Key Topic #2: NPS in a Growing World and Your Role in It

Learning Objectives

1. **Explain** how population growth, urban expansion, and agricultural intensification contribute to increased non-point source pollution globally and locally.
2. **Compare** the effects of land use types (e.g., urban, suburban, agricultural) on runoff volume and pollutant loading.
3. **Identify** common products or practices in daily life that contribute to non-point source pollution through indirect pathways (e.g., fertilizers, car washing, pet waste).
4. **Illustrate** the concept of a personal environmental footprint as it relates to NPS pollution, using tools such as footprint calculators.

Land Use

What are the trends in land use and their effects on human health and the environment?

- Definition of Land Use
- Effects of Land Use Changes
- ROE Indicators

Definition of Land Use

"Land use" is the term used to describe the human use of land. It represents the economic and cultural activities (e.g., agricultural, residential, industrial, mining, and recreational uses) that are practiced at a given place. Public and private lands frequently represent very different uses. For example, urban development seldom occurs on publicly owned lands (e.g., parks, wilderness areas), while privately owned lands are infrequently protected for wilderness uses.

Land use differs from land cover in that some uses are not always physically obvious (e.g., land used for producing timber but not harvested for many years and forested land designated as wilderness will both appear as forest-covered, but they have different uses).

Effects of Land Use Changes

Land use changes occur constantly and at many scales, and can have specific and cumulative effects on air and water quality, watershed function, generation of waste, extent and quality of wildlife habitat, climate, and human health.

EPA is concerned about different land use activities because of their potential effects on the environment and human health. Land development and agricultural uses are two primary areas of concern, with a wide variety of potential effects.

Land Development

- Land development creates **impervious surfaces** through construction of roads, parking lots, and other structures. Impervious surfaces:
  - Contribute to nonpoint source water pollution <https://epa.gov/nps/basic-information-about-nonpoint-source-nps-pollution> by limiting the capacity of soils to filter runoff.
  - Affect peak flow and water volume, which heighten erosion potential and affect habitat and water quality.
  - Increase storm water runoff, which can deliver more pollutants to water bodies that residents may rely on for drinking and recreation.[1] Storm runoff from urban and suburban areas contains dirt, oils from road surfaces, nutrients from fertilizers, and various toxic compounds.
  - Affect ground water aquifer recharge.
- **Point source discharges** from industrial and municipal wastewater treatment facilities can contribute toxic compounds and heated water.
- Some **land development patterns**, in particular dispersed growth such as "suburbanization," can contribute to a variety of environmental concerns. For example:
  - Increased air pollution due to vehicle use results in higher concentrations of certain air pollutants in developed areas that may exacerbate human health problems such as asthma.[2]
  - Land development can lead to the formation of "heat islands," domes of warmer air over urban and suburban areas that are caused by the loss of trees and shrubs and the absorption of more heat by pavement, buildings, and other sources. Heat islands can affect local, regional, and global climate, as well as air quality.[3]

Agricultural Uses

- Agricultural land uses can affect the **quality of water and watersheds**, including:
  - The types of crops planted, tillage practices, and various irrigation practices can limit the amount of water available for other uses.
  - Livestock grazing in riparian zones can change landscape conditions by reducing stream bank vegetation and increasing water temperatures, sedimentation, and nutrient levels.
  - Runoff from pesticides, fertilizers, and nutrients from animal manure can also degrade water quality.
- Agricultural land use may also result in **loss of native habitats** or increased wind erosion and dust, exposing humans to particulate matter and various chemicals.[4]
- Some land uses can accelerate or exacerbate the **spread of invasive species**. For example:
  - Certain agricultural land use practices, such as overgrazing, land conversion, fertilization, and the use of agricultural chemicals, can enhance the growth of invasive plants.[5] These plants can alter fish and wildlife habitat, contribute to decreases in biodiversity, and create health risks to livestock and humans.
  - Introduction of invasive species on agricultural lands can reduce water quality and water availability for native fish and wildlife species.

Research is beginning to elucidate the connections between land use changes and infectious disease. For example, some studies indicate that spread of vector-borne disease may be influenced by land use and/or other environmental change.[6]

Other studies indicate that fragmentation of forest habitat into smaller patches separated by agricultural activities or developed land increases the “edge effect” and promotes the interaction among pathogens, vectors, and hosts.[7]

In some cases, changes in land use may have positive effects, such as increasing habitat (as a result of deliberate habitat restoration measures) and reclamation of previously contaminated lands for urban/suburban development.

ROE Indicators

The ROE presents two indicators providing information about land use trends: Land Use and Urbanization and Population Change. Available indicators in this area are limited because numerous circumstances (including lack of data; varying approaches to data classification and management, and difficulty in delineating land use) create significant challenges and limitations in tracking trends in and effects of land use.

- **Lack of data:**
  - No indicators are available to assess the effects that trends in land use have on human health, as effects have not been shown or quantified on a national basis. Researchers have conducted site-specific studies on individual land uses, but little is known about overall national trends in land use and potential impacts on human health.
  - An additional challenge is that a variety of state and local laws, regulations, and practices govern the use of land. There are few state-level efforts to organize land use data; most activities occur over specific local, usually urbanizing, geographic areas.

    This means that land use records are not maintained statewide or nationally, as they are in other nations. This contributes to challenges in tracking and monitoring land use changes. It also means that efforts to coordinate land use across jurisdictions are difficult to develop.

- **Varying approaches to data classification and measurement:** Estimates of the extent of various land uses differ across data sources, and each source uses different classifications, measurement approaches, methodologies for analysis and interpretation, and sampling time frames. The data are collected by many different agencies that manage land for many different purposes.

  Some data collection efforts arise out of specific interests, such as tracking changes in the extent of agricultural land or farmland, or understanding how much land is used for timber production. These data collection efforts tend to develop their own classifications and categorization, making it difficult to integrate the data over time, across inventories, or as a national picture.

- **Difficulty in delineating land use:** Finally, the difficulty of actually delineating land use presents a challenge in developing data to determine trends. Land use is generally a function of laws, policies, or management decisions that may not always be possible to infer by examining the ground via surveys. Analysis of zoning maps or property records at the local level may be necessary to understand land use.

EPA
United States
Environmental Protection
Agency

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Protecting Water Quality *from* Urban Runoff

Clean Water Is Everybody's Business

In urban and suburban areas, much of the land surface is covered by buildings and pavement, which do not allow rain and snowmelt to soak into the ground. Instead, most developed areas rely on storm drains to carry large amounts of runoff from roofs and paved areas to nearby waterways. The stormwater runoff carries pollutants such as oil, dirt, chemicals, and lawn fertilizers directly to streams and rivers, where they seriously harm water quality. To protect surface water quality and groundwater resources, development should be designed and built to minimize increases in runoff.

The most recent National Water Quality Inventory reports that runoff from urbanized areas is the leading source of water quality impairments to surveyed estuaries and the third-largest source of impairments to surveyed lakes.

Did you know that because of impervious surfaces like pavement and rooftops, a typical city block generates more than 5 times more runoff than a woodland area of the same size?

How Urbanized Areas Affect Water Quality

Increased Runoff

The porous and varied terrain of natural landscapes like forests, wetlands, and grasslands traps rainwater and snowmelt and allows them to filter slowly into the ground. In contrast, impervious (nonporous) surfaces like roads, parking lots, and rooftops prevent rain and snowmelt from infiltrating, or soaking, into the ground. Most of the rainfall and snowmelt remains above the surface, where it runs off rapidly in unnaturally large amounts.

Storm sewer systems concentrate runoff into smooth, straight conduits. This runoff gathers speed and erosional power as it travels underground. When this runoff leaves the storm drains and empties into a stream, its excessive volume and power blast out streambanks, damaging streamside vegetation and wiping out aquatic habitat. These increased storm flows carry sediment loads from construction sites and other denuded surfaces and eroded streambanks. They often carry higher water temperatures from streets, roof tops, and parking lots, which are harmful to the health and reproduction of aquatic life.

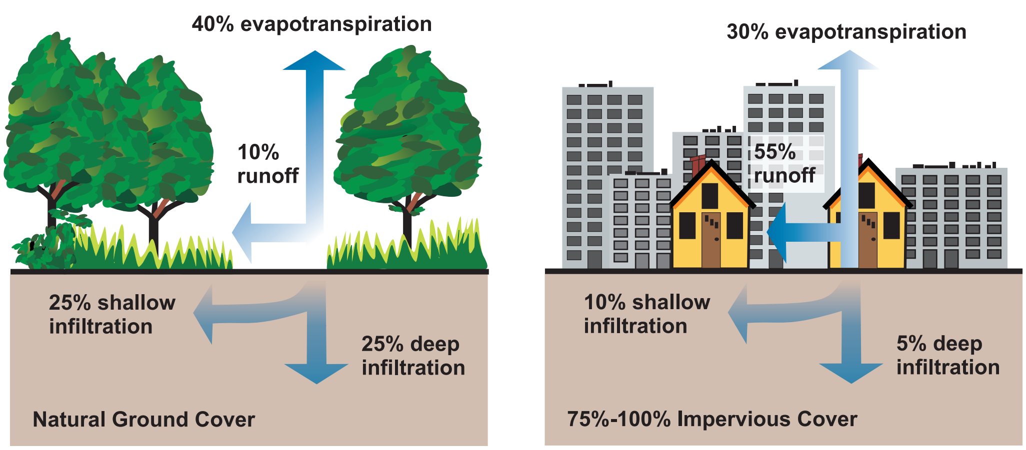
The loss of infiltration from urbanization may also cause profound groundwater changes. Although urbanization leads to great increases in flooding during and immediately after wet weather, in many instances it results in lower stream flows during dry weather. Many native fish and other aquatic life cannot survive when these conditions prevail.

Increased Pollutant Loads

Urbanization increases the variety and amount of pollutants carried into streams, rivers, and lakes. The pollutants include:

- Sediment
- Oil, grease, and toxic chemicals from motor vehicles
- Pesticides and nutrients from lawns and gardens
- Viruses, bacteria, and nutrients from pet waste and failing septic systems
- Road salts
- Heavy metals from roof shingles, motor vehicles, and other sources
- Thermal pollution from dark impervious surfaces such as streets and rooftops

These pollutants can harm fish and wildlife populations, kill native vegetation, foul drinking water supplies, and make recreational areas unsafe and unpleasant.



Relationship between impervious cover and surface runoff. Impervious cover in a watershed results in increased surface ruunoff. As little as 10 percent impervious cover in a watershed can result in stream degradation.

Managing Urban Runoff

What Homeowners Can Do

To decrease polluted runoff from paved surfaces, households can develop alternatives to areas traditionally covered by impervious surfaces. Porous pavement materials are available for driveways and sidewalks, and native vegetation and mulch can replace high maintenance grass lawns. Homeowners can use fertilizers sparingly and sweep driveways, sidewalks, and roads instead of using a hose. Instead of disposing of yard waste, they can use the materials to start a compost pile. And homeowners can learn to use Integrated Pest Management (IPM) to reduce dependence on harmful pesticides.

In addition, households can prevent polluted runoff by picking up after pets and using, storing, and disposing of chemicals properly. Drivers should check their cars for leaks and recycle their motor oil and antifreeze when these fluids are changed. Drivers can also avoid impacts from car wash runoff (e.g., detergents, grime, etc.) by using car wash facilities that do not generate runoff. Households served by septic systems should have them professionally inspected and pumped every 3 to 5 years. They should also practice water conservation measures to extend the life of their septic systems.

