is what gives plants their nutrients, and where the organisms living in the soil reside. The first layer of organic matter is the most pure, and the least decomposed. It is called the O Horizon, and it is made up of rotten organic matter called **humus**.

The next layer of the soil is known as the A horizon. This layer is also called 'topsoil'. This is where all the growing really takes place. Most plant roots are found here, as are most soil organisms. It is composed of a mix of both mineral and organic soil, the organic soil having been transported there by the downward movement of water through the substrate. The layer directly after this contains even less organic material, and is called the B Horizon. This zone is also known as subsoil, and it is where taproots are often found. Typically there are more stones found in this horizon than the horizons found above it.

The last layer, before the bedrock, is called the C Horizon. This is composed of mineral soil, bits of stone, and finer stone made up of the parent material called bedrock. This layer is barely altered from the bedrock. The bedrock is the final layer in the soil profile. This is solid rock.

The rest of the soil consists of water and air, which are stored in the pore spaces. Pore spaces are the empty spaces between soil and rock particles. Water moves downward through the soil, through the pores, and air is stored in the pore spaces. Good soil structure means a variability of both pore space size and particle size. Some water should be stored and some should pass straight through. One soil type means one of these actions will take place over the other. Water will pass quickly through sand, but clay soil will become inundated with water (water-logged). A mix of clay and sand means a mix in pore sizes, and this is preferable for most plant growth.

You will not find this exact profile everywhere in Ontario; for example, on the Canadian Shield in Northern Ontario, the soil layers are very thin and/or nonexistent. In some cases the soil may only be present in cracks in the rock. You might also find instances of thin soil cover along the Niagara Escarpment, and in the northernmost part of the province you'll find muskeg (this is a thick layer of peatmoss-rich organic matter that sits directly on bedrock).

4.2 Soil Variability

4.2.1 Particle size

Mineral soil includes various particle sizes, and each of these particle sizes has different properties. The mix of various particle sizes is called texture.

Soil can feel gritty (sand), silky (clay), or in between (silt). Soil texture feels and acts a bit differently when wet than dry. Clay soil will tend to hold its shape the best when wet, and coarse sand cannot hold a shape at all when moistened.

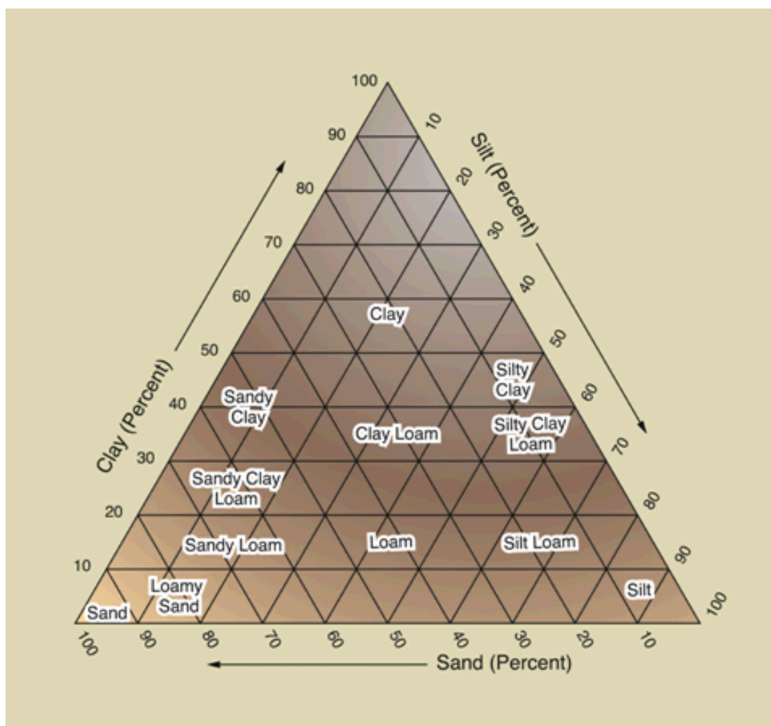

Figure 38. Soil texture by particle size distribution. (The Ministry of Agriculture Food and Rural Affairs, 2008)

Table 8. The size and feel of each soil texture class.

		Soil Textures
Soil Texture	**Particle Size** (mm)	**Dry Feel**
Fines:		
Clay	< 0.002	Very silky and smooth like baby powder.
Silt	0.002–0.05 mm	A bit grainy, but a bit smooth. It feels like white flour.
Sand:		
Very Fine Sand	0.05–0.10	Grainy, like cornmeal
Fine Sand	0.10–0.25	⇩
Medium Sand	0.25–0.50	
Coarse Sand	0.50–1.00	
Very Coarse Sand	1.00–2.00	Can feel very distinct particles, like kitty litter

4.2.2 Mineral Composition

The mineral composition of inorganic soil depends on the parent material. For example, if the parent material is made up of granite, as is common on the Canadian Shield, soil found there tends to have more quartz. In southern Ontario, the bedrock is limestone, and therefore the soil there is more calcareous (calcium-rich).

