9 Watershed Management: The Big Picture

Introduction

Our attention is drawn to water in lakes and streams. Houses line the shore, with windows facing outward to the water, drawing our eyes away from the surrounding hillslopes. The uplands surrounding each lake, however, are part of the lake's watershed. They are the source of water to the lake and cannot be ignored. Upland activities play an integral role in the health and sustainability of a lake. It is critical to understand the links between a lake and its watershed to help manage the watershed wisely and to protect the lake.

A watershed is defined as all land that contributes rainfall to a body of water. The watershed functions like a bowl, and water runs downhill to the bottom where the lake is located. The **watershed divide**, created by hills, ridges or mountains in the landscape, is equivalent to the lip of the bowl, and its location determines where rainfall will go. The watershed divide, therefore, determines the limits of water sources that enter each watershed. See Chapter one, "Lake ecology," Figure 1–4.

Watersheds vary in size, with the smallest catchment basins containing only a few square miles, nested within larger watersheds, which are embedded in the largest drainage basins, such as the Mississippi, Nile or Amazon rivers. These major basins may include tens of thousands of square miles. Traditionally, there has been no distinction in the naming of watersheds based on size, and the terms watershed, drainage area, river basin and catchment are generally used interchangeably. Major drainage basins have been identified within New York State. See Chapter two, "From Montauk to Erie," Figure 2–2.

These basins contribute significantly to the major waterbodies in the eastern United States. They drain to the four main points of the compass:

- North to Lake Ontario and the St. Lawrence River;
- West to the Ohio and Mississippi rivers;
- South to the Delaware River, Delaware Bay and the Susquehanna River--the major tributary of the Chesapeake Bay; and
- East to the Hudson River and the Atlantic Ocean

Natural water flowpaths

Despite enormous variability in watershed sizes, the processes controlling movement, availability and quality of water are similar. Understanding the flowpath of water moving through the watershed and the phases of the hydrologic cycle by which water is affected (Fig. 9–1), is critical for understanding and managing the landscape for sustainable water.

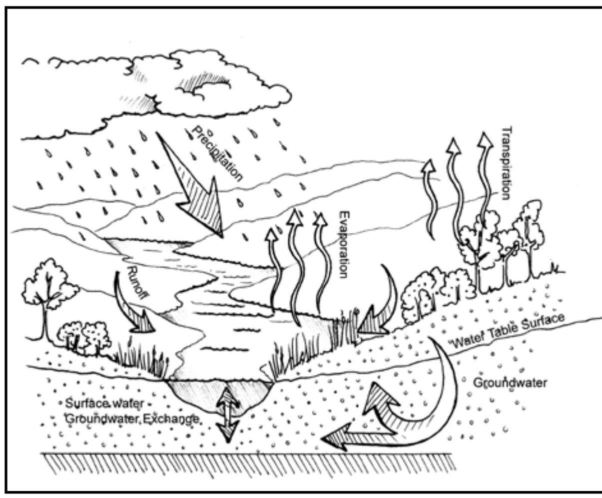

Fig. 9–1. Cross-section of a watershed showing the three major flowpaths of water after it enters the basin as rain or snow. (Credit: Chris Cooley)

Prior to human occupation, mixed hardwood forests covered much of the landscape of the northeastern United States and had become well established following the recession of the glaciers about 10,000 years ago. Within forests, most rainfall and snow are first intercepted by the vegetative canopies of dense, leafy treetops as well as shrubs and herbaceous or grassy meadows. These plant canopies take the full force of the falling rain and slow the impact of raindrops before they hit the soil surface, reducing their power to dislodge soil particles. Extensive networks of plant roots also help bind the soil and hold it in place.

In a forested landscape, most precipitation infiltrates into the soils instead of moving as overland runoff (Fig. 9–2). The amount of direct runoff depends in part on the duration and intensity of a precipitation event. This flowing water moves downhill following natural depressions in the land surface to form little creeks, which intercept other creeks and coalesce to form bigger streams and rivers. This interconnected system is the stream-channel network that drains water naturally from the watershed. The smallest creeks, roughly about three feet wide, are known as **headwaters** and cumulatively account for one-half to three-quarters of the total stream-channel length. These inconspicuous creeks intertwine throughout each watershed and provide a tight connection between the land and water.

Under dense, continuous vegetation, only a little water actually runs across the ground surface. Plant roots, soil clumps, earthworm holes and animal tunnels combine to create microscopic channels by which water moves downward. Surface layers of rich, black, loamy, organic matter also absorb water like a sponge. This organic matter can be very deep, derived from centuries of accumulation of decomposing leaf litter. Some accounts from pioneering explorers who first visited western New York describe the soil of the lowlands as having a rich, organic-matter layer from 8 to 12 inches deep. Such deep organic soils are hard to find today.

Water penetrates the soil surface until it meets bedrock or another impermeable surface and then begins to fill the pore spaces between the soil particles. This saturated zone is called groundwater, and the top

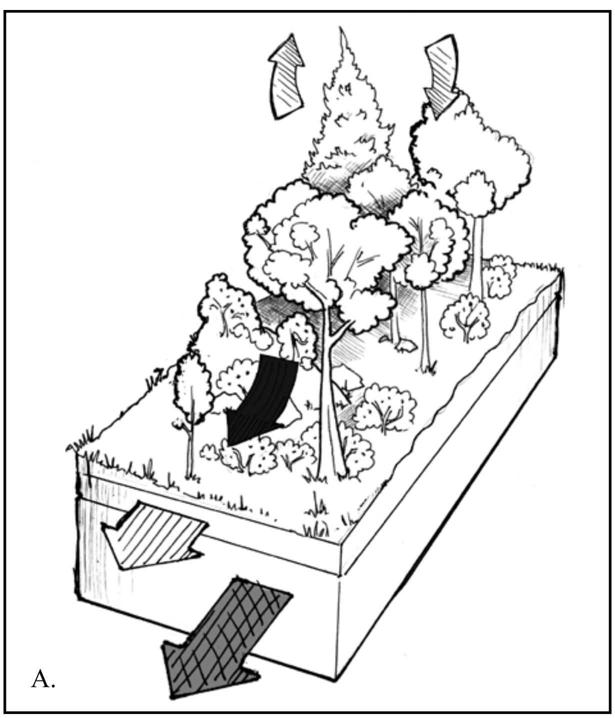

Fig. 9–2. Schematic showing how rainfall is distributed between runoff and infiltration to groundwater. A. Highly vegetated landscape. B. Landscape altered by impervious surfaces.

(CREDIT: CHRIS COOLEY MODIFIED FROM *RAPID WATERSHED PLANNING HANDBOOK*, 1998) is called the **groundwater table**. Some groundwater moves laterally along shallow flowpaths less than six feet deep below ground and makes its way into creeks. This shallow flow, plus direct overland runoff, occurs within minutes to hours of a rainfall event and is responsible for the visible rise in creek levels that occurs in response to an intense storm (Fig. 9–3). Much of the sediment movement in streams occurs during this initial rising water level, a phenomenon called "first flush." Snowmelt each spring also results in a high and prolonged rise in water level in most northern streams. Deeper groundwater, however, moves much more slowly. Groundwater continues to contribute to flow in the stream for days, weeks and even months after the precipitation event. This is called **baseflow** and is critical for maintaining life in streams and for providing aquatic habitats for fish, insects and other organisms. A nationwide study by the U.S. Geological Survey (USGS) in 1998 determined that roughly one-half of all water flowing in streams comes from groundwater (Winter et al, 1998).

Groundwater contributes significantly to the surface water of our lakes. Coastal-plain ponds of Long Island and other kettle lakes are actually a surface outcropping of the underlying groundwater table and usually have no evidence of stream inflows or outflows. Their water levels simply fluctuate with the natural rise and fall of the larger groundwater system.

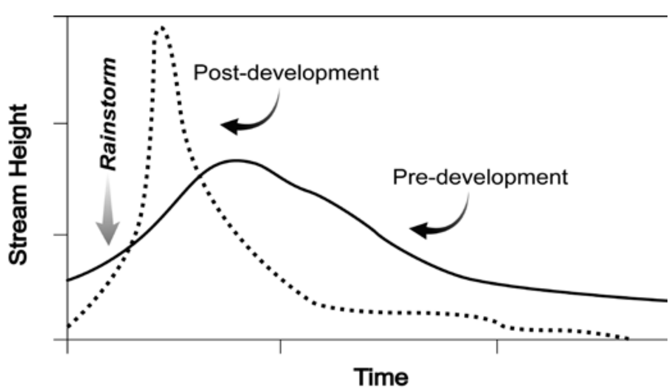

Fig. 9–3. Plot of stream level rise, called a hydrograph, during the course of a storm event both in the forested pre-development landscape and in a post-development landscape with lots of impervious surfaces.
(CREDIT: CHRIS COOLEY)

Groundwater is also a contributing source of deeper lake waters. The groundwater moves rapidly as shallow flow from near-shore areas and discharges directly into the lake along the shorelines. Deeper groundwater flowpaths, originating farther away in the watershed, also contribute to lakes but at slower rates. This invisible shoreline seepage is a common phenomenon in many lakes. Groundwater discharges from the sediment for distances of 30 to 40 feet from the lake's edge. On a hot summer day, swimmers can feel cooler groundwater seeping around their feet.

The water cycle is completed through the process of evapo-transpiration. This includes evaporation of water from lake and land surfaces and transpiration of water through stems and leaves of trees and other plants. Solar energy from the sun converts water from the liquid to the vapor form. Ultimately the water vapor condenses to clouds that start the process of precipitation again.

Human effects on watersheds

Humans have altered watersheds, and these changes have affected the quantity and quality of water that enter rivers and lakes. Humans have cleared forests, replacing them with buildings for residential, industrial and commercial development, with agricultural fields and lawns and with networks of roads. This means fewer forest canopies to intercept rainfall and fewer roots to bind and hold soil. Raindrops impact the soil, splashing and dislodging soil particles which are easily carried away by surface runoff.

Many soil properties that influence water retention have also been degraded. The sponge-like properties of soil depend on the amount of organic matter or decomposing leaf litter present. This organic matter, however, has largely been oxidized by exposure to the sun and washed away by rain. Annual harvesting of crops, without leaving leaves or stems behind, reduces organic matter buildup in fields. Repeated lawn mowing, with removal of grass clippings, has the same result. Most recently, exotic earthworms have invaded our landscapes as escapees from bait buckets or compost piles. These invasive species consume organic matter at high rates and have contributed to the decline in soil organic matter content.