Controlling Impacts from New Development

Developers and city planners should attempt to control the volume of runoff from new development by using low impact development, structural controls, and pollution prevention strategies. Low impact development includes measures that conserve natural areas (particularly sensitive hydrologic areas like riparian buffers and infiltrable soils); reduce development impacts; and reduce site runoff rates by maximizing surface roughness, infiltration opportunities, and flow paths.

Controlling Impacts from Existing Development

Controlling runoff from existing urban areas is often more costly than controlling runoff from new developments. Economic efficiencies are often realized through approaches that target "hot spots" of runoff pollution or have multiple benefits, such as high-efficiency street sweeping (which addresses aesthetics, road safety, and water quality). Urban planners and others responsible for managing urban and suburban areas can first identify and implement pollution prevention strategies and examine source control opportunities. They should seek out priority pollutant reduction opportunities, then protect natural areas that help control runoff, and finally begin ecological restoration and retrofit activities to clean up degraded water bodies. Local governments are encouraged to take lead roles in public education efforts through public signage, storm drain marking, pollution prevention outreach campaigns, and partnerships with citizen groups and businesses. Citizens can help prioritize the clean-up strategies, volunteer to become involved in restoration efforts, and mark storm drains with approved "don't dump" messages.

Related Publications

Turn Your Home into a Stormwater Pollution Solution!
www.epa.gov/nps

This web site links to an EPA homeowner's guide to healthy habits for clean water that provides tips for better vehicle and garage care, lawn and garden techniques, home improvement, pet care, and more.

National Management Measures to Control Nonpoint Source Pollution from Urban Areas
www.epa.gov/owow/nps/urbanmm

This technical guidance and reference document is useful to local, state, and tribal managers in implementing management programs for polluted runoff. Contains information on the best available, economically achievable means of reducing pollution of surface waters and groundwater from urban areas.

Onsite Wastewater Treatment System Resources
www.epa.gov/owm/onsite

This web site contains the latest brochures and other resources from EPA for managing onsite wastewater treatment systems (OWTS) such as conventional septic systems and alternative decentralized systems. These resources provide basic information to help individual homeowners, as well as detailed, up-to-date technical guidance of interest to local and state health departments.

Low Impact Development Center
www.lowimpactdevelopment.org

This center provides information on protecting the environment and water resources through integrated site design techniques that are intended to replicate preexisting hydrologic site conditions.

Stormwater Manager's Resource Center (SMRC)
www.stormwatercenter.net

Created and maintained by the Center for Watershed Protection, this resource center is designed specifically for stormwater practitioners, local government officials, and others that need technical assistance on stormwater management issues.

Strategies: Community Responses to Runoff Pollution
www.nrdc.org/water/pollution/storm/stoinx.asp

The Natural Resources Defense Council developed this interactive web document to explore some of the most effective strategies that communities are using around the nation to control urban runoff pollution. The document is also available in print form and as an interactive CD-ROM.

For More Information

U.S. Environmental Protection Agency
Nonpoint Source Control Branch (4503T)
1200 Pennsylvania Avenue, NW
Washington, DC 20460
www.epa.gov/nps

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EPA United States Environmental Protection Agency

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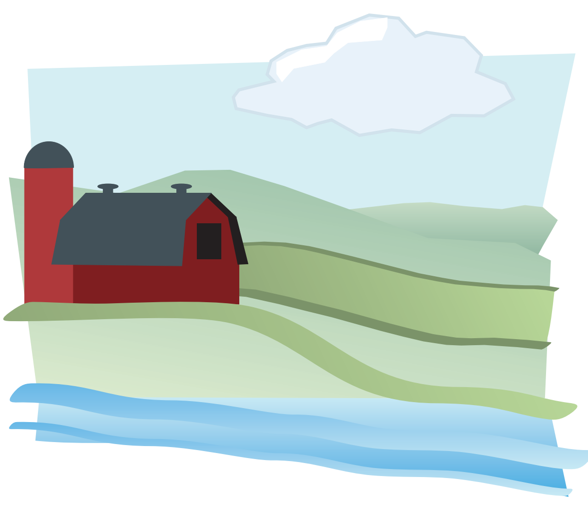
Protecting Water Quality *from* AGRICULTURAL RUNOFF

Clean Water Is Everybody's Business

The United States has more than 330 million acres of agricultural land that produce an abundant supply of food and other products. American agriculture is noted worldwide for its high productivity, quality, and efficiency in delivering goods to the consumer. When improperly managed however, activities from working farms and ranches can affect water quality.

In the 2000 *National Water Quality Inventory,* states reported that agricultural nonpoint source (NPS) pollution is the leading source of water quality impacts on surveyed rivers and lakes, the second largest source of impairments to wetlands, and a major contributor to contamination of surveyed estuaries and ground water. Agricultural activities that cause NPS pollution include poorly located or managed animal feeding operations; overgrazing; plowing too often or at the wrong time; and improper, excessive, or poorly timed application of pesticides, irrigation water, and fertilizer.

Pollutants that result from farming and ranching include sediment, nutrients, pathogens, pesticides, metals, and salts. Impacts from agricultural activities on surface water and ground water can be minimized by using management practices that are adapted to local conditions. Many practices designed to reduce pollution also increase productivity and save farmers and ranchers money in the long run.



What Is Nonpoint Source Pollution?

Nonpoint source (NPS) pollution, unlike pollution from point sources such as industrial and sewage treatment plants, comes from many diffuse sources. Polluted runoff is caused by rainfall or snowmelt moving over and through the ground. As the runoff moves, it picks up and carries away natural and human-made pollutants, finally depositing them into watersheds through lakes, rivers, wetlands, coastal waters, and even our underground sources of drinking water.

Did you know that runoff from farms is the leading source of impairments to surveyed rivers and lakes?

There are many government programs available to help farmers and ranchers design and pay for management approaches to prevent and control NPS pollution. For example, over 40 percent of section 319 Clean Water Act grants have been used to control NPS pollution from working farms and ranches. Also, many programs funded by the U.S. Department of Agriculture and by states provide cost-share, technical assistance, and economic incentives to implement NPS pollution management practices. Many local organizations and individuals have come together to help create regional support networks to adopt technologies and practices to eliminate or reduce water quality impacts caused by agricultural activities.

Sedimentation

The most prevalent source of agricultural water pollution is soil that is washed off fields. Rain water carries soil particles (sediment) and dumps them into nearby lakes or streams. Too much sediment can cloud the water, reducing the amount of sunlight that reaches aquatic plants. It can also clog the gills of fish or smother fish larvae. In addition, other pollutants like fertilizers, pesticides, and heavy metals are often attached to the soil particles and wash into the water bodies, causing algal blooms and depleted oxygen, which is deadly to most aquatic life. Farmers and ranchers can reduce erosion and sedimentation by 20 to 90 percent by applying management practices that control the volume and flow rate of runoff water, keep the soil in place, and reduce soil transport.

Nutrients

Farmers apply nutrients such as phosphorus, nitrogen, and potassium in the form of chemical fertilizers, manure, and sludge. They may also grow legumes and leave crop residues to enhance production. When these sources exceed plant needs, or are applied just before it rains, nutrients can wash into aquatic ecosystems. There they can cause algae blooms, which can ruin swimming and boating opportunities, create foul taste and odor in drinking water, and kill fish by removing oxygen from the water. High concentrations of nitrate in drinking water can cause methemoglobinemia, a potentially fatal disease in infants, also known as blue baby syndrome. To combat nutrient losses, farmers can implement nutrient management plans that help maintain high yields and save money on fertilizers.

Animal Feeding Operations

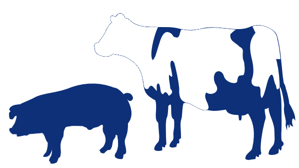
By confining animals in small areas or lots, farmers and ranchers can efficiently feed and maintain livestock. But these confined areas become major sources of animal waste. An estimated 238,000 working farms and ranches in the United States are considered animal feeding operations, generating about 500 million tons of manure each year. Runoff from poorly managed facilities can carry pathogens such as bacteria and viruses, nutrients, and oxygen-demanding organics and solids that contaminate shellfishing areas and cause other water quality problems. Ground water can also be contaminated by waste seepage. Farmers and ranchers can limit discharges by storing and managing facility wastewater and runoff with appropriate waste management systems.

Livestock Grazing

Overgrazing exposes soils, increases erosion, encourages invasion by undesirable plants, destroys fish habitat, and may destroy streambanks and floodplain vegetation necessary for habitat and water quality filtration. To reduce the impacts of grazing on water quality, farmers and ranchers can adjust grazing intensity, keep livestock out of sensitive areas, provide alternative sources of water and shade, and promote revegetation of ranges, pastures, and riparian zones.

Irrigation

Irrigation water is applied to supplement natural precipitation or to protect crops against freezing or wilting. Inefficient irrigation can cause water quality problems. In arid areas, for example, where rainwater does not carry minerals deep into the soil, evaporation of irrigation water can concentrate salts. Excessive irrigation can affect water quality by causing erosion, transporting nutrients, pesticides, and heavy metals, or decreasing the amount of water that flows naturally in streams and rivers. It can also cause a buildup of selenium, a toxic metal that can harm waterfowl reproduction. Farmers can reduce NPS pollution from irrigation by improving water use efficiency. They can measure actual crop needs and apply only the amount of water required. Farmers may also choose to convert irrigation systems to higher efficiency equipment.



Pesticides

Insecticides, herbicides, and fungicides are used to kill agricultural pests. These chemicals can enter and contaminate water through direct application, runoff, and atmospheric deposition. They can poison fish and wildlife, contaminate food sources, and destroy the habitat that animals use for protective cover. To reduce contamination from pesticides, farmers should use Integrated Pest Management (IPM) techniques based on the specific soils, climate, pest history, and crop conditions for a particular field. IPM encourages natural barriers and limits pesticide use and manages necessary applications to minimize pesticide movement from the field.

Farm Bill Conservation Funding

In May 2002 President Bush signed the Farm Bill, providing up to $13 billion for conservation programs for six years. This Farm Bill represents an 80 percent increase above current levels of funding available for conservation programs designed to prevent polluted runoff. For more information, visit www.usda.gov/farmbill.

Related Publications and Web Sites

National Management Measures to Control Nonpoint Source Pollution from Agriculture
epa.gov/nps/agmm

This technical guidance and reference document is for use by state, local, and tribal managers in the implementation of nonpoint source pollution management programs. It contains information on effective, readily available, and economically achievable means of reducing pollution of surface and ground water from agriculture.

Agricultural Nonpoint Source Pollution Management Web Site
epa.gov/nps/agriculture.html

This web site features a collection of links to helpful documents, federal programs, partnerships and nongovernmental orrganizations that convey advice and assistance to farmers and ranchers for protecting water quality.

National Agriculture Compliance Assistance Center
epa.gov/agriculture or call toll-free: 1-888-663-2155

EPA's National Agriculture Compliance Assistance Center is the "first stop" for information about environmental requirements that affect the agricultural community.

Animal Feeding Operations (AFO) Web Sites
AFO Virtual Information Center: epa.gov/npdes/afovirtualcenter
Overview of regulations and helpful links: epa.gov/npdes/afo

Funding Sources

Searchable Catalog of Federal Funding Sources for Watershed Protection
epa.gov/watershedfunding

Agricultural Management Assistance Database
www.nrcs.usda.gov/programs/ama

Clean Water Act Section 319(h) funding (epa.gov/nps/319hfunds.html) is provided to designated state and tribal agencies to implement approved nonpoint source management programs.

Environmental Quality Incentives Program (www.nrcs.usda.gov/programs/eqip) offers financial, technical, and educational assistance to install or implement structural, vegetative, and management practices designed to conserve soil and other natural resources.