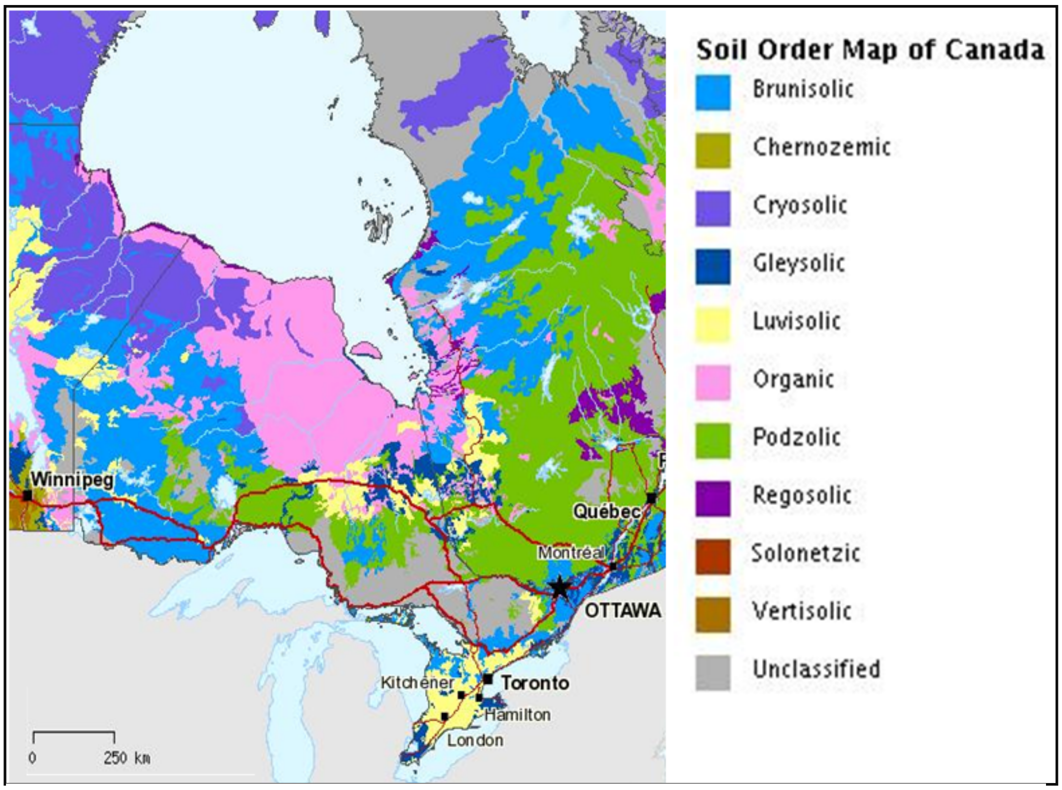

Figure 39. Soil distributions found in Ontario (Agriculture and Agri-Food Canada, 2010)

4.2.3 Moisture

Soil varies in each location by moisture as well as mineral and organic composition. The continued presence of water in soil leads to either **gleying** or **mottles** or both. Soil moisture is dependent upon soil texture. For example, the more clay a soil has the more moisture it can retain. The small particle size means that it is harder for water to pass through that particular soil. The opposite is true for sandy soils.

4.3 NPS Pollution and Soil

NPS can impact through soil erosion and chemical seepage.

4.3.1 Soil Erosion

Soil is affected through **erosion** via activities like poor farming practices. Small soil particles are transported by excess water after a precipitation event (rain or snow-melt) or after the irrigation of a field, and are carried off to nearby water ways. This **sedimentation** then reduces light and oxygen levels in the water ways, impacting the survival of aquatic species. As well, excess nutrients in the form of fertilizers applied to farm fields or animal manure may also get transported with the **sediments**, and these directly impact ecosystems. They increase the **nutrient load** in the water, potentially causing an increase in the growth of algae (of which one of the end outcomes is the removal of oxygen from the water), and the subsequent possible suffocation of aquatic organisms that require oxygen.

4.3.2 Chemical Seepage

Pesticides and fertilizers can percolate through the soil on farmland. This happens when pesticides and fertilizers that are applied by the farmer are carried through the soil profile and ultimately through to the water table, essentially contaminating it. This is a particular issue with nitrogen-rich fertilizers, which can cause nitrate loading in ground-source drinking water. Phosphorus (another element found in fertilizer) is also a concern as it has a tendency to adhere to clay particles, which then can enter waterways through sedimentation.

4.4 LID and Soil

LID practices can help reduce the negative impacts of NPS pollution in soils by limiting the following:

- Sedimentation that occurs after precipitation events in an urban centre
- **Effluent** and excess nutrients percolate, which are transported after a precipitation event

There are a number of LID best management practices to help prevent erosion along stream banks. One of these is site design, which can incorporate aspects like treed buffer zones. There are a number of features that shape stream banks (see Table 8), and these must be taken into consideration before rehabilitation or enhancement activities are undertaken.

Table 9. Effect of site and land use features on design of treed buffers Adapted from Lane (2008).

Feature	Implications
Soil Type (Sand, Loam, Clay)	• Runoff is greatest on clayey soils, while loamy soils are the most erodible • Soil drainage will affect tree, shrub and grass species suitability (e.g. flood tolerance)
Slope	• The steeper the slope, the greater the rates or erosion and runoff
Shape	• In some riparian areas, banks follow a straight path and floodplain width is uniform • In other areas, watercourses meander, floodplain width varies, and ravine slopes are deeply cut
Land Use	• Adjacent land uses could be residential, agriculture, natural areas, etc. • Within these land uses there are also differences (e.g. buffer strips
Riparian Type	• Lakeshore buffer strips differ from small stream buffers, both in species selection plantings and erosion control methods

4.5 Case Study: Sediment Barriers and NPS Pollution.

Sediment barriers are temporary fences or structures that are installed across or at the bottom of slopes. The purpose of the barriers is to stop any amount of sediment from collecting in runoff and contaminating aquatic ecosystems. There are many different types of sediment barriers; some of these include sandbags, hay or straw bales, brush from clearings, and slit fences. The main source of sediment runoff is construction sites because of the soil that is disturbed in the process of construction.

This case study looks at a sediment barrier that was tested by the University of Guelph and the Toronto Region Conservation Authority. In a 2009 study titled "Effectiveness of Compost Biofilters in Removal of Sediments from Construction Site Runoff", the authors of the study wanted to determine the effectiveness of a compost biofilter. They evaluated the through-flow capacity of the biofilter for hydraulic design of the system, biofilter effectiveness in removing suspended sediments from stormwater runoff near construction sites, and overall biofilter longevity. The compost biofilters were made up of yard wastes such as leaf, twigs, bark and wood chips, which were then stuffed into 'socks' composed of mesh tubes with different diameters ranging from 20 to 61 cm. After the biofilter's life expectancy is over, the filter is sent to a composting facility for recycling and the contaminated sediments are removed, sieved and sent to a landfill to be properly disposed of.

Through a literature review, this study found that if left unchecked construction sites can have four times higher total suspended solids than the median value for varying storm conditions. They also found that there is a 46% removal efficiency of incoming sediment in outflows of sediment barriers. The percentage of sediments removed depends on the site and on proper installation, and the effectiveness of the sediment barrier itself depends on the minimum particle size that it was meant to stop and the size of the sediments in the runoff.