Soil is also more compacted, with fewer air spaces or pores for water to move through. Tilling with heavy equipment and vehicle traffic causes clay particles to stick together, decreasing the soil's porosity when the soil is wet.

When rainfall occurs, less infiltration takes place due to these changes, and more overland runoff occurs. This overland flow is increased because we have replaced our natural soils with the impenetrable surfaces of asphalt roads, building rooftops and parking lots. Rainfall runs from these impervious surfaces and is captured by the network of drainage ditches and storm sewers that have been engineered to prevent road flooding. The network of ditches captures the runoff and rapidly transports it directly to the streams!

Consequently, the movement of water into creek channels becomes much more rapid as water from each part of the watershed races into the **stream channel** at about the same time. Stems and leaves of healthy vegetated streamsides would normally slow rising flood waters (Fig. 9–4). Curving meandering streams also would slow down the flow rate. In many places, however, streamside plants have been cleared and replaced with housing developments or fields. Stream channels have been straightened and shorelines hardened, creating perfect sluiceways to carry water downslope. Water levels rise faster and higher than before. Floods result, as has been clearly demonstrated along the Mississippi River in the United States and in recent floods and mudslides on deforested slopes elsewhere around the world. Studies now clearly document that the magnitude and frequency of floods has increased due to human development in watersheds.

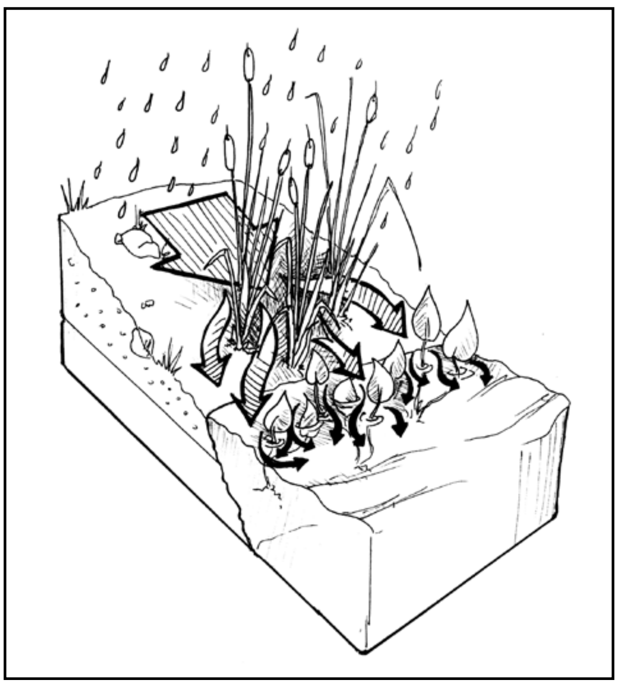

Fig. 9–4. Schematic showing how wetland plants intercept and slow down flowing water during storms. (CREDIT: CHRIS COOLEY)

It is necessary to reexamine the events in the hydrologic cycle to understand how flood frequency can be increasing, even when drought frequency is also increasing! Each watershed receives only a finite amount of precipitation. It can move across the surface as runoff, infiltrate the ground to contribute to groundwater or evaporate into the atmosphere. When runoff is increased, less water is available to recharge the groundwater, and the groundwater table drops in elevation. The groundwater drop is further exacerbated by withdrawal of water from wells for irrigation and drinking water. Society is increasingly turning to groundwater as a dependable, clean source of fresh water, and new wells are being drilled daily. While normal precipitation may have occurred in a watershed, losses from overland flow and increased pumping reduces the groundwater aquifer below a level needed to maintain streams, wells and vegetation. Humans perceive these conditions as a drought. Streams dry out, leaving fish and other aquatic organisms stranded. Wells run dry because the water table drops below the bottom of wells. Crops and garden plants die because they can no longer use deep roots to access moist soils and groundwater.

The increases in runoff due to poor watershed management are being exacerbated by changes in the patterns of timing and intensity of precipitation resulting from global climate change. Studies have clearly demonstrated an increase in the intensity of storm events in New York and parts of the Northeast over the past century. Results of model predictions by the Union of Concerned Scientists (Hayhoe, et al, 2007) suggest this trend will continue over the next several decades.

Human effects on water quality

It is not just the quantity of water that has been affected by changes in our watersheds. Water quality is also deteriorating. Contaminants enter above ground by surface flow in tributary creeks and below ground in groundwater. Contamination from clearly identified individual sources is called **point source pollution**. These sources include regulated operations such as industrial discharge, sewage-treatment plants or known groundwater pollutant sources such as landfills. Federal and state governments established a comprehensive program for addressing point source pollution with the passage of the *Clean Water Act* of 1972 and its subsequent amendments. Water pollution can also be due to an accumulation of contaminants from multiple smaller sources across the landscape, and this is called diffuse or nonpoint source pollution.

Nonpoint source pollution is difficult to control because it involves many small sources distributed across a broad area. Sediments eroding from cleared lands are a major problem, turning lake water brown and cloudy after every rainfall event. Runoff from parking lots and roads carries trace metals, aromatic hydrocarbons and other contaminants associated with vehicles. Pesticides and fertilizers are transported rapidly with runoff from suburban lawns and from croplands. At critical concentrations, all these chemicals can harm fish and other aquatic organisms. They also make the water unhealthy for swimming and drinking by humans.

Phosphorus is important for the growth of algae and plants. Under natural conditions it has limited availability in freshwater systems. Phosphorus contamination, however, is a concern because excess amounts cause algal blooms and lake eutrophication. Phosphorus from fertilizers and from livestock and human wastes is transported into fresh water whenever there is erosion from construction sites, croplands or lawns because it binds readily to sediment particles,

Some contaminants enter our lakes below ground, carried by groundwater from upslope septic systems, agricultural fields, livestock facilities, leaking fuel tanks, automotive or industrial spills. Wastes from livestock or septic systems create a different type of risk because they are a source of bacteria, viruses and other disease organisms that can threaten water quality and human health. Many of these **pathogens** persist for days or weeks in water and soil, and some have dormant stages that can last for years. These pathogens are transported easily in above-ground runoff but can also move in groundwater.

Healthy, vegetated wetlands and streamsides can help to eliminate many contaminants from groundwater before they enter surface waterbodies. Both wetlands and streamsides are the natural filter systems that interface between our terrestrial and aquatic habitats and remove contaminants using a variety of processes (Fig. 9–5).

- Growing plants take up phosphorus and other nutrients and transform them into leaves, roots and other tissues.
- Sponge-like organic matter in the soil binds to phosphorus and trace metals and stores these contaminants in the soil profile.
- Microbial organisms residing in the wetland soils can transform some chemical contaminants. In particular, nitrate (NO_3-), a component of fertilizers and animal wastes, is transformed into gaseous nitrogen (N_2) by denitrifying micro-bacteria and then released into the large atmospheric pool of nitrogen gas. Thus it is efficiently and inexpensively removed from groundwater.
- Bacteria and viruses also are removed during the transit through wetland soils, consumed in microbial food webs or bound to clays and organic matter.

These processes provide valuable ecosystem functions that have been lost in many places**.** More than half of the nation's wetlands have been drained and replaced with housing developments or croplands during the past 100 years. Streamside vegetation has been cleared and stream banks reinforced to make way for railways, roadways, crops and buildings. There are ongoing initiatives to restore legally recognized wetlands. There is no comprehensive federal or state protection, however, for most stream-side habitats, and much work is needed to reestablish wetlands nationally.

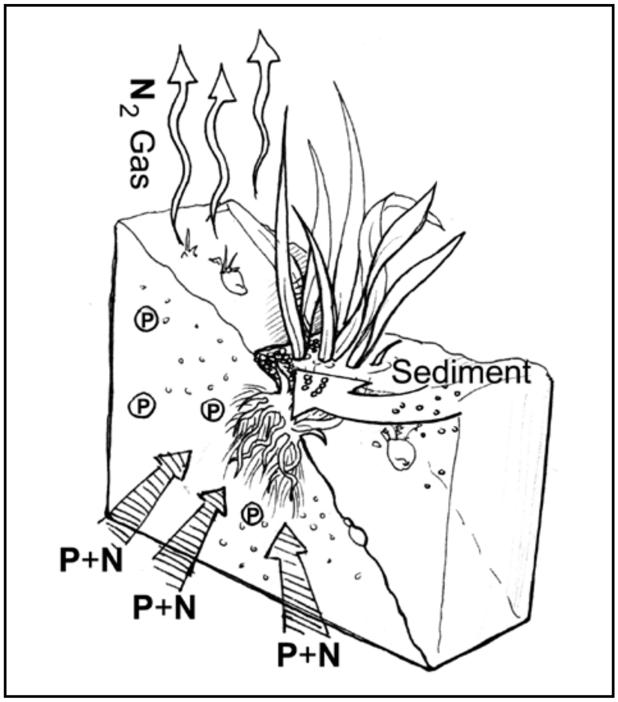

Fig. 9–5. Schematic showing how wetland plants remove contaminants from groundwater by plant uptake.
(CREDIT: CHRIS COOLEY)

What can you do?

Cumulative changes affect the quality and quantity of our water. It is important to manage the watershed to maintain a healthy lake. Traditional approaches to managing water resources have been nonintegrated and usually have competing management strategies designed to address single, narrow purposes. Typically, a river-lake system is managed simultaneously for waste disposal, flood control, recreational fishing and irrigation or public water supply by independent government agencies, without public input and without consideration of the cumulative effects on the long-term health of the water itself. In the last two decades, however, awareness of the cumulative environmental effects resulting from this approach has been recognized. There have been some radical changes to management strategies that include all stakeholders and particularly public citizens in the following activities:

- Discussion of how a water resource is used;
- Consideration of the watershed as the comprehensive unit of management; and
- Incorporation of mechanisms for monitoring success and providing feedback so that management strategies can be changed if stakeholders are dissatisfied or water quality deteriorates.

The immediate need of dealing with one site-specific pollution episode after another often demands attention and consumes the efforts of lake managers. Such ongoing, recognizable threats to water quality can continually dominate the focus of management and prevent development of long-term approaches for sustainable protection of a lake and its watershed. It is imperative, however, to build a proactive, comprehensive watershed plan. Information about legal requirements is developed in Chapter ten, "Legal framework." Chapters eleven, "Management Plan Development" and twelve "Implementation and Evaluation," discuss in detail the process of watershed management planning and implementation.