Conservation Reserve and Conservation Reserve Enhancement Programs (www.fsa.usda.gov/dafp/cepd/default.htm) implemented by the U.S. Department of Agriculture provide financial incentives to encourage farmers and ranchers to voluntarily protect soil, water, and wildlife resources.

For More Information

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A regional examination of the footprint of agriculture and urban cover on stream water quality

Abstract and Introduction

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ABSTRACT

Freshwater systems in cold regions, including the Laurentian Great Lakes, are threatened by both eutrophication and salinization, due to excess nitrogen (N), phosphorus (P) and chloride (Cl^-) delivered in agricultural and urban runoff. However, identifying the relative contribution of urban vs. agricultural development to water quality impairment is challenging in watersheds with mixed land cover, which typify most developed regions. In this study, a self-organizing map (SOM) analysis was used to evaluate the contributions of various forms of land cover to water quality impairment in southern Ontario, a population-dense, yet highly agricultural region in the Laurentian Great Lakes basin where urban expansion and agricultural intensification have been associated with continued water quality impairment. Watersheds were classified into eight spatial clusters, representing four categories of agriculture, one urban, one natural, and two mixed land use clusters. All four agricultural clusters had high nitrate-N concentrations, but levels were especially high in watersheds with extensive corn and soybean cultivation, where exceedances of the 3 mg L^{-1} water quality objective dramatically increased above a threshold of ~30 % watershed row crop cover. Maximum P concentrations also occurred in the most heavily tile-drained cash crop watersheds, but associations between P and land use were not as clear as for N. The most urbanized watersheds had the highest Cl^- concentrations and expansions in urban area were mostly at the expense of surrounding agricultural land cover, which may drive intensification of remaining agricultural lands. Expansions in tile-drained corn and soybean area, often at the expense of mixed, lower intensity agriculture are not unique to this area and suggest that river nitrate-N levels will continue to increase in the future. The SOM approach provides a powerful means of simplifying heterogeneous land cover characteristics that can be associated with water quality patterns and identify problem areas to target management.

1. Introduction

Non-point sources of contaminants, including runoff from agricultural and urban landscapes, are the most common sources of water quality impairment globally (Patterson et al., 2013; Lintern et al., 2020). Of the many contaminants that are found in urban and agricultural runoff, phosphorus (P) and nitrogen (N, especially as nitrate-N; NO3-N), are two of the most reported chemicals that routinely exceed thresholds for the protection of water resources (Omernik et al., 2016; Powers et al., 2016; Abbott et al., 2018). Likewise, chloride (Cl^-) is frequently measured at concentrations that exceed guidelines for aquatic life in seasonally snow-covered regions where winter road salt is applied, and salinity levels that approach seawater have been reported in some systems (Dugan et al., 2017; Kaushal et al., 2021). While Cl^- enrichment of waterways is almost always attributed to an urban origin, attribution of the sources of N and P is often more difficult, especially in heterogeneous, mixed land use watersheds that dominate most developed areas of the world (e.g., Kandler ¨ et al., 2017; Zeiger and Hubbart, 2017; Xue et al., 2023). For example, P enrichment is common in both agricultural and urban runoff (Macintosh et al., 2018), with high P exports in urban areas attributed to their 'flashy' hydrology, which enhances erosional losses as well as multiple, P-enriched sources in urban landscapes (e.g., Winter et al., 2007; Duan et al., 2012). Likewise, elevated P losses from agricultural landscapes are associated with P enrichment of soil due to long-term fertilizer and manure inputs (Beaulac and Reckhow, 1982), with much of the P in agricultural streams present in the particulate form (Reid et al., 2018; Sandstrom ¨ et al., 2020). In contrast, N in agricultural runoff tends to be dominated by dissolved inorganic NO_3-N and is frequently associated with fertilized cropland (Beaulac and Reckhow, 1982; Stets et al., 2015; Liu et al., 2022); although some studies have reported high NO3-N levels in urban runoff as well (Yang and Lusk, 2018). Even Cl^- attribution is not always straightforward, as Cl− is a component of fertilizer (i.e., potash; KCl) and Cl− enrichment has been reported in agricultural drainage waters (David et al., 2015). These ambiguities in source attribution are problematic for water quality protection, as best management practices will only be effective if they target the correct source.

Further complicating water resource protection is the dynamic nature of human land use, with both urban expansion and agricultural intensification being the primary culprits for persistent water quality impairments in inland and coastal systems around the globe (Brooks et al., 2016; Paerl et al., 2018; Basu et al., 2022). Indeed, agricultural intensification has been associated with urbanization, since urban expansion often occurs at the expense of peripheral agricultural land, which puts pressure on remaining agricultural landscapes to produce more from less (Hofmann, 2001). As well, changes in agricultural management practices like tillage type, fertilizer application, tile drainage, and crop rotation affect the amounts and forms (dissolved vs. particulate) of P and N losses to waterways. For example, conservation tillage practices that minimize mechanical disturbance of surface soil are associated with declines in overland runoff as well as particulate P losses via erosion (Bundy et al., 2001). However, some studies have suggested that the absence of mechanical mixing, especially in fine textured soils where fertilizers are surface broadcast, may unintentionally enhance losses of NO_3-N and soluble reactive P (SRP) by allowing surface-enriched nutrients to leach from soils via macropores (e.g., cracks and biopores) that persist year-round and provide conduits for dissolved nutrients to bypass the soil matrix (Joosse and Baker, 2011; Jarvie et al., 2017). This is of particular concern in tile-drained croplands, where bypass flow has the potential to leach nutrients directly to drainage tiles from where they can be delivered relatively conservatively to downstream aquatic ecosystems (Williams et al., 2016).

As contaminants are generated from a wide range of human activities dispersed across extensive areas, non-point source pollution is difficult to monitor and control and the relative influence of major sources such as agriculture and urban land uses can be challenging to distinguish from each other (Eimers et al., 2020). Models are useful tools for disentangling the complex spatial relationships between water quality, land cover and land use, and can inform management efforts by identifying 'hot spots' of contaminant release to waterways. Many previous modelling studies have focused on broad land cover categories (e.g., total agriculture; Tran et al., 2010; Nielsen et al., 2012; Mooney et al., 2020), or have aggregated urban and agriculture together into a 'developed' land category (Basu et al., 2022). However, this can obscure many aspects of land use management and shifts over time that are important predictors of water quality. Furthermore, past approaches have relied on conventional statistical methods due to their simplicity, whereas more recent advances in artificial intelligence, such as machine and deep learning methods, have greatly expanded the potential for evaluating non-linear relationships between spatial land cover with water quality (Maier and Dandy, 2000; Basu et al., 2022). In particular, self-organizing maps (SOM), an unsupervised artificial neural network, have been effective for explaining water quality patterns associated with land use and socio-environmental management (Kim et al., 2016; Neumann et al., 2017; Zhang et al., 2018; Gu et al., 2019).

Here, we apply a SOM approach to evaluate the contributions of various forms of land cover to water quality impairment in southern Ontario, a population-dense, yet highly agricultural region in the Laurentian Great Lakes basin where urban expansion and agricultural intensification have been associated with continued water quality impairments in Lakes Ontario and Erie, respectively (Thomas et al., 2018; DeBues et al., 2019; Sorichetti et al., 2022). The frequently complementary relationship between urban expansion and agricultural intensification is not unique to this area and affects many developed regions around the globe (Bren d'Amour et al., 2017). As such, results from this study may be viewed as a harbinger of what might be expected in other regions. The overall objective of this analysis was to evaluate the contribution of different types of land cover (urban vs. agriculture), land use (e.g., row crop agriculture vs. pasture) and agronomic practices (e.

g., conservation tillage, tile drainage) to water quality impairment, to ultimately inform management practices. Relationships between stream NO_3-N with row crop agriculture and related land use practices (e.g., fertilizer and manure application, tile drainage) were predicted, even across a broad geographic scale due to the high solubility and mobility of

NO3-N and the strong influence of N inputs associated with row crop production. Agricultural watersheds with a greater proportion of livestock production were expected to have the highest TP concentrations, and both types of agricultural watersheds were expected to have higher N and P levels compared with urban watersheds. Lastly, as elevated Cl^- levels are commonly associated with de-icing activities, the enrichment

of streams with Cl^- was predicted to be pervasive across all types of watersheds due to the ubiquitous presence of roads; however, Cl^- concentrations were expected to be highest in the most urbanized watersheds with higher human population densities.

Calculating Stormwater and Nitrogen Loading Reduction/ Prevention

Pollution Load Estimation Tool (PLET) See PLET
PLET employs simple algorithms to calculate nutrient and sediment loads from different land uses, and the load reductions that would result from the implementation of various best management practices.

The tool employs simple algorithms to calculate:

- nutrient and sediment loads from different land uses, and
- the load reductions that would result from the implementation of various best management practices.

Pollutant Load Reduction Calculator
From New York State Department of Environmental Conservation (DEC) to ensure consistency when estimating potential load reductions for selected Best Management Practices. DEC has developed the Pollutant Load Reduction Calculator with accepted efficiencies for nitrogen and phosphorus for commonly implemented practices. The method used to estimate load reductions does not account for soil information, slope, or other site specific factors that may influence potential pollution reductions for a practice. This additional information would impact the practice efficiencies. All best management practices have been assigned the same efficiencies, based on the efficiencies in DEC's Stormwater Management Design Manual.

Model My Watershed See Model My Watershed
Model My Watershed can be used in several ways to address nitrogen and stormwater reduction. Numbers 1 & 3 are really easy and intuitive to use – they make it feasible to look any many options fairly quickly. Number 2 takes more work and knowledge but can give you more precise estimates.

1. Use the multi-year model for average annual loads of N, P and sediment. You can use the Infiltration/Bioretention practice, based on total acres of implementation in the selected watershed area.
2. If you want to get a little more sophisticated, you can utilize the "multi-year model worksheet", which is significantly more complicated, but allows more control and manipulation of the details of land use and bmp functions.
3. You can also use the "Site Storm Model" option. This tool is a hybrid of the SLAMM, TR 55, and STEPL models and is primarily used for smaller, more developed areas. The model allows you to outline specific BMP areas, using your mouse, these include rain gardens, porous paving, green roof, vegetated basin, etc. The model also allows you to model changes to land cover, including assorted densities of development, forest, grassland, etc. The site storm model allows you to look at the impacts of different storm events (i.e. ½ inch rainfall vs 2 inch rainfall vs 5 inch rainfall) in different development or BMP scenarios. This tool provides outputs for the different storm events rather than the annual load estimates predicted by the multi-year model.

Calculating Pollution Prevent and Reduction from Tree Planting

US Forest Service i-Tree. See: MyTree calculator

The University of New Hampshire Stormwater Center – New England Stormwater Retrofit Manual See Stormwater Retrofit Manual
The manual presents the US EPA (Environmental Protection Agency) **Stormwater Control Measures (SCMs) Performance Curves as a tool to quantify water quality benefit (i.e. pollutant removal credit) for a range of sizes and types of SCMs** to aid in the selection process and justify the retrofit.The manual takes practitioners through the fundamental approach for retrofit, sizing, design and performance characterization, an introduction of performance curves and stormwater control measure design criteria including detailed sizing requirements and guidance.

The University of New Hampshire Stormwater Center - Pollutant Removal Credits for Buffer Restoration in MS4 Permits.
Sound management of buffer areas is an effective approach to protecting water quality in New Hampshire as well as other New England states. However, regulators and communities lack synthesized, scientifically justified guidance on how to quantify the water quality benefits of buffers and compare them to those derived from other structural Best Management Practices (BMPs). The *Credit for Going Green* project helped address this need by using an expert panel process to develop consensus-based recommendations for pollutant load reduction performance curves for restored or constructed buffers. These curves are intended to meet in-stream pollution reduction targets in development, redevelopment, restoration, or other land use change projects. This report describes the work and findings of the project's expert panel from January 2018 to March 2019.