The study used compost from three major compost producers in southern Ontario: the Region of Peel, the Region of Waterloo and Alltreat Farms. They then made biofilter socks from each compost producer, making three different biofilters using the same size compost. They also made two different sized socks: one 20 cm and the other 45 cm. They then preformed a number of tests on the biofilters to determine their effectiveness. The physical test that they preformed were to determine the size of the compost that would go into the sock. This test determined that there is a 60 – 70% void space in all three compost samples. The next test that they preformed was the clean water test, which tested for total suspended solids, pH, turbidity, phosphorous, electrical conductivity, total Kjeldahl nitrogen, total phosphorus, and total organic

Figure 40. Sediments in an aquatic ecosystem can cause many problems for wildlife, particularly for fish and amphibians. (Montgomery County Government, 2011)

carbon. Earlier they had predetermined a target water quality guideline for the protection of aquatic life, in which a maximum of 25 mg/L total suspended solids was given for chronic exposure and 80 mg/L for acute short-term exposure. They determined that after a 10-minute flush of water, the total suspended solids would be under 25 mg/L. Turbidity was the same for all compost types, and after 10 minutes turbidity reached zero. pH for all compost types met with the Provincial Water Quality Objectives set by the Ontario Ministry of Environment and was well within the 6.9 to 7.2 range. Total phosphorous concentrations dropped below the detection limit after about five minutes. Total organic carbon after five minutes ranged from 0 to 7 mg/L.

They also conducted field experiments where they looked at the effect of the number of socks and the performance of the biofilters. They conducted tests with 5, 10 and 15 socks and determined that 15 socks will achieve between 50 and 60% sediment removal efficiency.

In the end, the authors determined that the compost biofilters were as effective if not more effective than other sediment barriers in use. This method of sediment barrier is also more environmental friendly with the reuse of compostable material and the method of disposing of the biofilters themselves.

Case Study Questions

1. What are sediment barriers? What are they used for?
2. What kind of material was used in the compost biofilters in this study?
3. What did the authors determine to be the acceptable range of sediments in water for aquatic life?
4. Based on this case study, do you think sediment barriers are effective at preventing NPS pollution?

4.6 Activity: Where Does Water Go After School?

Adapted from Project WILD

The goal of this activity is to help students understand precipitation and how runoff from rainfall behaves in a number of environments, urban and rural. Understanding this cycle is key to understanding how urban landscapes with and without low impact development respond to situations where runoff and nonpoint source pollution, particularly sedimentation from erosion, can be an environmental issue. Students will be asked if they know where the water goes when it rains in their community. For the purposes of this exercise, the geographic focus is the school grounds.

Recommended Materials

Length of rope marked in 1 m increments, trundle wheel, computer with internet access, topographic map of area.

Methods

Sedimentation from runoff is an important part of NSP pollution, and understanding runoff (how water travels from one place to another on the surface) important in understanding the possible effects sedimentation can have on a local ecosystem. This sedimentation can carry toxins or an overload of nutrients, or increase the sediment load in our rivers and lakes.

One major aspect of urbanization is the increase of paved surfaces. This means that there are fewer natural areas for water to infiltrate the earth, and there is a greater likelihood of runoff contaminated with effluents and sediment. In more rural areas, areas with few to no paved surfaces, runoff after a precipitation event is less extreme, and there is a greater frequency of water percolation and infiltrating the soil. One must keep in mind that some methods of farming do drastically increase the instances of runoff, and can be comparable to runoff in urban environments.

Infiltrated water recharges our water tables (where some of us source our drinking water) and hydrates our forests. Some runoff is normal, and it is important for restoring water levels to aquatic habitats. For example, this runoff water will replace lake water lost due to surface evaporation, and outflow.

<u>Procedure</u>

1. The first step is for students to measure the surface area of their school grounds. The surface areas of the buildings are to be included in this calculation. This can be done with a length of rope, with increments of 1 metre demarcated.

   Area = Length x W

   If a trundle wheel is available, this is recommended. Students can also take the measurement from a mapping website, though measuring skills will be missed and accuracy may be lost.
2. The next step is to determine the amount of precipitation that this area receives. This can be achieved through 3 different means:
   - Using a weather resource website, such as Environment Canada.
   - Using a rain gauge.
   - Calculating the amount of rain that falls in a given storm.

   After this method has been chosen, the students are then asked to measure the amount of water that falls on the school grounds in a specific period of time. This gives a value for the depth of rainfall on the surface.
3. With the depth of rainfall measured and the area of the school grounds measured the next step is to calculate the volume of rainfall.

   Ex. area of school grounds = 5000m^2
   annual rainfall = 15 cm (0.15m)
   Volume = area x depth
   = 5000m^2 x 0.15m
   = 750 m^3 of rain
4. Once the volume of the rain has been calculated, the weight of the rain is next. Water weighs 1000kg per m^3.

   Ex. weight = volume x 1000kg
   = 750 m$^{3 \times}$ 1000kg
   = 750 000 kg of rain (750 tones)
5. The next step is to have students understand that there are large volumes of water that need to infiltrate the surface. On average, the infiltration rate for naturally vegetated ecosystems with uncompacted soils ranges from 377 to 634 mm hr, and on compacted soils it averages 160 to 188 mm hr. Urban areas consist of compacted soils and paved surfaces. On paved surfaces there is no

infiltration, only surface runoff. This runoff carries with it chemicals and sediments in its path. The students must then ask themselves a few questions:

- Where does the water go, when it leaves the school grounds?
- How much of this percolates through the surface?
- What possible kinds of pollutants does this rainfall come into contact with?
- Where is the nearest wildlife habitat to the school?
- How do people use the water between the time it leaves the school grounds and arrives in the wildlife habitat?
- What are some of the positive and negative effects that the water may have on the environment at various points on its journey?