General strategies for watershed management

Techniques available for improving water quality and quantity are as numerous as the list of land-use practices that may occur in a watershed. Specific problems and the typical recommended practices to solve them are described below. It is important to realize that different types of strategies may be relevant in dealing with any given issue. Three broad types of strategies in use are regulation, stakeholder outreach and education, and financial incentives.

Regulation

People generally assume that the only way to stop a problem is to create an ordinance or other regulation that makes an activity illegal. An example of an ordinance would be establishment of stream-side buffer requirements and prevention of vegetation clearing (see the sample ordinance.) Such legislative-based deterrents do play an important role. To be effective, however, they require resources for detection, policing and enforcement-processes that can require tremendous amounts of effort and time. Often towns have a direct opportunity to enforce such regulations only when landowners apply for a construction permit or variance. As a result, it is valuable to consider the advantages of two other strategies:

- stakeholder education; and
- financial incentives.

When used in the proper combinations, these strategies provide powerful tools for improving watershed management. As they are being implemented, it is important to provide mechanisms for monitoring and for incorporating feedback into the decision-making process.

Sample Ordinance: Streamside protection setback

The setting: Town of Ulysses, Tompkins County, NY Zoning Ordinance

The problem: As a result of the implementation of the U.S. Environmental Protection Agency (EPA) Phase II Stormwater Regulations in 2003, portions of the Town of Ulysses that adjoin Cayuga Lake were identified as constituting an MS4 community and, therefore, subject to Phase II regulations. Within this area, steep slopes are subject to increasing development pressure, and numerous small tributaries are sources of sediment and runoff into Cayuga Lake.

Response: Considering the broader issue of erosion control as a town-wide issue of importance, the town adopted a zoning ordinance designed to protect streamsides by requiring vegetated buffers adjacent to all streams. The zoning ordinance states:

> "USGS topographic maps will be used to classify impermanent and permanent streams. Impermanent, also known as seasonal, streams require a minimum of twenty-five (25) feet of setback on each side of the stream, extending from the stream bank towards the uplands. Permanent streams are required to have a minimum fifty (50) feet of buffer on each side of the stream, extending from the stream bank toward the upland."

Results: Existence of this ordinance in the town zoning law has facilitated the review of construction permits by board members and reduced ambiguity about required protection practices. Although in place for only one year, the ordinance provided valuable guidance for town planners and developers dealing with site plan design and approval.

Stakeholder outreach and education

Inappropriate landscape practices often arise from lack of information on the part of watershed residents. Most landowners have a natural sense of stewardship, and they want to take care of the land and water. Few people, however, are aware of the connection between activities on their property and the effects on a lake or stream that may be several miles away. Educating landowners about their actions and how they can affect downstream waters can be a powerful tool. This educational outreach includes holding workshops, developing and distributing fact sheets, home visits, billboards, radio or television advertising and a host of other strategies. Education is generally directed toward adults. Research suggests that long-lasting changes in behavior are best achieved by engaging youth through school or other activities. Children can often reach their parents with an educational message more effectively than agency professionals.

Financial incentives

Increasing awareness of good practices is an important first step for changing landowner behaviors and improving the lake watershed. Sometimes changing a land-use practice requires new equipment, labor or other resources that have costs beyond the scope of the individual landowner. Landowners also may not be able to afford the long-term maintenance costs of a given practice. Farmers tend to be supportive of replacing crops with natural woody vegetation along a stream's edge, but few can afford to do the actual streamside restoration or to absorb the annual loss of profit resulting from taking that land out of cultivation. Successful adoption of this practice by farmers is more likely if financial resources are made available in conjunction with an outreach program. It may be enough to provide planting supplies, loan earth-moving equipment or assist with labor during construction. Alternatively, it may be necessary to provide annual tax relief after the project is in place to augment a farmer's agricultural income.

Comprehensive watershed planning

The next step in planning is to take a comprehensive, big-picture look at the watershed. This holistic approach is needed to thoughtfully plan for the types, locations and amounts of future development that can potentially place negative pressure on the lake and its surroundings. This level of comprehensive planning is particularly useful where river or lake flooding or summer droughts have already become a problem.

The first focus will be to protect those areas of the watershed that directly influence lake water quantity and quality. Such critical areas should include the following:

- Groundwater recharge areas;
- Steep slopes which could be a source of erosion and runoff;
- Lake shorelines where vegetated buffers would help to filter water, buffer wave energy and reduce erosion;
- Wetlands of all kinds;
- Areas with sensitive soils, such as sands, which drain rapidly without attenuation of contaminants; and
- Vegetated buffers along all tributary streamsides, including headwater streams.

Comprehensive planning should also take into account biologically critical habitats in upland areas that provide important resources at different stages in the life cycle of desirable aquatic organisms. Herons and wading birds, for example, feed along the shallow water edge but use nearby woods for roosting and nesting. Certain types of lake fish migrate up tributary streams for spawning. Both amphibians and reptiles, typically viewed as purely aquatic organisms, incorporate the surrounding terrestrial landscape into critical parts of their life cycles. Snapping, painted and spotted turtles all have shelled eggs that must remain oxygenated during incubation. Female turtles will leave a lake and travel up to 500 feet or more into surrounding terrestrial uplands until they find appropriate habitat to dig their nests (Fig. 9–6). In contrast, salamanders, frogs and other amphibians lay their gelatinous eggs within the water, floating freely or attached to strands of vegetation. Once the juveniles have metamorphosed into their adult forms, many species of frogs and salamanders leave the water and migrate into the surrounding uplands for distances of 50 to 200 feet, where they may spend several years living under the litter, in the soil or on the vegetation. It is critical to protect all these outside-lake habitats to maintain the populations of such organisms for the long term.

These biologically critical areas should be included as lands are identified for protection. In addition, it may be important to identify and protect a buffer zone immediately outside the critical area where development and other activities are minimized. This buffer zone should consist of a naturally vegetated transition area that can provide a visual screen, a noise-reduction buffer and a first filtering system for trash and other wastes. Native plantings appropriate to the specific region of the state should be used.

Planning is also important outside of these critical areas. If flooding and summer droughts are becoming a problem, it will also be useful to take a fresh look at land uses across the watershed that accelerate runoff

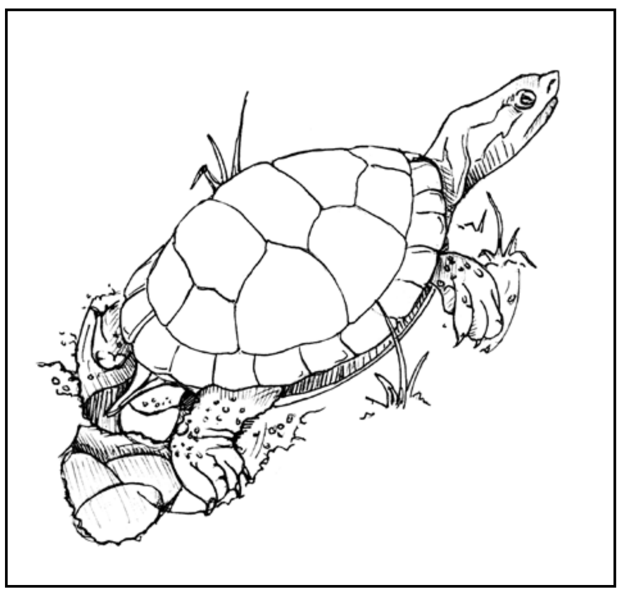

Fig. 9–6. Female turtle building nest in upland soil.
(Credit: Chris Cooley)

and decrease groundwater infiltration during storms. Impervious surfaces of rooftops, roads and parking lots are a primary culprit. A rule of thumb is that watersheds having more than 10 to 15 percent coverage by impervious surfaces will exhibit clear signs of altered stream-flow patterns, increased magnitude and frequency of flooding and reduced baseflow between storms, erosion, habitat collapse and loss of aquatic species. Numerous other types of land practices also will contribute to these problems:

- Loss of former wetlands that have been drained and ditched or filled to support railroads, agriculture, insect control or housing development;
- Streams that are straightened and dredged or have armored banks that rapidly convey water downstream;
- Extensive networks of roadside ditches that drain runoff directly into streams; and
- Fields left uncropped and exposed during storms and spring snowmelt.

Protection of steep slopes, reestablishment of green spaces or restoration of wetlands and stream channels are solutions that will help to alleviate these problems.

Management of growth

It may be desirable to limit the amount of development allowed to take place. Development can be valuable with benefits such as increased services or tax revenue available to the overall community. Higher density development, however, will also produce increased water use, waste generation and habitat loss. Certain types of businesses and industries have risks associated with the chemical wastes they produce. Once established, it is very difficult to remove buildings or families that have become "rooted" and view themselves as part of the community. Careful planning can allow development to proceed only to appropriate levels. Engagement of the community during this process is critical to avoid contention associated with the use of taking by eminent domain.

Various strategies are available. For most of these, however, the lake association will need to work collaboratively with the various local governments that exist within the watershed. Local governments in New York State play a major role in determining land use within their town, village or county jurisdictions. Watersheds rarely follow political boundaries. It will take some effort and patience to help the different town boards understand that they need to become part of a larger, more integrated group with common goals. A lake association can work collaboratively with local town boards to develop a long-term plan that meets the goals of both the towns and the lake association.

Local governments have the authority to prepare and adopt comprehensive plans, zoning and subdivision regulations. They frequently are in a position to decide what land-use issues will be addressed and what standards will be used. Ideally, each local government should have a current, comprehensive plan or master plan outlining the use of land resources within the area of its jurisdiction. This plan should be somewhat flexible because goals and objectives will change as the community grows and develops. The following is a list of strategies available for carrying out control of the development set forth in such a plan.