Natural Resources Conservation Service (NRCS) Soil Web Survey
The New England Stormwater Retrofit Manual by the University of New Hampshire Stormwater Center and the NRCS Web Soil Survey were used to estimate nutrient and sediment loading reduction.

Green Values Stormwater Calculator
This tool was developed by the Center for Neighborhood Technology in collaboration with the US Environmental Protection Agency's Office of Wetlands, Oceans, and Watersheds. **It aligns with methodology used for many regulatory requirements and provides a quick way to compare pre-development and post-development conditions using both conventional and various green infrastructure improvements**. Additionally, the tool displays construction costs, maintenance costs, and additional environmental benefits. The calculator allows you to define one or more properties and then evaluate what combination of Green Infrastructure Best Management Practices (BMPs) meet the necessary volume capacity capture goal in a cost-effective way. See Green Values Calculator

National Stormwater Management Calculator:
EPA's National Stormwater Calculator (SWC) is a software application tool that **estimates the annual amount of rainwater and frequency of runoff from a specific site using green infrastructure as low impact development controls.** The SWC is designed for use by anyone interested in reducing runoff from a property, including site developers, landscape architects,

urban planners, and homeowners. **The tool is free to use and offers a range of low-impact development practices that the user can model by modifying basic design properties**. The tool also offers construction and maintenance cost estimates, which can be useful in informing development design. See National Stormwater Management Calculator

Green Infrastructure Flexible Model (GIFMod)

A computer program that can be used to evaluate the performance of urban stormwater and agricultural green infrastructure practices. It allows users to build conceptual models of green infrastructure practices to predict hydraulic and water quality performance under given weather scenarios. Some examples of GI techniques include: Cisterns/Rain Barrels, Bioretention, Vegetated (Green) Roofs, Infiltration Practices (Basins, Trenches, Dry Wells), Pervious Pavement with Infiltration, and Vegetated Swales. See GIFMod

Visualizing Ecosystems for Land Management Assessment (VELMA) Model

A computer software model that regional planners and land managers can use to quantify the effectiveness of natural and engineered green infrastructure management practices for reducing nonpoint sources of nutrients and contaminants in streams, estuaries, and groundwater. These practices include riparian buffers, cover crops, and constructed wetlands. See VELMA

Estimating Stormwater Runoff

This chapter discusses the easiest methods to determine the stormwater treatment volume. Estimating stormwater runoff is a basic initial step in the design of the stormwater management system as well as the erosion control plan. This chapter presents several commonly used methods and procedures used in this process.

Stormwater Management and Calculations

From North Carolina this chapter provides runoff coefficient determined by estimating the area of different land uses within each drainage area. It provides formulas and calculations for various land types.

Computing Stormwater Runoff and Volumes

From NJ - **discusses the fundamentals of computing stormwater runoff rates and volumes from rainfall through the use of various mathematical methods.** To do so effectively, the chapter also describes the fundamentals of the rainfall-runoff process that these methods attempt to simulate. Guidance is also provided in the use of the **Natural Resources Conservation Service, Rational, and Modified Rational Methods/**

NY State DEC Stormwater Management Design Manual Runoff Reducation Worksheets – Farm Design Example

New York State Stormwater Management Design Manual Chapter 4: Unified Stormwater Sizing Criteria

This chapter presents a unified approach for sizing green infrastructure for runoff reduction and stormwater management practices to meet pollutant removal goals, **reduce channel erosion, prevent overbank flooding, and help control extreme floods.**

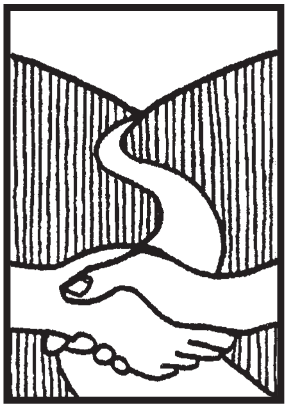
General Information about Green Infrastructure Resources

- EPA's Green Infrastructure Wizard, or **GIWiz**, provides access to tools and resources that can support and promote water management and community planning decisions including:
    - **Quick Links** – Customized access to thousands of green infrastructure tools & resources.
    - **Explore** – Access to an interactive database of green infrastructure tools & resources, based on your individualized specifications

Preventing N Loading at Treatment Plants

EPA Nutrient Control Design Manual
Design for WWTF and WWTP.

WD-03-42



Best Management Practices to Control

Nonpoint Source Pollution

A Guide for Citizens and Town Officials

Prepared by:

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NEW HAMPSHIRE DEPARTMENT OF Environmental Services

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INTRODUCTION

Residents and visitors alike will attest that New Hampshire's waters are an ideal place to swim, fish, and sail. Many people feel strongly that future generations should also have access to clean water. However, all freshwater lakes, rivers, and streams in New Hampshire are currently listed as "impaired" because of a fish consumption advisory for mercury contamination. Additionally, the state has 10,505 acres of lakes and 1,178 miles of rivers classified as threatened or impaired by other pollution sources. Fortunately, this is a small percentage of lakes and rivers in New Hampshire. Although there have been great advances in reducing pollution from industrial discharges and sewage treatment plants in the last 25 years, according to the EPA about half the water quality problems nationwide now are associated with nonpoint source pollution. Polluted runoff from the land is called nonpoint source (NPS) pollution. It occurs when rain or snowmelt flows over land as runoff, or through the ground as groundwater, picks up pollutants, and eventually discharges to a body of water.

Urban and suburban land uses, construction, forestry, septic systems, recreational boating, agriculture, and physical changes to stream channels are potential sources of NPS pollution. NPS pollution is widespread and we all contribute to it by driving a car, applying fertilizer to a lawn, converting land for a new home or business, and sometimes even taking a pet for a walk.

The purpose of this guide is to describe the causes of NPS pollution and to suggest ways that NPS pollution can be prevented or at least reduced. Best management practices (BMPs), which are land treatment or operational techniques used to prevent or reduce pollution, are listed along with references for more information. **Section 1** provides background information on water resources and how they can be impacted by NPS pollution. **Section 2** describes water resource impacts from existing and new development, provides suggested BMPs, references applicable laws and regulations, and lists additional resources. **Section 3** describes specific land use activities that could affect water resources, provides suggested BMPs, references applicable laws and regulations, and lists additional resources. **Section 4** describes how to get involved in local watershed organizations and volunteer water monitoring

What is a BMP?

There are multiple terms associated with the control of nonpoint source pollution. This document uses the term BMPs, which are individual practices that serve specific functions.

BMPs can be structural, such as a fence for excluding livestock or a buffer strip to reduce sediment in runoff, or non-structural such as street sweeping.

BMPs are designed to reduce the pollutants that are generated at and/or delivered from a source to a water body.

It is important to acknowledge that the term "best" is highly subjective and the appropriateness of certain practices may vary regionally or depending on land use.

BMPs, in general, control the delivery of NPS pollutants to water bodies in the following three ways:

- source reduction by minimizing pollutants available in the first place;
- retarding the transport of pollutants by reducing water transported or by retaining pollutants; and
- remediating or intercepting the pollutants before or after they are delivered to the water resource by chemical or biological transformation. ■

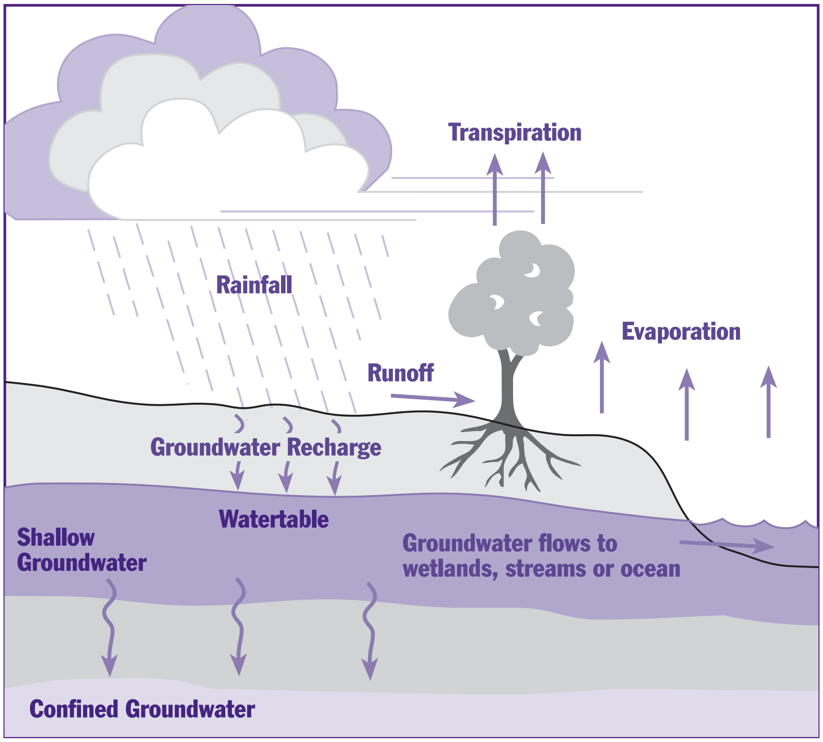
activities. Funding opportunities for efforts to reduce NPS pollution are listed in **Section 5**. Finally, the appendix lists contact information for agencies referenced in this guide.

The New Hampshire Department of Environmental Services (DES) is working to reduce nonpoint source pollution in New Hampshire in several ways. Many of our efforts are linked to the *New Hampshire Nonpoint Source Management Plan*, which was developed in October, 1999 and is available online at www.des.nh.gov/wmb/npsplan.pdf. This plan contains a five-year action plan and lists NPS types in order of priority. Anyone with further questions should contact the DES Watershed Assistance Section at (603) 271-2457. Many of the DES references listed in this guide can be accessed on our website at www.des.nh.gov.

1 WATER RESOURCES AND NONPOINT SOURCE POLLUTION

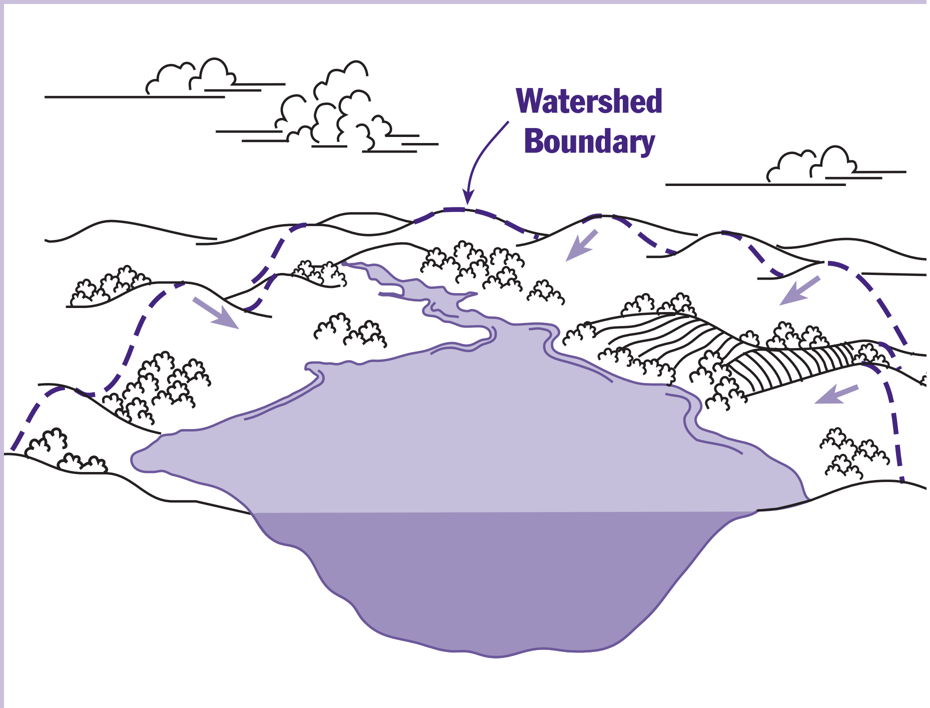
The Water Cycle and Pollution

Water in oceans, lakes, ponds, rivers, streams, wetlands, groundwater, ice sheets, and the atmosphere are all linked by the hydrologic cycle, the movement of water from one system to another. The atmosphere holds large quantities of water vapor, which falls as rain or snow. This precipitation falls directly into surface water bodies (such as a lake or river) or onto land surfaces, where much of it seeps into the ground and eventually becomes groundwater. Lakes, streams, and wetlands are formed where the slowly moving groundwater intercepts the ground surface. In fact, about 50 percent of the water in New England streams is groundwater discharge. Eventually, all of this water finds its way back to the ocean, where it will evaporate into the atmosphere, become rain or snow, and continue through the cycle.