6. The next step is to find a topographic map of the area, and track the route that the runoff water may take, and to find the location of the stormwater sewers in the paving surrounding the school

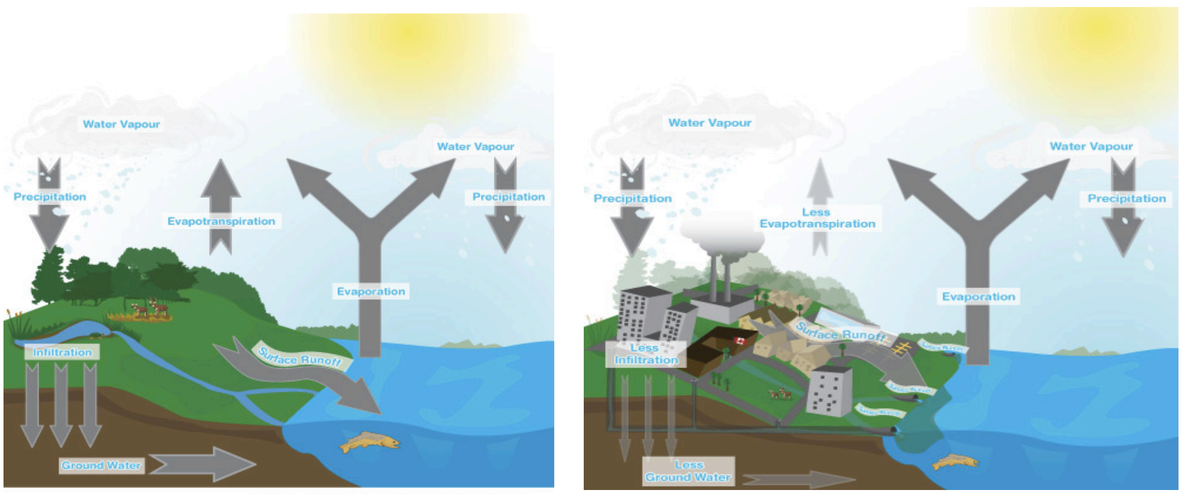

Figure 41. The difference between rural and urban water cycles. (Credit Valley Conservation,

<u>Activity Questions</u>

1. What happens to water collected in stormwater sewers? Will this water become drinking water in the future?
2. How will this water affect wildlife and aquatic ecosystems?

4.7 Review Questions

1. Define soils and name the variables by which they can be characterized.
2. Name the different soil horizons and describe them.
3. Explain the three types of texture classes and describe them.
4. Discuss how soils are impacted by NPS pollution and how LID can mitigate these effects.

5.0 Wildlife

This section will discuss how NPS pollution and LID affect wildlife and the relationships between these concepts. This section will focus on bioaccumulation, food webs, and how pollutants move through wildlife populations.

At the end of this section, students should be able to do the following:

- Understand and describe what an animal's role is in a food web and what its niche and habitat are
- Identify ways that wildlife are impacted by NPS pollution
- Describe how LID practices improve wildlife habitat and populations

5.1 Introduction to Wildlife

Wildlife are an important aspect of ecosystems within Ontario and around the globe. The increasing absence of wildlife can be partially attributed to **habitat** degradation resulting from nonpoint source pollution. This can cause a cascade effect through ecological systems. Wildlife is generally viewed as a component of habitat, though it is more correct to view habitat as a component of wildlife. Wildlife is a valuable feature of environmental systems: they provide multiple ecological functions that support **trophic** structures in ecosystems, energy flows, **food webs** and **nutrient cycling**. As systems become more complex and diverse with associated **biodiversity** and **species richness** increases, the greater the effect NPS pollution has on the biodiversity and the health of an ecosystem. Low impact development is a solution to minimizing adverse effects of wildlife, species loss and environmental destruction.

5.2 Impacts of NPS Pollution on Wildlife

By understanding the effects of NPS pollution on wildlife, we can trace the probable contributors of these pollutants based on what we see happening in local wildlife. By analysing factors such as presence and absence of species, and population abundance and diversity both within and among species, can elucidate overall trends that allow us to better understand how to manage wildlife. Although the definition of NPS pollution is pollution of unknown origin, by understanding direct effects

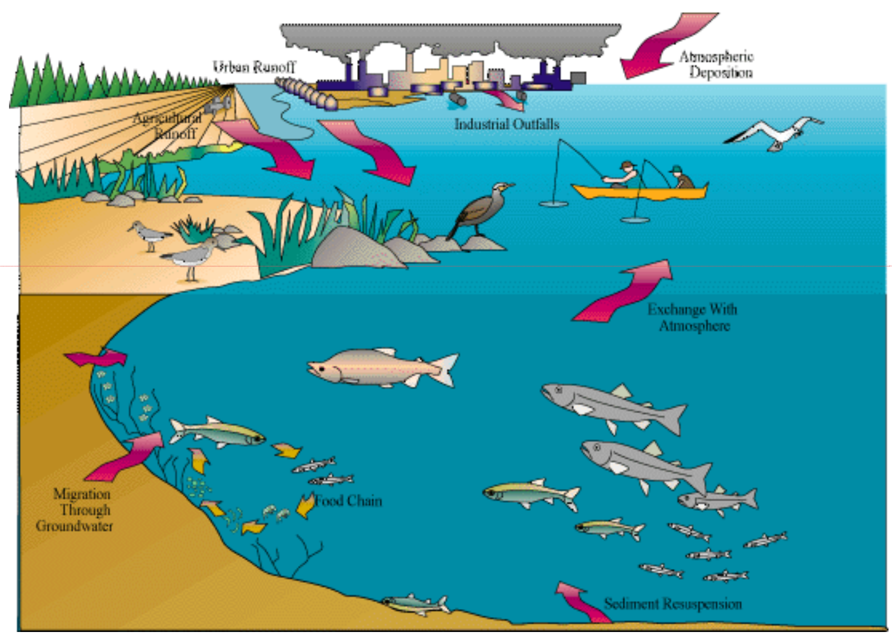

Figure 42. NPS pollution can come from many different sources (U.S. Environmental Protection Agency, 2008).

that specific pollutants have on wildlife it is possible to make conclusions about how NPS pollution works its way through populations. Human activities can cause a lot of problems:

- **Dredging** of rivers and streams causes sediment re-suspension and can lead to a release of mercury and PCB
- Atmospheric deposition of PCB's and phosphates impacts aquatic and terrestrial habitats
- Hydroelectric dams may cause erosion through increased water velocity
- Livestock and wildlife grazing can lead to an increase of nitrogen, phosphates and ammonia through an excess of manure or erosion or both
- Metal smelters (e.g. zinc, ore, etc.) can lead to water-borne heavy metals
- Agricultural runoff, farm effluents, **sheep dipping** practices, and other chemical use may lead to an increase of nitrogen and phosphates
- Urban, sewage and **grey water** runoff can also contribute to nitrogen and phosphates increases
- Mining and drill exploration and processing can introduce lead, heavy metals or PCB runoff

These contributors of NPS pollution are just a few among many, and they affect the condition of lakes, rivers, streams and other aquatic systems. This is water that wildlife depends on. Some wildlife are affected more than others, and the degree to which they are affected depends on the connection a particular species has to the pollutants. Will the effects be more direct or indirect?