Zoning

Zoning is a method by which local governments can protect natural resources using regulations to control land-use activities. The area in the town's jurisdiction is divided into districts. The local government then establishes laws which govern the use of land within each district. Zoning can protect water resources directly by identifying protection districts for physical or biologically critical areas, such as watersheds, wetlands and aquifer recharge areas. Through zoning laws for a given district, community development around a lake can be controlled by restrictions which define minimum setback distances from the lake's edge, percentage of a lot that can be occupied and minimum lot size. Some additional zoning regulations that help to protect lake water resources include the following:

- Restrictions on slopes greater than eight percent to reduce housing density;
- Preventing erosion and runoff by restricting maximum house size, percentage of land cleared, on-site stormwater runoff management, impervious surface coverage;
- Restrictions on type, location or maintenance operations of residential on-site waste-disposal systems to prevent pollution of lake water;
- Requiring minimum widths of vegetated buffer strips along stream edges and lakeshores to maximize water filtration and erosion control;
- Building code requirements with limits on height to prevent obstruction of views, design requirements to reduce flood vulnerability, use of permeable walkways and driveways and a requirement for on-site retention of all stormwater runoff; and
- Development density controls, including cluster zoning to concentrate human usage and allow for greater expanses of green space or requiring large minimum lot sizes to minimize the percentage of impervious surface coverage.

Zoning variances

A **zoning variance** is an exception granted by the zoning board of appeals to a landowner removing all or some zoning restrictions. Zoning variances can be developed in some areas to protect unusual landscape features, such as steep hillsides, scenic vistas, erosive sites and natural drainage which may restrict development. Special zoning provisions can be established such as "incentive zoning," which allows for cooperative arrangements between an individual property owner and the community.

Reality check on the power of zoning controls

Zoning laws are a critical first step because they provide the authority for controlling development. See Chapter ten, "Legal framework" for discussion about developing a town zoning ordinance. Without an ordinance in place that requires protection of vegetated streamside buffers, the majority of developers and landowners will not understand the need for setting aside land that could be cleared and used for other purposes. Having a regulation in place, however, is not sufficient by itself, and the laws do not necessarily reflect the reality of the process. Implementing and enforcing regulations is critical. The power for implementation is determined by the members of the town board, who are responsible for creating the zoning law; by members of the planning board, who determine how stringently new development permits are reviewed, and by members of the zoning board of appeals, who determine when the regulations can be set aside. In small communities, the composition of all three of these boards plays a big part in how development proceeds. Town board members are elected by the public, but members of the other two boards are appointed by the town board. The self-interests, political motivations, financial concerns or environmental attitudes of these individuals frequently influence how zoning is translated into practice.

Land acquisition

Land acquisition is a way to plan for the preservation of natural resources, open spaces and to provide areas for public recreation. Land acquisition is frequently accomplished by state, county or local governments or by a private non-profit organization such as The Nature Conservancy. Conservation easements and land trusts are the two methods of land acquisition most frequently used in New York State. Potential revenue sources for land-acquisition projects include state appropriations, county and local property taxes, county sales tax, local improvement districts, motel-hotel tax, transfer tax and user fees, as well as state and other local bond acts.

A **conservation easement** is a legal document which restricts the type and amount of development that may take place on a parcel of land. The most distinctive aspect of protecting land through granting a conservation easement is that the property remains in private ownership, yet its current and future use is regulated by a legal agreement which is stronger than local zoning or land-use laws. Conservation easements are often developed for open-space preservation, historic preservation, protection of natural habitats, and preservation of areas for public recreation or education**.** Additional details on easements are described in Chapter ten, "Legal framework."

A land trust established in the Thousand Islands handles conservation easements for almost 1,000 acres on Grindstone Island. These easements will prevent further development of the land and will preserve some of the island's scenic vistas. In addition, the easements will provide protection for one of the two remaining muskellunge spawning grounds by prohibiting cultivation, timbering and construction within 100 feet of the mean high-water mark.

Point source pollution control

The smelly, offensive discharge from an industrial pipe into a stream can easily be recognized as the source of a downstream fishkill. In the early years of water management, such pollution was considered synonymous with point source pollution. The first targeted national effort to clean up our waters was to eliminate these situations. The federal government established the *Clean Water Act* in 1972, empowering states to control these discharges. The act and its subsequent amendments identified a set of standards for acceptable drinking-water levels. It set standards for allowable maximum concentrations or allowable chronic exposures for designated periods at lower concentrations for many different pollutants. These standards are based on research studies that quantify the effects of contaminants on the health of humans, fish and other organisms, as well as the smell, appearance and other properties of water. New research may periodically indicate the need for tightening the standard for a specific pollutant. The *Clean Water Act*, now in place for almost four decades, has been highly effective at improving the quality of the nation's waters.

With the enabling legislation of the *Clean Water Act*, New York State created the State Pollution Discharge Elimination System (SPDES) which requires that a Department of Environmental Conservation (DEC) permit be obtained for "constructing or using an outlet or discharge pipe that discharges wastewater into surface waters or groundwaters of the state, or constructing or operating a disposal system such as a sewage treatment system."

The SPDES system designs permits to meet the water-quality standards established by the EPA. SPDES permits are in effect for five years and then require a renewal application. Transfer of ownership requires a reevaluation of the permit, as does any modification to the discharge. Additional details concerning the SPDES permit system are included in Chapter ten, "Legal framework."

Point-source discharges generally have been less problematic for lakes than for rivers in New York State because more discharges go into flowing waters or groundwater than directly into lakes. This is due in part to two old adages. "Out of sight, out of mind" dictates pushing wastewater quickly and as far away from lakefront or riverfront communities as possible, while minimizing the cost of piping wastewater deep into the bowels of a lake. "Dilution is the solution to pollution" utilizes the cleansing capacity of rivers and very large lakes. There remain, however, many lakes in New York State, particularly large lakes such as the Great Lakes, Oneida Lake and the Finger Lakes, that are used in part to assimilate wastewater. A greater number of lakes are downstream of wastewater-treatment plants.

The effectiveness of the SPDES approach is based on a system of regular monitoring of the quality and quantity of the permit-holder's outflow. The permit holder is required to monitor the outflow and report on a monthly basis or, at minimum, on an annual basis. DEC complements the self-monitoring with periodic sampling. Violations to the permit requirements, such as excessive eliminations, inadequate controls or insufficient reporting, can be subject to civil or criminal court action, fines or shutdowns. SPDES has proven to be an effective system for reducing water pollution. The weakness in the system is its dependence on self-monitoring, which necessitates that permit holders be honest, competent and willing to comply with permit requirements. Without such cooperation, small violations such as periodic dumping of larger pollutant quantities may pass through the monitoring process undetected.

Wastewater treatment facilities

The most common SPDES permits relate to **wastewater treatment facilities**. This type of permit deserves special consideration because wastewaters from these facilities often are discharged directly to watercourses, usually streams, rivers and lakes. Up to 95 percent of wastewater discharged from industrial and municipal treatment facilities consists of pure water. The balance consists of suspended materials, dissolved organic matter, microbiological pathogens such as bacteria, and nutrients such as phosphorus and nitrogen. The actual content of the wastewater depends on the source of the water. Industrial wastes can contribute a diverse and more toxic suite of contaminants, including trace metals and organic compounds. Each SPDES permit issued by DEC evaluates the specific chemicals used in the industry and sets limits on discharge concentrations to control environmental damage.

Wastewater treatment plants are designed to remove the bulk of these contaminants to protect downstream aquatic systems. The completeness of removal is dependent on the type of wastewater treatment system used.

Modern wastewater treatment technologies are capable of converting wastewater to drinking-water quality. Numerous municipalities around the world turn sewage into public drinking water, especially where water is in limited supply. Most of our southern states recycle water for irrigation or groundwater recharge. Industrial and municipal wastewater plants typically discharge into rivers, streams and lakes, only to have downstream municipalities withdraw water from that same waterbody for public drinking-water supplies. It might sound disgusting, but water leaving the space station's purification system is cleaner than the water most of us drink on earth. Wastewater from urine, oral hygiene, hand washing and condensation is reclaimed from the space shuttle's fuel cells. Even on earth, people might be consuming tomorrow what is flushed today because all the water on the earth is recycled.

Why not treat all wastewater to pollution-free levels? The simple truth is the cost involved. The higher level of treatment efficiency a system has, the greater the capital construction costs and the expenses for long-term operation and maintenance. Small, on-site systems, such as septic tanks and leach fields, are relatively simple, inexpensive systems that require little maintenance. They are not, however, very efficient at removing all pollutants humans dump down the drain and ultimately into our lakes and streams. Today there are ever-increasing numbers of on-site systems that use a wide range of technologies previously tested and used in full-scale wastewater-treatment systems.

Large-scale municipal wastewater treatment systems

Sewage collection systems convey wastewater from homes and businesses to a treatment facility. There are three types of gravity sewers: sanitary, storm and combined sewers that simultaneously carry both sanitary wastes and stormwater runoff. Unfortunately, many municipalities with regulated combined sewers often experience overflows during major rain events. When this happens, the combined flow exceeds the capacity of the wastewater-treatment plant, and untreated effluent is discharged directly into the stream or lake.

Throughout the nation, **sanitary sewer overflow systems (SSO)** and **combined sewer overflow systems (CSO)** lead to unregulated discharges. The Wet Weather Water Quality Act of 2000 addressed these problems through the Capacity, Management, Operations and Maintenance Program (CMOM). CMOM helps local municipalities develop capital improvements and maintenance plans for their collection systems. There are many methods for evaluating and testing collection systems for rehabilitation. Smoke testing, flow isolation, internal television inspection, dye tracing and hydraulic modeling are all methods for assessing what needs to be fixed. There are also many new trenchless technologies compared to dig-and-replace methods of repair. The EPA publishes guidance documents for CSO control, and these can be found by contacting the EPA's Office of Water Resources Center (see Appendix F, "Internet Resources").

Pump stations are used when sewers are located at too great a depth or on too steep an incline for gravity movement. Many communities in hilly areas may have numerous pump stations. Lake homes are often placed near the water and have to use a pump station to lift their wastewater up to a gravity-collection system if one is available. Pump stations are mechanical devices that rely on a constant power supply and maintenance. Homeowner systems do not normally have the advantage of duplicate equipment and standby generators that are available to larger municipal systems.

Preliminary treatment

Preliminary treatment is the first step in the process once the collection system conveys the wastewater to the treatment plant. Large screens remove large objects that can plug the pumps and then sand and stones that can fill up process tanks are removed.