The term "water pollution" often evokes an image of large pipes delivering unsightly wastewater from factories into rivers and streams. Public awareness of this problem and strict federal laws enacted during the past 30 years have made it rare today to find such obvious examples of water pollution. Yet water pollution remains a problem, due in part to nonpoint source pollution. Pollutants follow the paths water takes in the hydrologic cycle and affect the quality of our waterbodies. For example, pollutants from septic systems may impact the same groundwater that is tapped for water supply wells, or pollutants may move with the groundwater before discharging into a stream. Oil leaking from cars is carried with surface runoff from parking lots and is discharged into streams. Sulfur dioxide and nitrogen oxides emitted into the air from power plants and combustion engines are converted in the atmosphere to sulfuric acid and nitric acid and are deposited on the earth with precipitation. This acid deposition can cause several ecological problems, such as fish deaths. Similarly, tiny amounts of mercury enter our atmosphere from sources such as incinerators and power plants; the mercury attaches to rain drops and dry particles and follows the pathways of the water cycle. Mercury concentrations increase up the food chain from water to plankton to fish and to animals that eat fish. High concentrations of mercury in fish have caused many states, including New Hampshire and all New England states, to issue health warnings about freshwater fish consumption.

The Watershed Approach



A watershed is defined as the geographic area in which all water running off the land drains to a given stream, lake, wetland, or other waterbody. A watershed can be thought of as a funnel with the waterbody at the bottom of the funnel and the high points, such as mountains, at the top. The size of the drainage area can be as small as your backyard or as large as several thousand square miles. Nonpoint source problems can originate anywhere in a watershed.

There are five major watersheds in New Hampshire; these include the Coastal/Piscataqua River, the Merrimack River, the Connecticut River, the Saco River, and the Androscoggin River. These five watersheds are made up, in turn, of many smaller watersheds defined by each of the rivers, lakes, ponds, and streams that feed into the bigger rivers. It is most effective and easiest to work in the smallest watershed unit possible when addressing water quality problems.

Tackling water quality issues using a watershed perspective makes a lot of sense because water quality problems often result from a number of smaller sources that cumulatively have a measurable, negative impact on receiving waters. Moreover, good water quality is best protected by managing land use practices in the watershed. The challenge of using a watershed approach to manage water quality, however, is that watershed boundaries do not typically follow town, state, or international borders. Organizations and citizens within a watershed must often come together from across municipal boundaries to design creative management solutions. ■

Another form of nonpoint source pollution is hydrologic modification. This term refers to activities that affect the natural pathways of surface water, such as stream channel modification and channelization, dam construction and operation, and streambank and shoreline erosion. Although these activities don't seem like forms of pollution, they nevertheless are considered to be part of the NPS pollution problem. Many rivers and streams have natural flood control areas, such as oxbows, adjacent wetlands, and riparian zones. When these areas are modified or removed, significant changes in the ecological functions of surrounding lands are likely to occur. Channel modifications frequently degrade instream and riparian habitat for fish and wildlife. Other impacts include erosion and the reduction of the system's ability to filter pollutants. Similarly, increased development around the perimeters of lakes and ponds can change surface hydrology and reduce natural buffers.

2 BEST MANAGEMENT PRACTICES FOR DEVELOPED OR DEVELOPING LAND

This section discusses water quality issues related to previously-developed areas and developing areas, and offers management practices to reduce nonpoint source pollution for both types of areas.

Areas of New Development

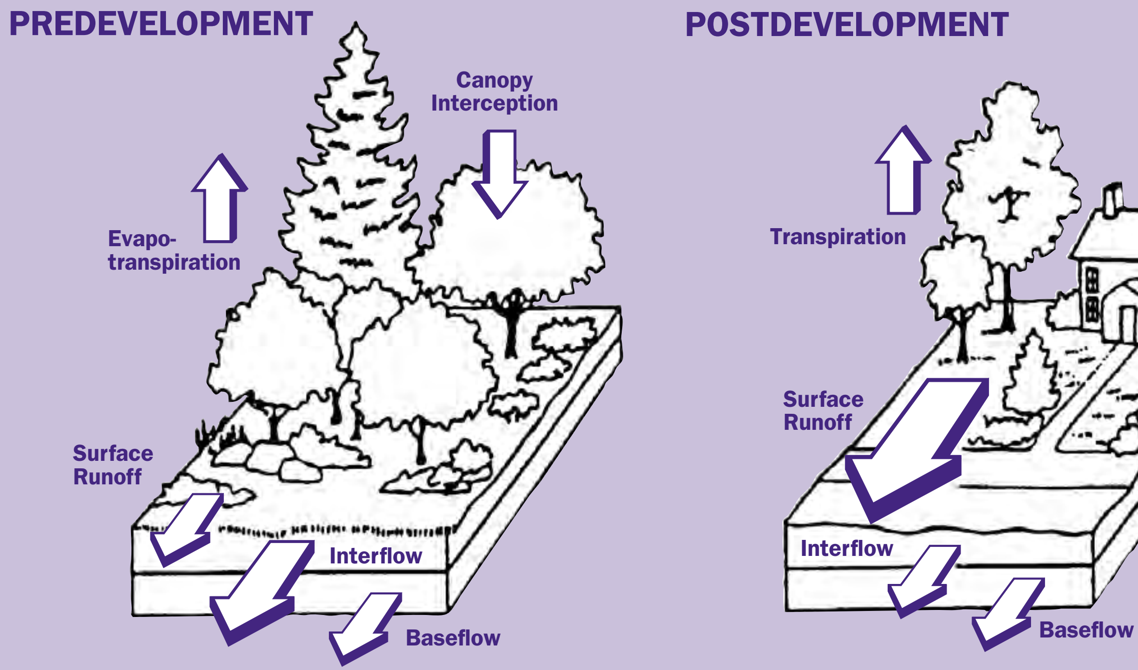
The rural character of New Hampshire is something many people cherish and wish to preserve. Nevertheless, it is obvious that the state is undergoing development and growth, particularly in the southern part and the Seacoast region. Between 1990 and 2000, the population of New Hampshire increased by 11.4 percent, which made it the fastest growing state in New England. Vacation homes comprised 10 percent of the residential units in the state in 2000, and as the regional and national population increases, the interest in New Hampshire as a place to have a second home will likely continue to grow. New Hampshire will have to accommodate new residents and vacationers with more houses, office buildings, shopping centers, schools, and roads. As land is converted from forests or farm fields to a house, road, or parking lot, there are inevitable effects on water quality and quantity.

New residential, commercial and industrial development can increase NPS pollution for many reasons, including the greater use of chemicals on developed land (e.g., fertilizer, pesticides, oil, detergents), the greater potential for erosion due to the disturbance and use of the site, and the increase in impervious cover, which results in more runoff. In addition, development often reduces the amount of vegetated areas that buffer the impact of the increased runoff and higher pollution levels.

Development can also impact the movement of water or hydrologic functions of a watershed. Such impacts can include

Impact of Impervious Cover

Development involves the construction of hard surfaces, such as roofs, roads, sidewalks, and parking lots, that water cannot penetrate. These types of surfaces are collectively referred to as "impervious cover." Impervious cover increases the amount of water that will run off land during a rainstorm or as snow melts, which can lead to increased NPS pollution. Numerous studies have examined the relationship between the amount of impervious cover in a watershed and the health of waterbodies in that watershed. These studies find that the quality of streams, wetlands, and other waterbodies declines sharply when the impervious cover within the watershed exceeds just 10 percent. Land use practices that reduce runoff or intercept runoff before it reaches a waterbody help reduce the impacts associated with impervious cover. Allowing water to infiltrate into the ground helps clean the water and restore groundwater levels, which is especially important during times of drought. ■



changes in the rate of flow of water, reduced amount of recharge or infiltration, and increased volume of water during storm events. Alterations to watershed hydrology can negatively affect aquatic habitat by lowering the water table, reducing base flows, increasing water temperatures, reducing shading of streams and rivers, and reducing the accumulation of natural biomass in streams and rivers.

Conventional stormwater management systems, including curbs, gutters, storm drains and piping, paired with a large structural BMP, such as a retention/detention pond, can help control peak flows and reduce water quality impacts. But, typically this does little to maintain natural hydrologic functions on the site, including natural infiltration rates or direction of water flow. Additionally, such traditional stormwater management systems are expensive and involve extensive earthwork and installation of materials.

Alternatively, a more innovative stormwater management approach can provide increased opportunities for stormwater to infiltrate, better maintain natural watershed hydrology, and limit impacts to habitat. The alternative approach uses open, grassed channels to hold and convey water along with numerous smaller-scale BMPs and landscape features dispersed throughout a developed area to regulate water flow and remove pollutants. Vegetation is recommended as part of any stormwater management approach to stabilize soil, filter out pollutants, and reduce runoff volume; it can be as simple as vigorous plantings around new construction.

In addition to providing for effective stormwater management, new developments can also be located and designed in ways that minimize NPS pollution. Municipalities can develop an education program and use their local planning and site plan and subdivision review processes to encourage the use of practices that minimize nonpoint source pollution.

BMPs for Areas of New Development

Both designing and locating new development offer opportunities to use BMPs to minimize NPS pollution.

Designing New Development

Conservation design minimizes the amount of land disturbed for development, maintains significant ecological areas in a natural state, and reduces the amount of impervious surface created. Energy and water efficiency also are maximized.

Following these practices provides other benefits in addition to protecting surface water quality. For example, the practices listed below help maintain groundwater supplies by increasing infiltration of water into the ground; help protect wildlife habitat by maintaining undisturbed land, especially along wetlands, streams, and other riparian areas; and help reduce air pollution from vehicle travel by encouraging more compact development that supports walking and biking and reduces vehicle use. Encouraging non-motorized transport through changes in design improves human health by improving air quality and by engaging people in physical activity. Improved human health in turn reduces medical costs associated with bad air quality (such as asthma) and inactivity (such as obesity and heart disease), which saves money for all of us.

Low-Impact Development Design

An alternative, more innovative stormwater management approach—called "low-impact development (LID) design"—can provide increased opportunities for stormwater to infiltrate, better maintain natural watershed hydrology, and limit impacts to habitat. LID focuses on:

1 site design techniques that reduce runoff and maintain existing hydrologic features; and

2 site-level or "at-source" stormwater controls.