5.3 Bioaccumulation

Toxins in contaminated water will affect different wildlife species differently. For example, in a river containing low-tolerant and high-tolerant aquatic **invertebrates**, alteration of the chemical quality of water allows only the high-tolerant species to survive or maintain natural cycles. These surviving species will also pick up toxins and pollutants, toxins that are then transferred to their **predators**. Factors such as the decreased biodiversity of that river and the increasing influence of high-tolerant species will affect higher trophic food chain levels. Predacious fish species, **amphibians**, birds (marsh and song birds) and **mammals** rely on the presence of contaminate-free aquatic invertebrates, as well as one another, for prey. Scientific evidence shows that even trace amounts of toxins consumed by wildlife can cause subtle effects on reproduction and development. In the short term these effects are unnoticeable, but in the long term these pollutants can have serious and damaging consequences. These can include irreversible damage on the immune system and nervous systems, impacted pre-natal and post-natal development, infertility, and the development of some cancers.

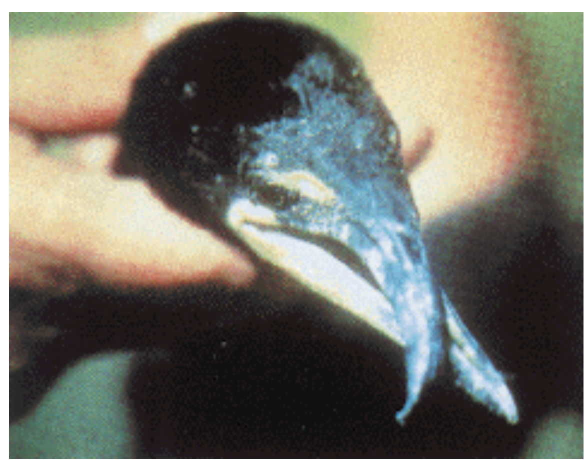

Figure 43. The crossed bill of this Cormorant is a possible affect of food chain contamination of lake ecosystems. (U.S. Environmental Protection Agency 2008).

5.4 Vertical Transmission

Another issue with wildlife and NPS pollution is the vertical transfer of toxins. For example, female eagles can pass on pollutants to their offspring as they develop through their unlaid eggs. If the female adult eagle has directly come into contact with contaminated fish prior to egg-laying, contaminants will directly effect unhatched chicks, which will then be subject to birth defects. The cascade effects of pollution have direct connections to wildlife's relationship with fresh water.

5.5 Specific Effects of NPS Pollution on Wildlife

Each pollutant can have different effects on wildlife and ecosystems. Examples of these effects include the following:

- Acid rain resulting from atmospheric pollution destroys fish life in aquatic systems
- Nutrient pollution such as phosphates and nitrogen causes intensified growth of aquatic vegetation and toxic algae; this excess growth chokes the life from the aquatic system by decreasing oxygen and increasing outbreaks of disease
- Chemical contamination such as oil can negatively influence development of aquatic organisms; stress and weaken immune systems allowing susceptibility to disease; cause damage to a number of body systems like the reproductive and nervous systems; and cause gastrointestinal irritation and liver and kidney damage
- PCB contaminants such as mercury can negatively impact behaviour, growth and development, alter or destroy reproduction, and cause death
- Fertilizers and pesticides can cause abnormal fish habits, physical characteristics and death
- High amounts of salt can also be lethal

Figure 44. Wildlife taking advantage of low impact development, a Killdeer perched on a green roof (Greenroofs.com, 2010).

5.6 How LID Helps Wildlife

LID designs can be as simple as maintaining open green spaces. Vegetation and **green infrastructure** (forests, shrub and grasslands) occur naturally and help prevent stormwater runoff and the associated negative consequences of NPS pollution. If urban green space is extensive enough and is maintained, these healthy habitats will buffer physical and chemical pollution, both directly and indirectly benefiting wildlife.

NPS pollution may not have immediate, visible effects on wildlife (unlike more noticeable effects on soils or aquatics), but they will become apparent over time. This delayed relationship is similar with the positive effects of LID: cascade ripple effects are also not instantaneous and generally occur over time. Ultimately, LID is a partial solution in offsetting the harmful impacts caused by NPS pollution. The overall goal of LID is not only reduce pollution but to create greener spaces on a larger scale, and this healthier habitat would encourage wildlife to flourish.

5.7 Case Study: Presence of Wildlife Increases with the Development of Urban Green Space

Sustainable urban settings often include functioning areas of green space to maintain ecological integrity within towns and cities. Orebro, a town in Sweden, measured bird diversity in order to understand how different types of urban green spaces were used by wildlife in different areas of the city. These urban areas were categorized into four sections: city centre, residential, green way and **urban periphery**. Within each section, the bird species found in each were categorized into biological groups with decreasing degree of **specialization** - for example, woodpeckers, hole-nesters, forest birds and urban birds.

After all the data had been collected and analyzed, researchers found that there was a lower bird species richness in the city interior and residential areas compared with the greenway and urban periphery. However, with the creation of more green spaces, over time the more specialized bird species increased in numbers in the city interior. These increases correlated with increased tree densities and natural vegetation in the city core. Overall, the bird populations increased in the city centre as the vegetation cover increased.

<u>Case Study Questions</u>

1. In your opinion, why would using a variety of natural vegetation types in an urban setting increase ecological integrity?
2. What are some of the other benefits of increasing the amount urban green space?
3. Do you think that urban green spaces are a good way to provide **ecological integrity** in a city? And if so, should towns and cities be increasing there own urban green spaces? How would they do this?