Primary treatment

Primary treatment is a physical process of settling solids that have a specific gravity greater than water and flotation of particles that have a specific gravity less than water. Material such as plastics and grease are removed from the surface of the primary tanks. Heavy solids sink to the bottom and are removed daily before they become anaerobic and produce methane gas. These solids are then pumped to the solids-handling units, where they go through digestion or dewatering. The residual sludge may be used as compost or spread on agricultural fields, although there are some concerns about the long-term effects of the associated chemicals and pathogens on soil and groundwater. The liquid, dissolved-solids product of primary treatment flows on to secondary treatment.

Secondary treatment

Some plants skip the primary treatment process, allowing wastewater to flow directly into the secondary process from the preliminary treatment process. There are many secondary processes, but they all have the goal of removing non-settleable solids and of converting soluble material into material that will settle for ultimate removal and separation from the liquid. The majority of secondary processes today use biological microorganisms that consume soluble organics in wastewater and convert them into biological cells which have specific gravity greater than water. These cells will settle to the bottom of a secondary clarifier, a large, low-velocity tank, and are later removed and processed in solids handling. Generally, there are two types of microorganisms used:

- Attached-growth microbes are found in processes such as trickling filters and rotating biological contactors. They attach to a media, and wastewater is introduced to them. These processes rely on a sufficient amount of food (wastewater), oxygen (ambient air) and a wide range of microorganisms (bacteria and protozoans) to convert wastewater into a growing biomat attached to the media. Eventually, the microbes detach from the media and flow into a downstream tank for removal. New attached microbes grow in their place, and the cycle starts again.
- Suspended-growth microbes live in a suspension of water, food and other microbes within a tank that has aeration (ambient air) introduced at the bottom to mix microbes with wastewater and supply oxygen for their respiration. This process is called activated sludge, and there are many variations of the process. Some are designed specifically to remove carbonaceous materials, and some are designed to remove nitrogen and phosphorus. As with the attached-growth process, there is a secondary clarifier that settles the microbes for removal to solids processing or reuse back into the aeration tank.

Tertiary treatment

Tertiary treatment provides additional treatment beyond typical secondary levels. A variety of processes available include using microbes under aerobic and anoxic conditions, chemical precipitation, sand filtration, microfiltration, membrane filtration, activated carbon, reverse-osmosis, constructed wetlands and other processes specific for nearly anything desired to be removed. These cutting-edge technologies can be specially tailored but are expensive to construct and operate. Many are being widely used, however, in sensitive watersheds that require very low levels of nitrogen and phosphorus discharges.

Post treatment

The treated water is conditioned to make it more suitable for aquatic life in the receiving water prior to discharge into a stream or lake. Some wastewaters may need post treatment to adjust the pH to an acceptable range or adjustments may be needed to add dissolved oxygen. Some industrial facilities also adjust the temperature of the water being discharged. Almost all municipal systems are required to disinfect their treated water prior to discharge to remove any possible pathogenic microorganisms that might make it through the treatment processes. Most facilities use chlorination because of its low cost and ease of use, but it interacts with organics to form chlorine-produced disinfection by-products (DBPs). As an alternative, many plants are using ultraviolet (UV) light technology to radiate microorganisms and prevent their replication.

Solids-handling systems

Solids-handling systems include a variety of processes that stabilize the solids produced in the treatment facility. Treatment facilities have used anaerobic digestion for more than 100 years to produce methane gas and a stabilized, solid by-product. Some plants use an aeration process establishing aerobic digestion. Incineration of undigested solids, which requires a stringent air permit to operate, can be found at some facilities. A variety of composting processes are used that help recycle wastewater solids for many uses, including the local golf course. Ultimately, solids removed from the plants go into farmland and landfills or are sold at the local garden store as bagged compost. Everyone agrees that recycling is the green thing to do, as long as it does not end up in our waterways and cause greening up of our streams and lakes.

Phosphorus and nitrogen removal

In an effort to control aquatic plant growth, phosphorus removal is being required to lower effluent levels. Many new technologies have been employed to achieve levels below 0.2 milligrams per liter (mg/l) total phosphorus. The lower Potomac River basin and the New York City watershed are good examples of municipal wastewater facilities that have achieved phosphorus levels below 0.2 mg/l.

Phosphorus removal is achieved both biologically and with physical-chemical methods. Biological phosphorus removal requires a modification of conventional activated-sludge treatment systems, including the addition of an anaerobic phase that results in the growth of a microbial population with higher cellular phosphorus content. Plant operators can vary the time and level of anaerobic and aerobic zones to create a stressed environment, resulting in phosphorus uptake and phosphorus release.

Chemical removal of phosphorus involves the addition of metal salts, such as aluminum sulfate, and sodium aluminate or lime to form insoluble phosphate precipitates. Iron salts typically used are ferric chloride, ferrous chloride and ferrous sulfate that can be used in dry or liquid form. The physical process of tertiary filtration is used in wastewater facilities to remove phosphorus that is attached to solid particles. The New York City watershed wastewater facilities use both chemical and microfiltration processes to significantly reduce phosphorus levels for direct discharge into numerous reservoirs that supply unfiltered drinking water to the city. Some of these facilities are producing treated wastewater with phosphorus levels of less than 0.05 mg/l.

The use of biological phosphorus removal, chemical precipitation and microfiltration are difficult for homeowners to manage in small, on-site systems. Many new attached-growth and suspended-growth on-site systems are available to homeowners who have limited site conditions and requirements for higher levels of performance than a typical septic system and soil adsorption field can provide.

There is also an increasing trend toward removal of nitrogen. Regulations may require removal of all forms of nitrogen or just ammonia ($NH4+$) to prevent lake eutrophication or to reduce ammonia toxicity for freshwater aquatic organisms. Some New York State wastewater facilities are required to provide treatment that can achieve ammonia levels of less than 0.5 miligrams per liter (mg/l). This uses a biological treatment process called nitrification, where the ammonia form is oxidized to nitrite and then to nitrate. Two microorganisms, *Nitrosomonas* and *Nitrobactor,* are responsible for the two-step process. Many factors affect nitrification, such as temperature, alkalinity, and adequate numbers of healthy microorganisms.

Many municipal and industrial wastewater-treatment systems extend nitrification one more step. Denitrification is the biological conversion of nitrate-nitrogen to more reduced forms. A variety of nitrification and denitrification processes include suspended-growth and attached-growth microorganisms, such as activated sludge, trickling filters and rotating biological contactors.

Small, on-site, homeowner-managed systems have been designed in the last decade to improve wastewater treatment efficiencies for nitrogen and phosphorus by using proven technologies employed in municipal wastewater facilities. Which of the many advanced new systems on the market work the best? Studies around New York State lakes are working to validate whether these systems can achieve lower levels of nitrogen and phosphorus to protect water quality. The Skaneateles National Community Decentralized Wastewater Demonstration Project is evaluating alternative, on-site systems around Skaneateles Lake, which provides unfiltered drinking water for the City of Syracuse.

The Environmental Technology Verification (ETV) Program was created by the EPA to facilitate the use of innovative environmental technologies through performance verification. It seeks to provide high-quality, peer-reviewed data on technology performance to those involved in the design, distribution, permitting, purchase and use of environmental technologies. All ETV evaluations are conducted in accordance with rigorous quality-assurance protocols to ensure that the data generated and the results are defensible. National Sanitation Foundation International (NSF), in cooperation with the EPA, operates the water-quality protection centers (WQPC). NSF Standard 40 pertains to residential wastewater-treatment systems. Lake homeowners who are interested in nitrogen reductions will find that NSF Standard 245 has useful information about advanced nitrogen removal (see Appendix F, "Internet Resources").

The Buzzards Bay Massachusetts Alternative Septic System Test Center is another ETV partner that has been validating the performance of on-site treatment technologies. These testing centers operate various on-site systems under a wide range of conditions, including normal loading, spike loading, cold temperatures, warm temperatures and what happens when the homeowner goes on vacation and there is little or no flow entering the system. Systems are tested for efficient removal of pollutants and also are evaluated for electrical use, chemical use, noise, odors, mechanical components and electrical/instrumentation components. They are also studied to determine how difficult the systems are to operate and maintain, how much sludge they produce and how often the homeowner needs to remove the sludge that has accumulated. The ETV program has illustrated that some manufactured systems do not live up to their performance claims and can be difficult to maintain. Alternative treatment units were once banned in Texas because of the lack of maintenance and the failures that resulted. NSF standards 40 and 245 now require vendors of certified systems to provide a two-year initial service policy, including four site visits. They also:

- must extend the policy if the homeowner desires additional service;
- must have standby parts in stock; and
- must be able to provide service within 48 hours.

NSF will withdraw their certification if vendors are not compliant.

This publication could not begin to review all the new systems available, so before purchasing an expensive new system, check the EPA's ETV reports, as well as the work by the Massachusetts Alternative Septic System Test Center (see Appendix F, "Internet Resources").

Role of lake associations

Within the context of watershed protection, it would be useful to identify and locate all SPDES permit holders in the watershed. This list is public information and can be obtained directly from the DEC website. The type and location of discharge at each site can be added to your map system. It is not appropriate for a watershed group to actually monitor or sample outflows, at least if the intent of the monitoring is to litigate discharge violations. Good self-monitoring and increased vigilance against violations of SPDES discharges, however, may be a benefit resulting from increased community interest in permitted discharges.

Associations may gain the greatest benefit from working cooperatively with SPDES permit holders. Citizen volunteers may be able to assist in the monitoring program or provide public praise for effective efforts to protect water quality.

Because sewage treatment plants are the most prevalent sources of discharge, there is value in learning about current treatment levels, the types of contaminants moving through the system, and whether the treatment plant is part of a CSO. If the lake association decides that greater protection is needed, they can promote cost-effective solutions. A common solution is to upgrade to secondary or tertiary treatment. Another option is to separate industrial from residential wastes to remove specific toxic substances. It is also worthwhile to educate homeowners about limiting their use of toxic household substances and disposing of them appropriately instead of into the sewer or septic-system network.

One option for a CSO is to create separate systems for stormwater and sanitary flows. However, the cost of separation is usually high. An association will have to do its homework to convince the local municipality that such upgrading or retrofitting is justified. Valid arguments include:

- Linking phosphorus removal in the treatment plant to phosphorus levels in the lake;
- Cost of phosphorus removal from other sources;
- Connection among nutrients, algae, clarity and lakeshore owner perception;
- Percent of tax base associated with lake residents versus per-resident cost of upgrade; and
- Expense of in-lake management methods associated with excessive phosphorus, such as copper sulfate, alum and water-treatment costs.