The fundamental LID site planning concepts include:

- using hydrology as a basis for designing new development;
- thinking "micromanagement" for stormwater control;
- controlling stormwater at the source;
- using simplistic, nonstructural stormwater control methods when feasible; and
- creating a multi-functional landscape and infrastructure.

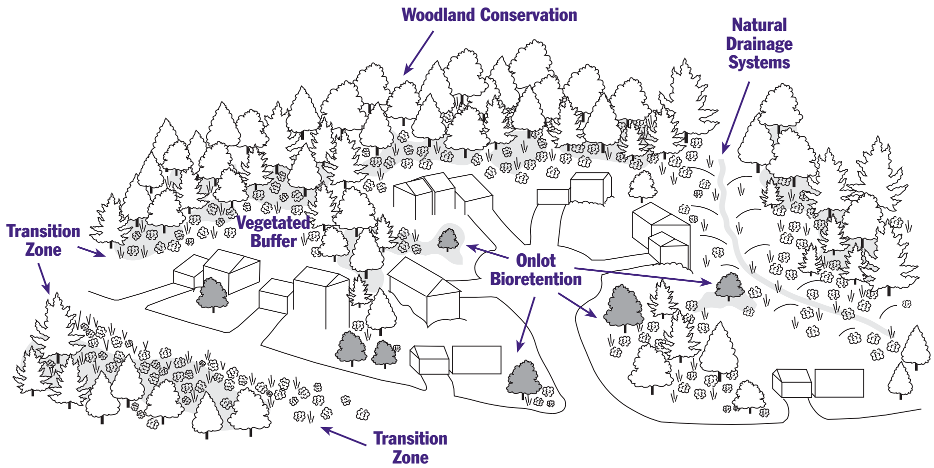
Hydrology is integrated into the site planning process by first identifying and protecting the following areas important to the natural hydrology of the site: streams and their buffers, floodplains, wetlands, steep slopes, high-permeability soils, and woodland conservation zones. Future development is then located in remaining areas that are less sensitive to disturbance or have lower value in terms of hydrologic function. The development is then designed to minimize clearing and grading, minimize and disconnect impervious surfaces, minimize the quantity and velocity of surface runoff, and provide for on-site/on-lot management of runoff. Additionally, the existing topography and drainage pattern is maintained to disperse flow paths.

Whenever possible, LID designs use open, vegetated drainage systems in lieu of conventional storm drains. LID flow and conveyance systems are designed to maximize overland sheet flow, involve wider, rougher, and longer flow paths, and include pockets of vegetation (trees and shrubs) in the flow path. In addition, flows from large paved surfaces are dispersed in multiple directions, using sheet flow when feasible.

In addition to the above design considerations, LID involves micromanagement of stormwater using small-scale integrated management practices (IMPs) distributed throughout the site. Example IMPs include on-lot bioretention facilities, dry wells, filter/buffer strips, grassed swales, bioretention swales, wet swales, rain barrels, cisterns, and infiltration trenches. These techniques are used to control runoff at its source. As with other BMPs, IMPs also require monitoring and periodic upkeep, including trash removal and maintenance of vegetation. But with education on the purpose and proper care for IMPs, private property owners can often assume responsibility for maintaining IMPs located on their property.

Communities that wish to benefit from the LID approach may need to develop an oversight program and adopt flexible zoning options in their subdivision and site plan ordinances to facilitate the use of LID techniques by developers. ■

Locating New Development



- Locate development close to existing developed areas.
  - Provide a greater chance of connecting to a sewer system, which reduces the possibility of NPS pollution from individual septic systems.
  - Require less pipe to connect to the sewer system, which lowers the chance for leakage of untreated wastewater, and lowers the cost of the project as well.
  - Shorten the distance to shopping and other services/activities to reduce vehicle travel, thereby reducing local air pollution, and increasing opportunities to walk or bike. This can also reduce NPS pollution from the deposition of air pollutants.
- Locate close to existing roadways.
  - In addition to the above benefits, a shorter access road and/or driveway will reduce the amount of impervious surface created by the development.
- Locate away from surface waters.
  - Increase opportunities for treatment of runoff before it reaches surface water.

Principles of Conservation Design

- Use narrower and shorter streets, driveways, and rights-of-way.
- Put sidewalks on only one side of the street.
- Allow for smaller lots and narrower setbacks and frontages to reduce the amount of land "disturbed" by development, maximize the amount of land retained in open space, and require less roadway and driveway.
- Reduce the size of parking areas and use permeable surfaces for overflow parking areas.
- Reduce the amount of area maintained as lawn, and use drought-tolerant species of grass to reduce watering needs where grass is desired.
- Disconnect impervious surfaces (e.g., slope driveways towards lawns or other vegetated areas rather than the street).
- Maintain significant vegetated buffers for surface waters and do not mow to the edge of the water.
- Use open, grassed swales to convey stormwater rather than a curb and gutter system.
- Use all available natural resource information in designing the development.
- Integrate smaller-scale BMPs and landscape features throughout the site to manage stormwater and control NPS pollution.
- Require enhanced performance septic systems or regular septic system inspections when a development is not served by sewer.
- Encourage onsite collection or infiltration of rainfall/runoff from individual homesites (e.g., install rain barrels and cisterns to collect roof runoff, incorporate small bioretention areas or 'raingardens' on home sites to manage rainwater). ■

Previously-Developed Areas

Many people think that urban areas are found only in large cities and towns, but many of New Hampshire's villages and small towns also have areas that are densely developed. Pockets of development in rural towns, such as shopping centers, have some of the same water quality issues that cities do. The practices discussed in this section apply to any developed area.

Developed areas typically have higher amounts of impervious surfaces and existing stormwater drainage systems. Many older stormwater drainage systems collect water and pollutants from impervious surfaces and discharge them directly to a stream, river, or other surface water body. As a result, watershed hydrology is impacted and pollutant loads increase.

To reduce NPS pollution, management of developed areas can take steps to prevent pollutants from entering stormwater. Additionally, urban and developed areas can be retrofitted by installing structural BMPs to reduce, collect, and treat stormwater. Redevelopment and renovation of existing sites provides excellent opportunities for improving stormwater management and reducing NPS pollution. DES has written a guide summarizing innovative retrofit BMPs called *Innovative Stormwater Treatment Technologies: Best Management Practices Manual.*

DES has produced other BMP manuals specifically for developed areas, *Best Management Practices for Urban Stormwater Runoff* and *Stormwater Management and Erosion and Sediment Control Handbook for Urban and Developing Areas in New Hampshire.* The first guide covers the BMPs required by the DES Alteration of Terrain Permit Program. The second is a comprehensive reference for structural and vegetative BMPs, such as detention basins, level spreaders, grassed waterways, and others.

An additional guidance document, *Managing Stormwater as a Valuable Resource: A Message for New Hampshire Municipalities and Water Suppliers,* provides information on managing stormwater to protect water supply resources and the conditions under which artificial infiltration BMPs, such as infiltration trenches and infiltration basins (or ponds), can be used.

Planning boards may need to enlist professional engineering services to review development proposals. Such services may be available through county conservation districts, regional planning agencies, and private consultants.

BMPs for Previously-Developed Areas

The following practices and structural BMPs can reduce NPS pollution from existing developed areas:

General Guidelines

- Use vegetation extensively to filter runoff before it enters surface waterbodies.
- Divert runoff around sites where pollutants could be picked up by surface flow (e.g., gas stations).

- Inspect areas periodically to make sure that potential pollutants, such as raw materials for an industrial process, are not left in areas where they can be transported by runoff into waterbodies.
- Keep parking areas, outdoor storage areas, and streets clean of debris. Street sweeping can be used to remove sediment, debris and trash from streets and parking areas.
- Clean out catch basins and other flow control devices regularly to prevent backup and overflow of sediments and pollutants.

Specific Structural BMPs

- **Bioretention Area**

  A practice to manage and treat stormwater runoff by using a conditioned planting soil bed and planting material to filter runoff stored within a shallow depression. The system can include the following components: a pretreatment filter strip of grass in an inlet channel, a shallow surface water ponding area, a bioretention planting area, a soil zone, an underdrain system, and an overflow outlet structure. For example, vegetated islands in parking lots can be recessed, rather than raised, and designed as bioretention areas.

- **Grassed Swale**

  An engineered grassed channel to transport stormwater. Dry swales facilitate quality and quantity control by allowing for infiltration. Wet swales use retention time and natural growth of water-tolerant vegetation to regulate flow and quality of stormwater before discharge.

- **Infiltration Trench**

  An excavated trench that is backfilled with stone to form a subsurface basin. Water is slowly infiltrated into the soil, usually over several days. Most effective when combined with some form of pretreatment, such as a filter strip, to reduce the amount of sediment reaching the trench.

- **Infiltration Basin or Pond**

  A grassed, flat-bottomed basin preceded by a sediment forebay or riprap apron to slow the flow of water and trap sediment. Water is slowly infiltrated into the soil, usually over several days.

- **Dry Well**

  A small excavated pit backfilled with aggregate, usually pea gravel or stone. Used to infiltrate runoff from building rooftops and in modified catch basins, where the inflow is direct surface runoff.

- **Stormwater Treatment Chamber**

  An underground, divided chamber used to remove sediment, oil and debris from stormwater. Such chambers are typically used in conjunction with a stormwater retention or infiltration BMP.

Laws and Regulations For Developed or Developing Land

As of March, 2003, the National Pollutant Discharge Elimination System (NPDES) Stormwater Phase II rule ("Phase II") requires operators of small municipal separate storm sewer systems (called MS4s), operators of municipally-owned industrial activities, and operators of small construction sites (one acre or more) to implement programs and practices to control polluted stormwater runoff. More information on these regulations can be found at www.des.nh.gov/stormwater.

Local planning boards are authorized to regulate subdivisions and nonresidential and multi-family residential site development under **RSA 674:35** and **674:43**, respectively. The requirements for developing a local master plan are found under **RSA 674:1-4**. Zoning ordinances are covered under **RSA 674:17-20**. Innovative land use controls are described under **RSA 674:21**.

The Comprehensive Shoreland Protection Act (**RSA 483-B**) establishes minimum standards for the future subdivision, use, and development of the shorelands within 250 feet of the state's public waters. When repairs, improvements, or expansions are proposed to existing development, the law requires these alterations to be consistent with the intent of the Act. DES is responsible for enforcing the standards within the protected shoreland, unless a community adopts an ordinance or shoreland provisions that are equal to or more stringent than the Act. In addition to the standards of the Act, development within the protected shoreland must always comply with all applicable local, state, and federal regulations.

All state laws in New Hampshire can be searched online at
gencourt.state.nh.us/rsa/html/indexes/default.html

Site excavation is governed by **RSA 485-A:17**, known as the Alteration of Terrain or Site Specific Permit Program. Development as well as redevelopment activities may require a permit under this program. Please see page 23 for more information.

RSA-482-A and the rules promulgated under that law (**Env-Wt 100-700**) require that projects be designed to avoid and minimize impacts to wetlands and other jurisdictional areas. The impacts that are proposed must be only those that are unavoidable. It is the responsibility of the applicant to document these considerations in the application for a permit.

RSA 485-A gives DES the authority to regulate septic systems. Design, operating, and permit requirements are found in Administrative Rule **Env-Ws 1000**. The regulations require all subdivisions creating lots smaller than five acres to obtain approval from DES. If the site lies within a protected shoreline area, all lots, regardless of size, require approval from DES (**RSA 483-B**). Any developed waterfront property on great ponds and tidal waters with an on-site subsurface system must be assessed for compliance with current standards prior to the execution of a purchase-and-sale agreement (**RSA 485-A:39**).