5.8 Activity: Planning for Healthy People, Wildlife and Communities
Adapted from Project WILD

The goal of this activity is to help students understand the importance of land use planning in an urban setting, and to recognize the negative influences that pollution has on wildlife and the urban ecosystem. The activity will explore how to improve wildlife impacts by designing an environmental and socially sustainable community though proper land use planning.

Methods

Students are asked to visualize and research the community where they live, and what it was like before development took place. Four types of pollutants are introduced, and once their characteristics are understood, students will design planned sustainable communities that deal with the effects of these pollutants.

Background

Generally cities develop over time with little thought of community functions and future issues. They form from this way to satisfy a communities notion of basic needs and dependencies, which include: food, shelter, transportation, trade, and a sense of solidarity amongst citizens. Although communities and cities do meet these needs, they also contribute to high population densities and an interruption of ecosystem integral functions. Unfortunately, for these reasons urban areas contribute to the presence, increase and transportation of pollutants. These are pollutants that fall into the following four categories:

- Chemical Pollution
- Thermal Pollution
- Organic Pollution
- Ecological Pollution

Figure 45. Water drains into a local waterway (Facts About Water Pollution. 2011).

It is this pollution that infiltrates the basic cycles of ecosystems, entering and disrupting waterways, degrading the state of and interconnectedness of water. Every day water continues to be polluted, which sometimes stresses ecosystems and wildlife habitats to the point where they cannot support life.

Other impacts of unplanned urban development can include: an increase in crime and unemployment, poor housing, smog, contamination of water supplies by industrial and sewage waste disposal, and increased energy consumption and transportation costs. Urban sprawl is among major issues facing Ontario's cities and towns. We need to make some the ethical decisions and ask questions when developing land-use plans. This must be done whether redeveloping old cities or building new communities. Students are asked to take into consideration the benefits of LID and naturalized vegetated land, and how both can provide essential services that can reduce pollution and minimize ecological and human heath issues, while maintaining an environmental and socially sustainable community.

Recommended Materials

For the Models (recommendations)

- Heavy cardboard or masonite, salt clay for model building (salt, flower and water to make salt clay, glue, toothpicks, natural materials (dried grass, twigs, etc.), construction paper, tempera paint and brushes, etc.

For the Visual Drawing (recommendations)

- Large-scale paper or bristle board, pencils and erasers (rough sketching), straight-edge rulers, drafting triangles, colouring materials (pencil crayons, markers, paint, etc.)

Procedure

1. Students are asked to visualize a large community or city they live in or near, and what it looks like. Then get them to imagine what the natural area would have looked prior the urban development. This includes the type of vegetation, terrain geography, wildlife, and water systems (creeks, rivers or lakes).
2. The next step is to research these details. As a group, the students are to report back with visual and verbal descriptions, and share their research (vegetation types, wildlife, food and water sources that wildlife depend on). The goal is that everyone involved in this activity will get a realistic perspective of the natural ecosystem that once existed in their area.
   (Research sources can include provincial, regional, city or county historical societies, libraries, etc. City, regional and provincial land-use planning offices may also have such information)
3. What are the four major categories of pollution? Discuss each and how these pollutants can affect the health of wildlife, humans, and ecosystems.
4. Divide into smaller groups of 2–4 students. Each group is to develop a community in the naturalized area, which reflects the referenced research compiled by the whole group. When planning a design for the community the students should aim to develop a community in where people live and work with the least possible negative impact on the existing vegetation, air quality, water, soil and wildlife. At the same time these communities should strive to meet the social needs of the people in the community. Be mindful of the four pollutants, and their sources and effects. A number of considerations must be met:
   - Water sources, including the transportation and treatment of water
   - Economic base: e.g., industry, small business
   - Kinds of housing, school, shopping areas, jobs sites
   - Ecological and recreational features: e.g., open space, green belts, parks
   - Sewage and water and trash disposal
   - Aesthetics
   - Environmental safe guards (buffers, river riparian zones, green roofs)
   - Renewable energy
   - Other criteria as brainstormed by students

5. Once each group has come up with a community design plan, discuss their plan with them.
6. After the design plans have been approved, supply the groups with necessary materials to visually draw/draft or construct a scale model. (See recommended materials)
7. After community design models are completed, allow group to explain the design features of their community. Discuss the positives and negatives of the design models in detail. Include such questions as "What actions have you taken to reduce the spread of pollution contamination caused

by waste produced by this particular community?" and "If there is a severe winter or drought, would it be necessary to take special measures to assist the wildlife?"

8. After a week or so has passed, ask the groups if they had to live in the communities they designed, would they go about changing any of its aspects of it.
9. Ask a local architect, city planner, wildlife biologist or other resource manager to visit the whole group, in order to review and discuss the various model communities with the groups who designed them.

Case Study Questions

1. What do you think are the most important considerations in urban planning when considering wildlife?
2. Does your community have any LID or green practices in place to reduce NPS pollution or create habitat for wildlife?

Figure 46. Fish killed due to polluted water (Facts about Water Pollution, 2011).

5.9 Review Questions

1. How does NPS pollution affect wildlife? Give specific examples.
2. Give examples of human practices than create pollution than harms wildlife.
3. What is bioaccumulation? How does it impact species and food webs?
4. List some effects of specific pollutants on wildlife.
5. Give one example of a LID practice that benefits wildlife and discuss it in detail.

6.0 NPS Pollution and LID Throughout Ontario

Toronto has approximately 135 green roofs constructed that make up more than 36,517 m^2. These green roofs are built on both privately or publicly owned buildings. These building can be residential, commercial, and even institutional. A good example of a green roof in Toronto is the York University green roof, which was installed in 2001 and is approximately 20,175 ft^2. It is located on the Computer Science and Engineering building.

Figure 47. Green roof on Computer Science and Engineering building at York University (City of Toronto, 2011c).

The RiverSides organization in Toronto runs the Water in the City Walk. The walk is a self-guided tour around Toronto that teaches you about how rainfall travels from where it lands to Lake Ontario. Along the way it explains road runoff and combined sewer overflows. It also talks about how you can reduce the amount of runoff from your home by implementing strategies like rain barrels and permeable surfaces.

In Windsor, Ontario they have a downspout disconnection program where the city will disconnect your downspout for free. This water can then be used for watering gardens and lawn care. A rain barrel pilot project was also created in Windsor in 2008 to determine the benefits of using a rain barrel. The study is being conducted in an area where basement flooding is high. Some 250 homes are part of the project.