Nonpoint source pollution controls

Nonpoint source pollution includes a broad and complicated array of contaminants such as sediments, nutrients, pesticides, pathogens and a mixed cocktail of pharmaceuticals and personal health-care products. These pollutants are introduced from a multiplicity of small sources, not from well-defined individual sources. Controlling nonpoint source pollution is not as simple as "turning off the faucet," for it often occurs within a large land area. This pollution moves through complex transport and delivery mechanisms within the lake watershed and enters watercourses at many locations. Management is based on sources, in the context of the major land use and associated contributing stakeholder groups.

Best Management Practices

A lake association or other local resident groups have a number of options available to reduce nonpoint source pollution coming from the watershed and affecting the lake. A **Best Management Practice (BMP)** is any procedure that prevents or reduces the availability, detachment or transport of pollutants. Control of any one of these phases can reduce pollutants delivered to waterbodies. Pollutants that can be controlled through the use of management practices include sediments, nutrients, pesticides, pathogens and pharmaceuticals. Public education is a BMP that can directly affect nonpoint source pollutants entering waterways (see "Pollution control guidelines for lakeshore homeowners").

A lake association must assess the types of pollutants and the conditions associated with various land uses in the watershed and identify which uses may be potential sources of nonpoint pollution. The goal is to increase the adoption of management practices appropriate to that land use, through a combination of vigilant monitoring, outreach, ongoing education, incentives and enforcement of legislative deterrents.

Pollution control guidelines for lakeshore homeowners

Never wash anything directly in the lake. Using soap or a cleaning agent to wash dishes, pets or people contributes pollutants to the water. Avoid washing boats or cars near the lake where detergent and oil may pollute the water.

Never discard branches, leaves, grass clippings or any dead plant material from the yard into the lake, drainage ditches or on flood-control lands. They can clog the shoreline, and will add extra nutrients during decomposition. Branches and stumps can foul fishing lines.

Never throw the ashes from a wood stove, fireplace or campsite into the lake. Ashes contain phosphorus, nitrogen and carbon which fertilize aquatic plants. Spreading the ashes on your garden or lawn is a more sensible use and provides an alternative to commercial fertilizers.

Minimize your use of fertilizers, and never fertilize the strip directly along the shoreline.

A good practice is to plant a strip of trees or shrubs along the shoreline. The plant roots reduce erosion, and the vegetation can absorb fertilizer runoff before it reaches the lake. It also has scenic benefits and discourages geese trespassing.

For lawn and garden care, consider the same suggestions that are used by farmers to reduce fertilizer use and waste. See "Agricultural sources" in the "Nutrients and pathogens" section below.

BMPs are selected to address specific pollution problems appropriate to a site's characteristics, operation considerations and budget. Agricultural practices, for example, have been developed for cropland, pastures, barnyard or manure management and pesticide control. Urban practices have been designed to keep city streets and roadsides clean, while construction practices have been developed for erosion and runoff control. Forestry practices have been developed for activities such as road construction in timberlands, timber harvest techniques, regeneration of forests cut or killed by disease or fire and the use of pesticides.

Management practices were seldom designed with water-quality protection as the primary goal, but rather to maintain productivity on the land, reduce costs of pesticides and fertilizers or prevent lawsuits because of mudslides or flooding on neighboring properties. Regardless of their original intent, many of these practices are useful in lake-restoration projects. Managers of lakes and streams generally use management practices to control erosion and sediment, nutrient and pesticide runoff. These processes are often interrelated. Reducing the delivery of sediment to a waterbody, for example, will also reduce nutrients or pesticides bound to sediment particles. The reader is encouraged to see Appendix G, "References Cited" and Appendix H, "Additional Readings" to explore BMP practices in more detail.

The remainder of this chapter gives an overview of major nonpoint source pollutants, key sources and the Best Management Practices for reducing or eliminating the contaminants.

Erosion and stormwater runoff

A watershed land surface intercepts rain events, and a large portion of the rainfall moves across the surface to lakes and streams as runoff. Increased volume and intensity of **stormwater** contributes to an increase in the magnitude and frequency of floods, increased erosion and degraded stream and lake systems. Equally important, however, are the large quantities of contaminants which are transported along the way, including suspended sediments and attached or dissolved nutrients such as phosphorus, trace metals, petroleum hydrocarbons and de-icers from roadways. EPA Phase II stormwater regulations involve two programs to control construction activities and municipal separate storm sewer systems (MS4s). These regulations were initiated to help reduce stormwater runoff from these sources and require that small towns of applicable densities or that discharge into critical water bodies develop plans for reducing stormwater runoff from their jurisdictions. New York State Stormwater Phase II is administered by DEC. Some of the required activities are the development of pollution prevention protocols, drainage-use ordinances, GIS mapping, outfall inspections, outreach activities and watershed vulnerability analysis.

Agricultural sources

Erosion of sediments from unvegetated farm fields has traditionally been identified as one of the leading sources of sediments. The use of BMPs is being fostered through education awareness programs, tax relief and a multitude of federally funded initiatives such as the Conservation Reserve Program. These BMPs include the following:

- Maintenance of a cover crop during winter months;
- Use of mulch and silage to protect the soil;
- Tilling and crop planting parallel to topographic contours to slow water flow and trap sediment;
- Use of a filter strip along field edges or a riparian buffer along stream banks to trap and slow runoff;

Case study: Agricultural Best Management Practices

Lake setting: Cannonsville Reservoir, a 4,800-acre potable impoundment in Delaware County in the Catskill Region, is the third-largest reservoir the New York City reservoir system.

The problem: The New York City Department of Environmental Protection (NYCDEP) has developed a comprehensive management program to address point and nonpoint source pollutant loading to the New York City reservoir system in hopes of avoiding expensive water filtration of its surface water supplies as required by the federal Safe Drinking Water Act. As part of their filtration avoidance agreement with the EPA, the city partnered with the local farm community to establish a voluntary, incentive-based watershed agriculture program (WAP) that funds the design and implementation of individual farm plans. More than 85 percent of the farms within the New York City watershed system are currently participating in the WAP. At the onset of the program in 1993, DEC, with funding from WAP, launched a long-term paired watershed study designed to quantify the water-quality effects of agricultural BMPs implemented under the WAP on a single upland dairy farm located in a sub-watershed of Cannonsville Reservoir.

Response: A variety of agricultural BMPs were implemented on a 160-hectare, third-generation dairy farm with 80 milking cows and 35 heifers. These included a storage lagoon for manure and milkhouse washwater, stream corridor and silage-storage relocation, diversion ditches, contour strip cropping, improved crop rotation and manure-spreading schedules. Stream flow, nutrient and sediment concentrations were continuously measured during event and baseflow conditions for two years pre-BMPS and nine years post-BMPs in the farm watershed. They also were monitored at a nearby 86-hectare, forested, control watershed basin. Weather and runoff conditions were comparable at the two watersheds during the study period.

Results: Runoff events were shown to be important contributors of phosphorus, delivering an average of 57 percent of soluble phosphorus and 84 percent of particulate phosphorus total annual loads from the farm site. A statistical comparison of the first six years of data from the paired watersheds demonstrated that the blending of farm-management and physical-infrastructure BMPs resulted in seasonal reductions of 35 to 50 percent in the event-loading of soluble phosphorus, and reductions of 15 to 40 percent in the event-loading of the particulate phosphorus. Annual event-load reductions were 43 percent for soluble phosphorus and 29 percent for particulate phosphorus. Load reductions were greatest in winter and summer and occurred despite a slight increase in herd size during the course of the study. Presumably, decreases in stream losses of phosphorus were a consequence of greater retention of phosphorus within the farm watershed, an outcome that could eventually lead to saturation of soil with phosphorus. This saturation likely will result in higher stream losses once again as the soil's capacity to retain phosphorus is exceeded.

Lessons learned: Agricultural BMPs can effectively reduce phosphorus discharge into outflow streams from farmland, but in the absence of efforts to improve the overall mass balance of phosphorus on the farm, they ultimately will increase phosphorus retention within the farm watershed and likely lead to soil saturation. Livestock farms, in particular, need to reduce importation of phosphorus in feed and fertilizer, in addition to applying soil and water BMPs to effect a sustainable improvement in water quality. While the extent of agricultural BMPs in this study may be larger than on the typical New York State dairy farm, most of the practices utilized are commonly recommended for both small and large New York State farms (Bishop, et al, 2005).

- Strip cropping of corn or vegetables alternating with strips of a grain crop to help capture and slow runoff;
- Use of grassed waterways and farm ponds to capture sediment moving from fields;
- Planned, rotational grazing of livestock to help reduce soil erosion;
- Fencing of streams to keep livestock away; and
- Protection of the soil surface by retaining last year's crop residue before and during planting and by reducing tillage and soil turning.

Residential development

Another of the major sources of runoff originates from the spread of urban development across the landscape. It occurs during the construction process when land is being cleared and exposed. Uprooting trees and shrubs disturbs the soil and removes the network of roots that helped to hold the soil in place. Runoff continues after construction from the resulting impervious surfaces of rooftops, roadways and parking lots. Construction strategies for reducing this runoff include the following:

- Reducing the total amount of impermeable surfaces by replacing them with gravel or permeable pavements;
- Replacing expanses of lawn with landscaped patches of trees, shrubs and mulch to capture and hold rain water;
- Disconnecting gutters and other features that transfer rooftop runoff to roadside ditches, which then transmit it straight to streams; and
- Diverting on-site runoff to rain gardens or small depressions where water has time to infiltrate the soil.

It is useful to remember that rainwater contains fewer dissolved ions that make "hard' groundwater so challenging. If possible, consider rain barrels to harvest roof runoff as an alternative source of freshwater for laundry, showers and watering gardens.

Town maintenance

Local governments can play a pivotal role in stormwater management. First, they can develop regulations for housing densities, zoning and the building-permit process. They can mandate the amount of impervious surface in the watershed and encourage or mandate the use of BMPs to treat on-site runoff.