What the Implementation of Phase II Means

For regulated MS4s, six minimum control measures must be implemented within five years of receiving the Phase II permit. Permittees must submit an annual report to EPA summarizing their progress toward achieving specific measurable goals in the six categories.

EPA has issued guidance on recommended BMPs and developing measurable goals and conducted a series of workshops on the Phase II requirements. DES is providing technical and financial support whenever possible.

Six Minimum Control Measures

1. Public education and outreach
2. Public participation and involvement
3. Illicit discharge detection and elimination
4. Construction site runoff control
5. Post-construction runoff control
6. Pollution prevention and good housekeeping

3 BEST MANAGEMENT PRACTICES BY LAND USE/ACTIVITY

This section identifies some of the land uses that generate NPS pollution, lists ways to control pollution by land use, and provides a list of resources.

Households

See BMP Resources on page 36

Reducing NPS Pollution Around Your Home

There are a number of BMPs that a household can employ to reduce their contributions to NPS pollution. Although each individual household may contribute only minor amounts of NPS pollution, the cumulative effects of household-level action to reduce pollution by an entire neighborhood or region of households can be significant.

Potential household contributions to NPS pollution include:

- bacteria, chemical, and nutrient discharges from septic systems;
- chemical use, storage, and disposal;
- sediments, chemicals, and nutrients from lawn and garden activities;
- runoff from impervious surfaces (e.g., driveways, roofs, patios);
- pet waste; and
- air pollution contributions, from energy use and vehicle use.

Septic Systems

A proper, well-maintained septic system will adequately treat your sewage. If it is not taken care of, a septic system may become clogged and overflow on the ground or cause wastewater to back up into the house. A failed system is unhealthy, expensive to replace, and may contaminate nearby ground and/or surface waters, including nearby wells. Taking a few precautions can avoid costly septic system problems.

- Know the location of your septic tank and leaching area; mark the tank cover(s) with partially buried bricks.
- Have your tank inspected yearly. If the sludge and surface scum combined are as thick as one third the liquid depth of your tank, have the tank pumped out by a licensed septage hauler.
- Keep bulky items such as disposable diapers, sanitary pads, cigarettes, or paper towels out of the system. These will clog the leaching system.
- Keep toxic materials such as paint thinner, pesticides, or chlorine out of your system. These chemicals may kill the necessary bacteria in the tank.
- Do not use septic tank additives. They may cause harm by killing essential bacteria.
- Repair leaking fixtures promptly; use water-reducing fixtures wherever possible to reduce the amount of water the system must treat.
- Avoid putting food waste and grease into the system or using a garbage disposal. Food waste will not only fill your septic tank rapidly and require more frequent pumping, but will also float and can eventually clog the leaching system.
- Keep deep-rooted trees and bushes away from the leach field.
- Keep vehicles, livestock, or heavy foot traffic away from the leach field, as the weight may compress the soil too much or break the pipes.
- Minimize the use of detergents and bleaches; use alternative cleaning products such as baking soda, borax, or non-chlorine scouring powders. Many cleaning products such as toilet bowl cleaners contain chlorine and strong acids that will kill the necessary bacteria in the septic system.

Chemical Use, Storage and Disposal

Hazardous household products such as cleaners, paint thinner, spot remover, oven cleaner, furniture polish, drain opener, pool chemicals, and even hair spray can be found in most home storage cabinets. Hazardous products can usually be identified by a warning label on the container. These products, when handled improperly, can contaminate a well, poison a stream, or disrupt the proper functioning of a septic system.

- Buy nontoxic alternatives whenever possible.
- Read the label carefully before buying, using, or disposing of products.
- Buy only the quantity that you need and use only the recommended amount.
- Store and label wastes safely, then bring them to a local household hazardous waste day collection (contact DES at 271-2047 for locations near you). Many towns also accept used oil for recycling.
- Hazardous chemicals should NOT be poured on the ground or down the drain, discarded in the trash, buried, or burned!

Lawn and Garden Activities

Landscaping and gardening practices can contribute to NPS pollution through lawn chemicals, fertilizers, silt, and sand. However, with a few minor changes, backyards can actually play an active role in improving water quality.

- Test your soil to know what it actually needs before you apply fertilizer or lime (contact your county UNH Cooperative Extension office for information on soil testing).
- When fertilizer is necessary, select a slow-release fertilizer to avoid excess nutrients running into the water. Under the Shoreland Protection Act, a 25-foot fertilizer-free buffer must be maintained around wetlands and surface water.
- Plant natural, native plant species instead of non-native plants (plants that were introduced for agricultural purposes or by accident). Native plants generally require much less water, herbicides, fertilizers, or trimming.
- When possible, reduce the size of your lawn by planting low-maintenance groundcovers, trees, flowers, and shrubs to help water infiltrate into the ground and prevent soil erosion.
- For new lawns, use 6-12 inches of topsoil to encourage deeper root growth
- For waterfront or wetland areas, maintain or plant a natural vegetation buffer at least 100 feet wide between the lawn and the water to hold soil in place, absorb pollution before reaching the water, and provide wildlife habitat. Some species of wildlife require more than 100 foot buffers.
- Start composting in your backyard and use compost on your gardens and lawns and around trees and bushes. Composting your yard and food waste is easy and will reduce the need for fertilizers and water by adding nutrients and helping the soil retain moisture.
- Refrain from using pesticides near surface water.
- Read pesticide labels carefully.

Impervious Surfaces

Runoff from stormwater washes across yards, driveways, roads, and patios, picking up loose soil, pet wastes, fertilizers, pesticides, oil, soaps, and other pollutants and depositing them into streams, rivers, and lakes. Water directed to pervious surfaces will help filter many of these possible contaminants before entering our surface waters in addition to recharging our groundwater supplies.

- Limit the amount of impervious surface on your property (impervious surfaces include sidewalks, roofs, driveways, and patios).
- Replace impervious surfaces with natural ground cover or with material that allows some water to seep into the ground, such as gravel, brick, stepping stones, wood chips, or other porous surface.
- Direct runoff from impervious surfaces to areas on your property where the water can seep into the ground. For example, direct roof downspouts away from the driveway or the storm drainage system and into a gravel swale or grassed area, or collect roof runoff in a screened-top rain barrel and use to water plants around your yard.
- Maintain or restore natural vegetated areas as buffers along river, lake, and coastal waterfronts.
- Sweep driveways and walkways instead of hosing them down.

Pets

Scooping your pooch's poop isn't just a neighborhood courtesy; it is also the healthy and environmentally sound thing to do. Pet waste may be a source of bacteria and nutrients in water. Just as we don't want human sewage in our water, it is important to prevent pet waste from littering our towns and being carried into our waterways. People drinking and swimming in water contaminated by pet waste could ingest harmful pathogens.

- Pick up pet waste and flush it down the toilet, bury it in the yard, or put it in the trash. Another option is to install an underground pet waste digester that works like a small septic tank. Some local laws or neighborhood rules may restrict their use.
- Do not put pet waste into storm drains.

Air Pollution – Acid Deposition

Through rain or snow, acid deposition deposits acids and acidifying compounds to the Earth's surface, which then move through soil, vegetation, and surface waters. Acid deposition is formed when emissions of sulfur dioxide and nitrogen oxides react with other substances in the atmosphere to form the acidic compounds. Sulfur dioxide and nitrogen oxides are emitted primarily from power plants and motor vehicles as a result of burning fossil fuels.

Acid Deposition leads to adverse impacts such as increased mortality among sensitive species, decreased visibility, and stunted forest growth. In addition, soils that are saturated with nitrogen have little capacity to buffer acid rain before it enters streams. The use of nitrogen fertilizers, nitrogen-fixing crops, and fossil fuels has doubled and continues to increase the rate of nitrogen entering the land.

- Reduce your use of electricity (turn off lights, turn down thermostats, hang laundry to dry, take quick showers, etc.).
- Drive your car less by carpooling, biking, walking, and combining trips.
- Maintain your car's pollution control equipment, keep your tires properly inflated, and keep your engine tuned.
- When buying a new appliance, such as a refrigerator or clothes dryer, put energy efficiency at the top of your list of desirable features and look for the Energy Star label indicating the item is energy efficient.
- When buying a new vehicle, ask the car dealer for a Granite State Clean Car and look for the Clean Cars Label indicating the vehicle meets lower emission standards and better fuel economy.
- Contact your electric utility to see what it is doing to reduce emissions.

Laws and Regulations

A complete copy of the rules governing septic systems in New Hampshire **Env-Ws 1000**, Subdivision and Individual Sewage Disposal System Design Rules is available at www.des.nh.gov/rules/envws1000.pdf. Hardcopy available at DES, 29 Hazen Drive, Concord, NH 03301, (603) 271-2975 for $10.

More information on the **Shoreland Protection Act** is available at www.des.nh.gov/cspa.

Under **RSA 261:153(V)** and **RSA 149-M:18**, city treasurers and town clerks can assess a fee to pay for collection and disposal fees of motor oil, car batteries, and car tires. A Vehicle Registration Fees fact sheet is available at www.des.nh.gov/sw.htm or call DES at (603) 271-2975.

After January 1, 2005, owners of on-premise heating oil tanks must meet DES "Best Management Practices for the Installation or Upgrading of On-Premise-Use Heating Oil Tank Facilities." On-premise-use facilities include heating oil tanks and piping located at single family homes, apartments, commercial buildings, and industrial facilities. Failure to achieve compliance by that date will prevent access to the state cleanup funds should an oil release occur. To assist owners in meeting this new requirement, **RSA 146-E** authorizes a grant program (up to $1,000) for owners who demonstrate a financial need. For more information, see DES fact sheet *OIL-24: Best Management Practices for the Installation and Upgrading of On-Premise-Use Heating Oil Tank Facilities* at www.des.nh.gov/factsheets/oil/oil-24.htm.

All state laws in New Hampshire can be searched online at **gencourt.state.nh.us/rsa/html/indexes/default.html**

Site Excavation and Road Construction

See BMP Resources on page 38

Site excavation and development, road construction, and road maintenance activities may not last long, but erosion and sedimentation from any earth moving can have long-term impacts on water quality. Towns may face financial impacts from removing sediments from ditches, culverts, and drains.

The road building process is more susceptible to erosion problems than other types of construction. Drainage ditches and channels built along roads to carry stormwater will erode easily before they are properly stabilized. Site excavation and development may make soil and attached chemicals more available, resulting in polluted lakes and streams. Bare soil particles are dislodged by rainfall and can be transported down slope to streams, lakes, and wetlands. The extent of erosion is influenced by exposure, rainfall intensity and duration, soil type, vegetation, topography, and season.

The sedimentation or deposition of material eroded by water from site excavation or road construction and maintenance activity can have significant negative effects on water quality and aquatic habitats from increased sedimentation. In addition to habitat losses for fish and invertebrates, wetlands can fill in and vegetation can be smothered; culverts and ditches can be plugged; and recreational potential can be reduced when soil loss from excavation activities is high. Nutrients and chemicals can be released from sediment that enters a waterbody. Released phosphorus can cause algal blooms in lakes and encourage eutrophication.

Construction sites may use numerous chemicals at the site, such as pesticides, fertilizers, petroleum products and construction chemicals. Solid wastes and sometimes hazardous wastes may also be handled on site. The "Chemicals and Petroleum Products" section of this document discusses BMPs for preventing NPS pollution from these sources.