Sudbury has initiated many objectives aiming to reduce the amount of wastewater and runoff, one of them being to encourage residents to use rain barrels to reduce runoff. In 2009, the city hosted a one-day rain barrel sale so residents could purchase a 208 L barrel for $49. Sudbury also wants to reduce contaminated runoff into lakes. Science North and the City of Greater Sudbury worked together to develop a shoreline demonstration to promote shoreline stewardship practices. JL Richards & Associates designed the Vale Inco Living with Lakes Centre to manage stormwater before it enters into Ramsey Lake. The stormwater management system for the centre incorporates many LID practices such as permeable pavements, bioswales, a retention pond and an oil and grit separator.

Figure 48. Green roof on the Canadian War Museum (Canadian Museum of Civilization Corporation, 2009).

Ottawa has one of the largest green roofs in North America that is 10, 684m^2. This green roof sits on top of the Canadian War Museum and is covered in a natural tall grass species that is found along the Ottawa River. The roof is a self sustaining ecosystem that needs little maintenance in fact the plants on the green roof clean in the environment around the building by reducing the amount of smog in the air and by reducing the amount of runoff. With the roofs 300 millimetre mix of soil and retention board the green roof can hold up to 720,000 litres of rain water.

7.0 Conclusion

As you have read this study guide you now know that nonpoint source pollution can affect aquatics, forests, soils and wildlife in a very negative way. Some examples of the consequences of NPS pollution include having polluted stormwater enter into rivers and contaminating the water for fish and other wildlife, or having soils being eroded from river banks and from tree roots, killing trees. You have also learned that these processes can be minimized or even eliminated through the employment of LID best management practices. Many of these strategies are urban-based, such as green roofs and permeable pavements, but others can be rural such as rain barrels that collect water for gardening and other lawn maintenance. With the use of these strategies and through public education and awareness programs about what NPS pollution and LID are, the amount of this kind of pollution can be greatly reduced.

Conventional forms of development can have adverse effects on the environment; however, local decision-makers and community members have the power to choose how they develop and can take measures to offset these impacts through the use of LID practices. Through the use of natural resource planning and site design in new development, stormwater can not only be managed to have neutral effects on waterways but can actually used to enhance natural features.

7.0 Glossary

Amphibians - A cold-blooded vertebrate that spends some time on land but must breed and develop into an adult in water. Frogs, salamanders, and toads are amphibians.

Aquatic Ecosystem - A localized group of interdependent organisms together with the environment that they inhabit and depend on, relating to or involving water.

Bedrock - The solid rock that underneath all the soil horizons, or that is exposed at the surface.

Benthic - Relating to or characteristic of the bottom of a lake, or deep river, or the animals and plants that live there.

Berms - A natural ridge or flat platform.

Bioaccumulation - The accumulation of a harmful substance such as a radioactive element, a heavy metal in an organism, especially an organism that forms part of the food chain.

Biodiversity - The variety of different types of plant and animal life in a particular region.

Bioindicator - A biological indicator of the well-being or abundance of an organism, which is then used to describe the quality of the ecosystem; also, an organism used as such an indicator.

Biology specialization - An organism or a part of an organism that has been adapted to a specific function or condition.

Bioretention areas - Process in which contaminants and sedimentation are removed from the storm water runoff.

Brunisolic Soil - Brown coloured soils with a low clay content and a higher sand content. They are often found to be slightly acidic and are found in areas of mixed forest (both coniferous and deciduous trees).

Buffer Zone – A designated area that protects something against impact, or reduce the shock of an impact.

Calcareous Soil - Calcium rich soil that contains a majority of carbonates ($CaCO_3$).

Carbon Sink - Anything that absorbs more carbon that it releases.

Cascade - A succession of things such as chemical reactions or components in an electrical circuit, each of which activates, affects, or determines the next.

Channelization - The straightening of streams and rivers to reduce meandering sequences and increase the flow of water

Chemical Pollution - The introduction of toxic substances into an ecosystem.

Chernozemic Soil - This is soil with a darker A horizon, and are rich with organic matter. Found mainly in grassland and prairie areas.

Cryosolic Soil - This is soil found in regions of Canada that experience permafrost (soil that remain at or below 0^oC throughout the year), and are composed mainly of peat.

Ecological functions - Relating to living organisms that serve as an action or use for which something is suited or designed.

Ecological integrity - Relating to the environment and the way that plants, animals, and humans live together and affect each other in a state of being sound or undamaged.

Ecological Pollution - Pollutants which are stresses ordinarily created by natural processes. This can include adding a naturally occurring substance that is not a normally present in a particular ecosystem. Ex. Extreme tides can introduce saltwater into habitats ordinarily protected from seawater.

Effluent - Sewage or other liquid waste that is discharged into a body of water.

Erosion - Erosion refers to the wearing away of the surface of the earth by running water, wind, or ice. ex. acid rain, contamination of water supplies by pesticides, etc.

Eutrophication - The process by which a body of water becomes rich in dissolved nutrients from fertilizers or sewage, thereby encouraging the growth and decomposition of oxygen-depleting plant life and resulting in harm to other organisms.

Evapotranspiration - Evaporation and transpiration; the process by which plants release water they have absorbed into the atmosphere

Exotic Species - Any specie intentionally or accidentally introduced to an area outside of its present range

Fertility - The ability to produce offspring, especially in large numbers.

Food-web - The interlocking food chains within an ecological community.

Forbs - Any broad-leaved herbaceous plant that is not a grass.

Forest Regeneration- To redevelop a forest, or to bring back to its original state.

Gley Soil - Soil that forms in waterlogged soils, and is indicated by grey colours, and mottles.

Gleying - The tendency of soil forming in wet anaerobic conditions to turn grey in colour

Gleysolic Soil - This is soil that forms in the continued presence of water and an absence of oxygen. It is usually composed mainly of clay and can be blue to grey in colour.

Green Infrastructure - A building, bridge, framework, or other object that has been put together from many different parts and was produced in an environmentally and ecologically friendly way, e.g. by using renewable resources.

Grey Water - Waste water that can be reused for some purposes without purification, e.g. bath water, which can be used to water plants.