Second, towns designated as municipal separate sewer and stormwater systems (MS4s) are required under EPA Phase II regulations to adopt an ordinance that controls stormwater runoff from construction and post-construction activities. Best Management Practices for stormwater runoff include the following:

- Disturbed area limits are designed to minimize the area affected by construction activity. Where possible, soil disturbance should be phased or restricted to only the parts of the development site that are under active construction.
- Surface roughening can be applied on the exposed soil when vegetation is removed. Construction equipment is used to scarify or groove the soil, following the slope contours. The grooves spread the runoff horizontally and increase the time for water to soak into the ground.
- Non-vegetative soil stabilization includes actions such as covering disturbed areas with mulches, nettings, crushed stone, chemical binders and blankets or mats. This BMP is a temporary measure that should be used only until a long-term vegetative cover is developed.
- Silt fences combined with hay bales have been a common practice to capture sediment transported in runoff and prevent its movement downslope. Proper placement and monitoring are critical to ensure its success.
- Mulching is used to protect constructed slopes and other bare areas. Materials such as grain, straw and hay are applied to critical areas, reducing runoff and evaporation loss and holding seeds, lime and fertilizer in place.

Third, town managers can directly control a major source of stormwater contaminants through the management practices they employ in maintaining town roads. Road salts, such as sodium chloride (NaCl) and calcium chloride (CaCl), are the predominant road de-icers used in the northeastern United States. They have contributed to a significant rise in conductivity in streams. Conductivity is a measure of dissolved ions in water. Modern storage facilities with roofs, cement pads and berms are critical for capturing precipitation and preventing salt-contaminated runoff. Outreach and support from tax-paying stakeholders is needed to encourage the use of alternative de-icers, such as biodegradable, sugar-based products.

Town highway staffs also maintain networks of ditches connecting impervious surfaces to streams. Recommended BMPs to reduce the adverse effects of these ditches on streams include the following:

- Discouraging ditch scraping that leaves bare soil exposed during storm events;
- Encouraging reshaping and widening of ditches as necessary to allow regular mowing. Using good hydroseeding practices, including not seeding before a rain event or late in the fall when seeds will not have time to germinate;
- Installing check-dams to slow water velocities along steep, hillslope ditches; and
- Directing the ditch discharge away from streams and into an infiltration basin, a constructed wetland or a detention pond so that the water can recharge the groundwater slowly.

Finally, town managers should be encouraged to use their influence in decisions concerning the use of combined sewer and stormwater overflow systems. Qualified advisors can be consulted concerning the problems associated with CSOs and the need to decouple these two sources of runoff contaminants.

Nutrients and pathogens

Phosphorus is the key ingredient causing eutrophication of freshwater lakes and streams, and nitrogen is now recognized as the comparable factor causing estuary pollution. Both phosphorus and nitrogen are bound to suspended sediments and also are dissolved in water. A primary source of these contaminants is the fertilizers used for crops and lawn management. Nutrients are also derived from manure wastes associated with livestock, pets on lawns and human wastes inadequately treated by on-site wastewater systems. Animal wastes from all sources host pathogens including bacteria, viruses and protozoans and can be a threat to human health.

Agricultural sources

The agricultural industry has been strongly targeted for nutrient reduction during the past several decades. BMPs are well established and work well where applied and enforced. These include the following recommendations concerning fertilizers:

- Proper storage of fertilizers to avoid spills;
- Soil testing to determine proper application rates;
- Timely application during the growing season to maximize plant uptake and minimize runoff or groundwater contamination during storms and snowmelt;
- Minimizing erosion by integrating nutrient management with the BMPs identified for stormwater runoff control;
- Strategies for wellhead protection, including storing fertilizers more than 100 feet from a well; and
- Crop rotation with legumes to reduce the need for fertilizers.

Manure from pigs, cows and chickens is a major focus for on-farm management and includes the following:

- Testing manure to match application rates to plant-nutrient needs and soil-test data;
- Pasturing livestock at proper densities for soil type, slopes and groundwater depths;
- Requiring permits for concentrated animal feedlots;

- Constructing and managing storage facilities to avoid runoff and leaks, including sewage lagoons, earthen storage ponds, tanks or sheltered concrete-slab areas; and
- Developing a constructed wetland for treatment of wastes.

Urban sources: On-site wastewater treatment systems

New York State lakefronts are vulnerable to contamination from on-site wastewater treatment systems, better known as **septic systems**. Site conditions such as steep slopes, poor soils and small lots can make it difficult to design an effective traditional system. Steep slopes direct wastewater breakouts and surface-water runoff directly into the lake before it can be adequately treated. A system correctly designed for a seasonal-use cottage will be burdened by increased use when the cottage is converted to year-round use. Untreated or partially treated wastewater contains nutrients that contribute to aquatic blooms and degrade water quality. Wastewater may also contain pathogens, disease-causing microorganisms such as bacteria (*E. coli*), viruses and protozoa such as C*ryptosporidium*.

Traditional septic systems

Traditional or conventional systems consist of three main components (See Fig. 9–7).

- A collection system of pipes that convey waste to the septic tank;
- A tank, where solids and floatable materials are collected; and
- A soil-based treatment system, commonly called a leachfield or a drainfield, where most of the wastewater treatment occurs; a distribution box divides and directs flow through the multiple lines of a leachfield.

Septic systems, when properly designed, installed and maintained, are an effective and economical way to treat wastewater. Proper care and regular maintenance prolong the life of the system and are wise and cost-effective investments.

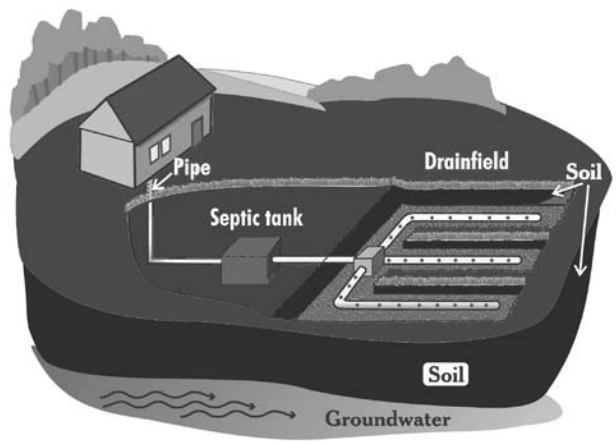

Fig. 9–7. Traditional or conventional systems consist of three main components. (CREDIT: EPA)

Household chemicals, such as paints, wood preservatives or solvents, should never be poured down the toilet or drain. These common household products can destroy the natural bacteria in a septic tank and pollute a lake. Local recycling and household hazardous waste collection programs should be used for these materials. Local recycling coordinators can inform residents about the preferred or required methods for proper disposal of these materials if recycling is not an option. Many communities have annual collection programs for materials that need special handling.

Other suggestions for proper care of an on-site system include avoiding the use of garbage disposals and reducing the amount of water to the system. Garbage disposals add unwanted solids and grease to the septic system and require a larger septic tank. Keep excess water out of and away from the system by conserving water, fixing leaks properly and diverting water from sump pumps and roof gutters away from the drainfield. Excess water saturates the system, reducing its effectiveness. Install low-flow faucets, shower heads and toilets to further conserve water.

For a system to work properly, solids in wastewater must remain in the tank until they are pumped out. If heavy or floatable solids are washed out of the tank, they are carried into the leachfield pipes and can clog the drainage conduits. This can happen because of a structural problem in the tank; too much water or additives that keep solids in suspension.

Septic systems should be inspected each time they are pumped, preferably every two to three years.

A septic tank is different from a holding tank that collects wastewater until it can be professionally pumped out. Holding tanks do not treat wastewater but simply store it to prevent it from entering the ground and eventually the lake. Holding tanks are usually only a temporary option because frequent pumping is expensive and inconvenient. At some lakes, however, they may be the only option for small lots near the water or in ground incapable of successfully operating a leachfield. County health departments have the final decision, and some counties will not permit holding tanks to be used.

Alternatives to traditional septic systems

It is often difficult to remedy failing on-site systems in lakefront environments. Municipal sewers may not be feasible due to expense, especially in areas of low-density population, in locations distant from the treatment plant or where the ground is hilly, rocky or wet. Alternative leachfield designs are often the best solutions for difficult lakeshore properties where soil is unsuitable (such as clays) or where there is insufficient depth to bedrock or groundwater.

All alternative systems must be designed and submitted to the local health department by a system professional. Appendix 75-A of the New York State Public Health Law, 201(1)(1) specifies that all alternative dispersal systems must be preceded by a dual-compartment septic tank or two septic tanks in series and of sufficient volume. Local health departments can answer specific questions.

Three of the most common alternatives include the raised-bed system, the mound system and the sand-filter system. Other alternatives may be allowed by the local health department on a limited experimental basis or for replacement systems on difficult sites.

- The raised-bed system is used where soil is suitable but of insufficient depth. One foot is the minimum required soil depth for a conventional system. An additional amount of suitable soil with a percolation rate of 5 to 30 minutes per inch is trucked onto the site, and a conventional stone and pipe leachfield system is constructed. Sufficient soil must be available to provide

Case study: Septic management and education

River setting: The 1,000 Islands area of the St. Lawrence River is a vital ecological, recreational and economic resource in the northwestern area of New York State.

The problem: Sewage pollution in the busy summer resort region of the 1,000 Islands was perceived to be a major problem, primarily due to many poorly functioning septic disposal systems.

Response: The Save the River organization was formed in the late 1970s to address winter navigational issues within the St. Lawrence River and eventually became involved in other water-quality and ecological issues. The organization implemented an alternative sewage project, funded by the DEC in 1988 under the motto "Save the River—It's Not a Sewer." The project consisted of a public educational campaign focused on extensive distribution of educational brochures outlining sewage problems and booklets highlighting alternative methods of wastewater disposal. Voluntary inspections were conducted, including septic tank inspections, system surveys and dye tests. Homeowners with systems that "passed" the inspection were awarded a handcrafted River Great Blue Heron Clean Water Award statuette. Those failing inspections were provided site-specific recommendations to upgrade their septic system.

Results: More than 500 homes were surveyed, with about half passing the inspections. Many of the failed systems were upgraded, at least in part due to the non-confrontational approach to upgrading systems and to the additional value gained by passing the inspection. Those gains included an improved septic system, reduced impact on river-water quality, and a visible symbol of environmental stewardship, many of which were proudly displayed and observable from the river (Marr, 1991).

one to two feet or more of separation from the original ground surface. Gravity distribution may be used where the imported soil provides a minimum depth of two feet between the trench bottoms and the original ground surface. If that is not possible, dosing or pressure distribution is required using a siphon or pump.