BMPs for Marinas

- Use only phosphate-free detergents and establish a wash area over an infiltration trench or a vegetated swale. If possible, use a high-pressure sprayer with no detergents, or wait until the boat is out of the water to clean it.
- Perform periodic engine maintenance (e.g., changing oil, winterizing) out of the water. Propylene glycol should be substituted for ethylene glycol antifreeze when winterizing engines. The oxidation of propylene glycol yields pyruvic and acetic acids, which are not toxic to aquatic organisms.
- Scrape, sand, sandblast, and paint boats away from the open where dust, paint chips, or paint spray can be blown into the water. Whenever these types of practices are conducted, appropriate containment devices should be used.
- Install containment booms at fueling stations. Institute weekly inspections to ensure facilities are maintained in good condition.
- Divert clean runoff and install infiltrating catch basins around boat launches to prevent pollutants from washing down the ramp and entering the lake.
- Provide public rest rooms and pumpout facilities to eliminate the potential discharge of wastewater to waterbodies.

Laws and Regulations

RSA 482-A and the administrative rules of the Wetlands Bureau (**Env-Wt 100-800**) regulate the construction of docks and marinas. Piers, floats, tie-off piles, and mooring buoys in navigable waters of the U.S. typically fall under the State Programmatic General Permit process, which is a cooperative program with the U.S. Army Corps of Engineers.

Moorings are regulated by the Department of Safety under authority of **RSA 270** and administrative rules **Saf-C 400-413**.

RSA 487:2 prohibits the operation of boats constructed to discharge wastewater upon waters of the State.

RSA 485-A:55, 56 prohibits the sale of detergents, except dishwasher detergents, that contain more than a trace amount of phosphorus.

The Clean Vessel Act was passed by Congress in 1992 and reauthorized in 1998 to help reduce pollution from vessel sewage discharges. The Act established a five-year federal grant program administered by the U.S. Fish and Wildlife Service. All recreational vessels must have access to pumpouts under the Clean Vessel Act. Funds are provided to states for the construction, renovation, operation, and maintenance of pumpout stations for pumping waste out of recreational boat holding tanks and dump stations for emptying portable toilets. For a directory of New Hampshire boat pumpout locations and information about boat pumpout service see www.des.nh.gov/wmb/cva.

All state laws in New Hampshire can be searched online at
gencourt.state.nh.us/rsa/html/indexes/default.html

Agriculture and Golf Courses

See BMP Resources on page 42

There are approximately 2,900 commercial and small-scale farms and 100–110 golf courses in New Hampshire, according to the 1997 USDA Census of Agriculture and the N.H. Golf Association. In addition, there are countless backyard hobby farms throughout the state. Farming depends on maintaining the productivity of the land, yet its activities can also contribute nonpoint source pollution. Golf courses generally require intensive turf management, which often means chemical applications. The three primary nonpoint source concerns from agricultural and golf course land use activities are soil loss or sedimentation, nutrients, and pesticides.

Runoff from bare fields can pick up soil particles, causing erosion of the land and sedimentation of waterbodies. Excessive irrigation on managed turf can sometimes result in deep percolation and runoff. Soil particles suspended in surface water

reduce the amount of sunlight available to aquatic plants; impair the gills of fish, shellfish, and aquatic insects; and diminish the in-stream habitat for aquatic organisms. Soil particles not only affect stream or lake sediment loads, but can also introduce pollutants to the system, because pollutants attach to the particles.

Runoff from fertilized fields and golf courses can cause algal blooms and related problems by introducing unnatural concentrations of nitrogen and phosphorus to an aquatic ecosystem. Nutrient runoff can increase the productivity of aquatic plants that will eventually die and decay. The bacteria decomposing the dead organic matter can deplete the oxygen supply in the water and cause unpleasant odors for recreational users of lakes and streams. Runoff from manure is also a source of bacteria, which can adversely affect human health.

Pesticides, fungicides, and herbicides applied to farmlands, lawns, and golf courses can also degrade water resources. Exposure to certain chemicals can cause poisoning to people and wildlife, through direct exposure and drinking water.

BMPs for Agriculture and Golf Courses

Although the activities are different, the basic goals of BMPs for agriculture and golf courses are very similar. They are as follows:

- Reduce the off-site transport of sediment, nutrients, and pesticides.
- Control the rate, method, and type of nutrients and chemicals being applied.
- Reduce the total chemical loads by use of integrated pest management (IPM), economic thresholds, alternative pest control, and soil testing.

Several BMPs for agriculture and golf courses are listed below by pollution source. Many of these can also be applied to home use. For new golf courses, several problems can be avoided if the designer fits the course to the existing terrain as much as possible, and takes into consideration waterbodies, wetlands, and steep slopes at the site. Most of these BMPs are applicable to agriculture. The BMPs that are also applicable to golf courses are marked with the symbol ▲.

Managing sedimentation

- Minimize tillage when farming and minimize extensive earth-moving when designing a golf course. ▲
- Plant a cover crop and/or allow crop residue to remain on the soil after harvest.
- Plant vegetative filter strips along surface waters and between fields and fairways.▲
- Protect the soil with rotational grazing.
- Rotate crops that provide limited ground cover with those that provide generous ground cover.
- Plant crops along contour lines when possible.
- Construct and stabilize diversions to control runoff across cropland and gully erosion. ▲
- Reduce erosion and sedimentation by barring access by livestock on bare streambanks.

Managing nutrients effectively

- Monitor the level of nutrients in soils by regular soil testing. ▲
- Divert, collect, or store runoff water from buildings and yards. ▲
- Install a vegetative filter along surface waters, feedlots, and edges of fields. ▲
- Avoid spreading manure or fertilizer during winter. ▲
- Incorporate manure into soil as soon as possible after spreading to minimize runoff during rainstorms.
- Prevent or control livestock access to waterbodies and implement "pasture pumps" or other watering systems next to heavy use areas and feed bunks.
- Diversify crop rotations and plant cover crops after harvesting that use residual nutrients.
- Determine manure application rates and timing according to nutrient needs of the crop.
- Set realistic yield goals.

Reducing pesticide use

- Apply pesticides only when needed. ▲
- Use insect-resistant crop or turf varieties. ▲
- Spot-treat insect infestations when possible. ▲
- Conserve beneficial insects.▲
- Select the least-toxic pesticide and use organic pesticides. ▲
- Observe setback zones. ▲
- Store, handle, and dispose of chemicals safely, according to state and federal regulations. ▲
- Manage crops to compete aggressively with weeds.
- Control weeds with cover crops.
- Use crop rotation and plant diversity to control insects.
- Plant pest-repelling plants next to crop plants (e.g., marigolds next to tomatoes).
- Contact the N.H. Department of Agriculture or your local county Cooperative Extension office (listed in the phone book) for assistance or advice on IPM programs, which use biological and nonchemical controls to reduce pesticide use. ▲

Laws and Regulations

The N.H. Department of Agriculture Division of Pesticide Control enforces state pesticide laws affecting sale, storage, and application of all registered pesticides. The N.H. Pesticides Controls law, **RSA 430:28-48**, requires pesticide applicators to obtain permits from or to be licensed by the Division of Pesticides Control prior to application. Pesticides must be registered with the state, and applicators must submit reports of pesticide usage annually. Commercial applicators are also required to pass an exam that covers label protocol, chemical safety, environmental consequences, pest types, and use of application equipment. See rules **Pes 100-1000** (www.state.nh.us/agric/pecorl.html) for more information on certification, storage of pesticides, application, and setbacks from water resources.

The Comprehensive Shoreland Protection Act stipulates that no fertilizer, except limestone, shall be used within 25 feet of the high water line of a waterbody. See www.des.nh.gov/cspa/483B.htm.

The Manure, Agricultural Compost, and Chemical Fertilizer Handling Law, **RSA 431:33-35**, required the N.H. Department of Agriculture, Markets, and Food to develop BMPs for handling these materials and to investigate complaints of mismanagement. If the investigation finds that BMPs are not used, the department will notify operators in writing and require them to submit plans for compliance if the corrections are not made within 10 days.

The federal National Pollutant Discharge Elimination System (NPDES) program requires concentrated animal feeding operations (CAFOs) to obtain discharge permits. Large CAFOs are determined by the number of animals on the site, and the threshold is specific to the type of animal. Medium CAFOs are determined by the number of animals and whether or not the facility discharges to surface water. Small facilities can be designated as CAFOs at the discretion of the permitting authority (EPA). For more information on the CAFO final rule, see EPA's website at http://cfpub.epa.gov/npdes/home.cfm?program_id=7.

Nutrient Runoff and Land Use

Which type of land use has higher amounts of nutrients in runoff – agricultural land or developed (urban, suburban, industrial, and commercial)? You might think agriculture, given the application of manure and fertilizers. But modeling studies in the Chesapeake Bay watershed and the Lake Champlain basin have shown that runoff from developed areas can produce just as much, or up to three times more, phosphorus and nitrogen per acre of land. Maintaining farmland in your community may be better for water quality than developing land! For information on incorporating agriculture into land use planning, see the technical bulletin *Preserving Rural Character: The Agricultural Connection.* Available online at www.state.nh.us/osp/planning/guide/docs/Tech Bulletin6.pdf)

All state laws in New Hampshire can be searched online at **gencourt.state.nh.us/rsa/html/indexes/default.html**

What Is a Water Footprint?

It is important for individuals, households, businesses and countries to ask "What is a water footprint?" as they do an assessment of water use patterns at different levels.

An Assessment of Water Use Patterns at Different Levels, Both Direct and Virtual.

Fresh water is vital to life, but as the world's population grows, so does its use of water. It takes water – a lot of it – to **produce food**, to **make energy** and to **manufacture consumer products**. This is what's known as **virtual water** and it's important to do an assessment of water patterns at different levels of water use.

Globally, the increase is due primarily to increasing virtual water use, as more people consume more water-intensive food, electricity and consumer goods, putting increasing pressure on water resources. Strained resources are a source of both concern and conflict in the arid parts of the world – including the US – where food is grown, goods are manufactured and water is already in short supply. Entities at many levels have started doing an assessment of water use patterns at different levels and asked, "What is a water footprint?"

By the year 2030, experts predict that global demand for water will **outstrip supply by 40 percent** [PDF]. Impacts from climate change have already led to changes to the water cycle, leading to prolonged periods of drought (and, conversely, more extreme rainfall) in some areas. Reduced water supplies could add to water insecurity both in the US and in other countries.

Water footprints help individuals, businesses and countries because they reveal water use patterns, from the individual level all the way to the national level. They shine a light on the water used in all the processes involved in manufacturing and producing our goods. They also account for the amount of water contaminated during manufacturing and production.

These footprints give everyone – from individuals to business managers to public officials – a solid frame of reference that helps the world be more efficient and sustainable with water use. By **understanding our water footprints**, we can appreciate the role water plays in everyone's lives.

Blue, Green or Grey Water Footprints – How Are They Measured?

A water footprint is measured in terms of the volume of water consumed, evaporated and polluted. The Water Footprint Network, whose research provides the data splits water footprints into **three corresponding categories**:

Blue Water Footprint: The amount of surface water and groundwater required (evaporated or used directly) to produce an item.

Green Water Footprint: The amount of rainwater required (evaporated or used directly) to make an item.

Grey Water Footprint: The amount of freshwater required to dilute the wastewater generated in manufacturing, in order to maintain water quality , as determined by state and local standards.

Examples of how each of these contributes to a food item's total water footprint can be found in the **Water Footprint of Food Guide**. To explore food as well as some other items, go to the Water Footprint Network's **Product Gallery**.

Who Created the Concept of Water Footprints?

The concept, sources and methodology come from the **Water Footprint Network** (WFN). The concept was created by **Dr. Arjen Hoekstra** who, along with the others at the WFN, developed the framework and established the international organization as the foremost research network in the discipline.