Gullies - A channel or small valley, especially one carved out by persistent heavy rainfall.

Habitat - The natural conditions and environment in which a plant or animal lives, e.g. forest, desert, or wetlands.

High tolerant - Able to physically put up with harsh conditions or treatment in relation to water quality.

Horizon - A layer of soil or soil material approximately parallel to the surface. It differs from other layers in properties such as colour, structure, texture, consistence, and chemical, biological, and mineralogical composition.

Humus - The fraction of soil organic matter that remains after most of the added plant and animal residues has decomposed. It is usually dark brown in colour.

Infiltration Rates – The time and speed it takes to pass through a substance by filtration, or make a liquid or gas pass through a substance by filtration.

Invertebrates - An animal that does not have a backbone, e.g. an insect or worm.

Low Impact Development - Describes those practices that minimize the effects of nonpoint source pollution through site design and planning

Low Tolerant - Unable to physically put up with harsh conditions or treatment in relation to water quality.

Luvisolic Soil - Luvisolic soils are found in forested ecosystems and have a sandy to silty A horizon, a B horizon that has a higher clay content, and a C horizon rich in calcium carbonate. It is greyish in colour.

Macroinvertebrates - Macroinvertebrates or benthos are large, bottom-dwelling organisms such as worms, crustaceans, caddis fly larva, may fly larva, etc.

Macrophte - An aquatic plant that grows in or near water, they can be emergent, submergent or floating.

Mammals - A class of warm-blooded vertebrate animals that have, in the female, milk-secreting organs for feeding the young. The class includes human beings, apes, many four-legged animals, whales, dolphins, and bats.

Metabolic - Relating to or typical of metabolism.

Microorganisms - A tiny organism such as a virus, protozoan, or bacterium that can only be seen under a microscope.

Moisture - Water contained in the soil.

Mottles - Spots or blotches of different colour or shades of colour interspersed with the dominant colour. They indicate poor drainage.

Nonpoint Source Pollution - Pollution that collects from diffuse sources and runs into water bodies after rain and snowmelt

Nutrient Cycling - A constant reciprocating flow of food substance needed for living and growing.

Nutrient Load - Nutrient load refers to any dissolved nutrients in a body of water. They are usually nitrogen compounds.

Organic Pollution - Pollutants originating from natural sources, such as effluent from manure. These pollutants can increase the drastically increase the nutrient load in aquatic ecosystems or introduce bacteria to human drinking water.

Organic Soil - The organic fraction of the soil; includes plant and animal residues at various stages of decomposition, cells and tissues of soil organisms.

Parent Material - The unconsolidated and chemically-weathered mineral or organic matter from which the horizon of a soil has developed.

Percolation - The downward movement of water through soil; specifically, the downward flow of water in saturated or nearly saturated soil.

Periphyton - Sessile organisms, such as algae and small crustaceans, which live attached to surfaces projecting from the bottom of a freshwater aquatic environment.

Photosynthesis - A process by which green plants and other organisms turn carbon dioxide and water into carbohydrates and oxygen, using light energy trapped by chlorophyll.

Podzolic Soil - Podozolic soil is soil found primarily in the Canadian Shield, and is acidic in nature. The A horizon is high in sand content and is light grey; it has a reddish brown B horizon.

Pore Space - The total space not occupied by soil particles in a volume of soil.

Post-natal - Occurring or existing after birth.

Precipitation event - When it rains or snows.

Predate - The capturing of prey as a means of maintaining life.

Predators - A carnivorous animal that hunts, kills, and eats other animals in order to survive, or any other organism that behaves in a similar manner.

Pre-natal - Occurring or existing before birth.

Primary Producers - Any green plant or any of various microorganisms that can convert light energy or chemical energy into organic matter.

Profile (of Soil) - A vertical section of the soil through all its horizons and extending into the parent material.

Regosolic Soil - This soil occurs throughout Ontario, but is never the dominant soil type. Regosolic soils are found in landscapes experiencing high erosion such as floodplains or agricultural areas.

Reproduction - The production of offspring or new individuals through a sexual or asexual process.

Rills - To form small channels in a ploughed field as a result of the runoff of rainwater.

Riparian Zone - Area is the interface between land and a river or stream.

Salinization - The process through which systems accumulate soluble salts.

Sedimentation - Sedimentation occurs when soil becomes suspended in moving water but fall out of suspension when the water stops moving, or are trapped out of suspension by a barrier (such as tree roots or other plant material).

Sediments - Sediments are soil particles that are suspended in water**.**

Sheep dipping – The process by which sheep are dipped into liquid disinfectant to destroy parasites and to clean their wool, especially before shearing.

Soil - The unconsolidated material on the immediate surface of the earth that serves as a natural medium for the growth of plants.

Soil Profile - A vertical section of the soil through all its horizons and extending into the parent material.

Soil Texture - The relative proportions of the various soil particle sizes in a soil.

Solonetzic Soil - A hard soil rich in clay and found in the Prairies, but have a higher content of sodium than vertisolic soil.

Species Richness - Diversity is an index that incorporates the number of species in an area and also their relative abundance.

Strip-cropping - The growing of different crops on alternate strips of ground that usually follow the contour of the land, recourse to minimize erosion.

Symbiotic - A close association of animals or plants of different species that is often, but not always, of mutual benefit.

Thermal Pollution - When water of a different temperature (above or below the normal condition) is introduced into an aquatic ecosystem. For example, power plant turbines need water to cool them, and this newly heated water is then introduced into a natural system, and this drastic alteration in water temperature can disrupt the cycles of aquatic organisms.

Trophic - Relating to the nutritive value of food.

Turbidity - The cloudiness or haziness of a fluid caused by individual particles that are generally invisible to the naked eye, similar to smoke in air.

Understory Vegetation - Area of a forest that grows at the lowest height level below the forest canopy.

Urban Heat Island Effect - Is a metropolitan area that is significantly warmer than its surrounding rural areas.

Vector - To transmit from one organism to another.

Vertical Transmission - The biological transfer of pathogens or toxins to offspring via maternal connection.

Vertisolic Soil - Soil rich in clay, and found mainly in the Prairies.

Watershed - The land area that drains into a particular lake, river.

Windthrow - Refers to trees uprooted or broken by wind

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