- The mound system is also an above-ground distribution system created with fill material, usually a porous, sandy soil. Although the overall size of the mound is substantially smaller than a raised-bed system, it has more stringent soil characteristics and construction specifications, including required pressure distribution. In both the raised-bed and mound systems, wastewater from the septic tank is allowed to seep through the soil bed or is pumped there for more even distribution. This provides distribution and treatment or additional decomposition of waste materials by soil microbes. The wastewater filters down through the original ground surface to the groundwater table.

- A sand-filter system can also be used where soils are unsuitable for conventional drain fields. Wastewater flows from the septic tank to a pump or siphon tank, which periodically releases the water to a sand filter that is two to three-feet deep. This allows the filter to dry before the next "dose." The filter is lined with clay or plastic to prevent wastewater leakage. The filtrate may be collected and piped to a disinfection unit. Some residential sand filters may require a surface water discharge, but they usually are approved only to correct an existing problem when no other alternative is available. DEC has not allowed surface discharge for new residences since October 1990. Municipal or commercial septic tank sand-filter systems, however, may still be able to use surface discharge.

Sand-filter systems usually are fairly effective and require little maintenance, but the capital cost is high, and filter beds may need frequent replacement. The same considerations of soil and site conditions required for conventional septic tank leach fields are also applicable for raised-bed and mound systems.

Other proprietary alternatives are available, including peat-filter systems and synthetic media filters. If either system is approved, the local health department may require monitoring performance of the systems and a service agreement between the homeowner and the manufacturer or a local service provider.

On very small lots or where water is severely limited, lakeshore owners are adopting waterless toilets for managing human wastes. Incinerator toilets use electricity to burn organic wastes, converting them to dry ash. Dry-composting toilets depend on decomposition of wastes by adding sufficient quantities of sawdust or other carbon sources. These alternative toilets eliminate any potential for leaching of wastes into lakes. Both types of toilets may require special permits from the municipality.

Systems for small communities

In many communities, site conditions may preclude the use of even alternative on-site systems. Where lot sizes or soil and site conditions are not suitable for on-site systems, cluster systems may be appropriate. In cluster systems, wastewater is transported through small-diameter sewers to a drainfield, mound or sand filter which is used by several residences. Cluster systems can be both inexpensive and simple to operate and can work well if management and maintenance of the system is well organized and efficient.

Municipal law in New York State allows the formation of special districts for this purpose. Private maintenance corporations, such as transportation corporations or homeowner associations, are also possible, but most DEC regions prefer municipal ownership. To protect drinking-water supplies, some municipalities have adopted watershed rules and regulations that govern on-site wastewater treatment system design, installation, inspection, management and maintenance. All current watershed rules and regulations are on the New York State Department of Health (DOH) website. See Appendix F, "Internet Resources," and search "Title 10."

Small communities can explore a range of other options. Small-diameter gravity systems, pressure or pump systems and vacuum systems all allow residential septic tanks to be connected to the main municipal sewer system if it has available capacity. Oxidation ponds and ditches, facultative lagoons, trickling filters and overland flow treatment are well suited to small communities. They are less expensive, more energy efficient and easier to run and maintain than conventional centralized wastewater treatment facilities. Both DEC and the EPA publish helpful "standards" manuals that are available on their websites. See Appendix G, "References cited" and Appendix F, "Internet Resources."

Role of lake associations

Lake associations can conduct educational programs on septic-system care, encourage local legislation to require regular septic-system pumping and inspection and promote high professional standards or even certification of contractors that pump and inspect these systems.

The first step is to educate lakeshore owners about the importance of maintaining a functioning wastewater-treatment system. A well-informed lake homeowner should be aware of the location and condition of his or her septic system, how to detect potential problems and the health and water-quality problems that can develop when a system fails. Fact sheets or display booths at an annual fair are a good place to start.

Some lake organizations would like to collect information on how many and which systems are failing. Several methods are being used by different lake associations, and some have partnered with local municipalities to hire trained inspectors to conduct inspections.

One method of detecting septic system leaks is by using a septic leachate detector. This is a hand-held fluorometer that can locate effluent plumes and domestic wastewater in lakes. The probe is submersed in lake water in front of a shoreline home. A response can be noted on the chart recorder if human sewage, detergents and the whiteners found in laundry products are detected. The septic leachate detector (otherwise known as a septic snooper) has proven to be an effective tool for public health officials, water-planning agencies, consultants and engineers. A significant limitation to its widespread use, however, has been its high purchase cost.

Dye tests have been used by some lake communities interested in detecting failed septic tanks. Dye is flushed down a toilet, and its appearance in the lake is seen as evidence of system failure. Unfortunately, the accuracy and value of this simple test is limited. A failing system may not be detected. They do not consistently detect leachfield failures, or wastewater may be short-circuiting to groundwater and never reaching the leachfield.

Lake associations can promote legislation that requires septic-system pumping and inspection when ownership of the property is transferred or at specified time intervals. The time frame is frequently shorter for homes closer to the lake than for those in the uplands. To be effective, those doing the inspections must be properly trained. The New York Onsite Wastewater Treatment Training Network offers a series of state Education Department-accredited workshops that are administered by SUNY-Delhi but are held statewide at locally sponsored sites. Lake associations can sponsor or give scholarships for training. Continuing education credits are offered to professional engineers, code-enforcement officers and wastewater treatment plant operators. Others who have attended include town supervisors, planning and zoning officials, lake association members and property owners, contractors, wastewater-treatment system service providers, engineers and sanitarians.

Pesticides

The United States currently consumes about one billion pounds of pesticides annually. Once applied, they do not disappear from the landscapes. In 2006, the USGS released a survey of 100 pesticides in 51 major river basins nationwide. They detected pesticides in almost every stream studied. Pesticides were found in shallow groundwater beneath both agricultural lands and urban areas. Most frequently detected in agricultural streams were atrazine, metolachlor and cyanazine. Most frequently detected in urban streams were simazine, prometon and tebuthiuron, which typically are used in cities for controlling pests. The pesticides were almost always detected at low concentrations that were unlikely to affect people, but they were detected in most fish. Most waterbodies had more than one pesticide present.

There are several reasons for reducing our dependency on pesticides and reducing their presence in lakes and other aquatic environments. A growing body of evidence is showing that even low concentrations of different pesticides can affect the reproduction, growth and health of frogs and other aquatic organisms. There is also some disturbing evidence that human health is affected as well. In agricultural settings, weeds and insect pests consistently have been shown to develop resistance to pesticides, resulting in a need for more or stronger chemicals to maintain crop yield. Several strategies can be used to reduce both total use of pesticides and the risk of their movement into groundwater and surface waters.

Agricultural uses

The agricultural industry is the primary consumer of pesticides, and its use is well controlled. Regulations exist, and widespread education encourages the following BMPs:

- Good training and certification of applicators to ensure their safety and to protect the health of the environment;
- Proper storage of pesticides to prevent spills;
- Crop monitoring to identify pest outbreaks early so fewer pesticides are needed;
- Use of alternative integrated pest-management approaches, such as tilling for weed control or alternating crops to prevent pest population buildup;
- Following recommendations regarding the application of pesticides by not exceeding the recommended dose rates and by applying pesticides under proper weather conditions so they won't be washed or blown away; and
- Scouting for pests and using spot treatment instead of broadcast application.

Homeowner uses

Homeowners are seldom recognized as major users of pesticides, and, therefore, fewer education programs or strategies have targeted them. Options to reduce such homeowner usage include the following:

- Educating to increase awareness of good pesticide management practices, including proper storage, application and disposal;
- Working with supply vendors to provide smaller package sizes so that unused pesticides will not need disposal, and encouraging homeowners to purchase small packages;
- Considering alternatives to pesticides for pest management, such as using the dryer for clothing and blankets to kill fleas and ticks instead of spraying with pesticides or substituting less hazardous but common household products such as soap and water or borax;
- Minimizing pesticide application rates on lawns or other outdoor areas;
- Encouraging proper disposal of residual waste and packaging instead of dumping them down the drain; and
- Helping to establish hazardous-waste collection days and pick-up sites.

Antibiotics, pharmaceuticals and health-care products

Although identified openly but indecipherably on ingredient labels of bottles and boxes, chemicals have been almost totally overlooked for their effects on water quality and the environment. Thousands of new chemicals have been introduced recently in cosmetic, health care, pharmaceutical and other consumer products. Researchers from USGS (Kolpin, et al, 2002) found traces of these products in 139 rivers in 30 states. Caffeine is now so ubiquitous that it is becoming a signature of sewage contamination in freshwaters. It is a better indicator than *Escheria coli* (*E. coli*) counts because *E. coli* can come from other sources such as farmland runoff.

Triclocarban, a chemical which makes soap "antiseptic" is a good example. In use for nearly 50 years, it gained public appeal and widespread use in handsoaps about a decade ago. Scientists have recently looked at the effects of this chemical. A study by Halden and Paull (2005) found that triclocarban is barely broken down by conventional sewage treatment. Approximately 70 percent is released when treated sludge is spread on farmland. The by-products form an animal carcinogen as the sludge degrades. Its other effects have not yet been investigated. It is ironic that the Federal Drug Administration (FDA) determined in October 2005 that triclocarban does not provide any more benefit than regular soap in reducing the spread of illness.

How are these thousands of chemicals affecting the health of lakes, streams and humans? Drs. Wilson and Smith, of the University of Kansas at Lawrence, and their colleagues investigated the effects of triclosan, a chemical used in acne soaps, and the antibiotic ciprofloxacin, used to treat urinary tract infections. They found that their presence in stream water eliminated one to two species of algae from the stream community (Wilson, et al, 2003). Tergitol, a component of hair dyes and spermicides, reduced the number of algal species present by 50 percent and the volume of algae by 75 percent. Dr. Stuart Levy (2001), of Tufts University in Boston, found that *E. coli* can develop resistance to triclosan. More disturbing are the increasing findings of "intersex" fish in the past few years from both the freshwaters of the eastern United States and marine waters off California. Male fish have been found with ovary, egg-laying tissue in their testes. Small-mouth bass with this abnormality have been collected throughout Maryland's Potomac River. In November 2005, affected sole and turbot were collected off southern California. Scientists hypothesize that the likely causes are contraceptives, as well as endocrine disruptors, estrogen-like chemicals released from plastics and other consumer products that are common in sewage wastewater as well as pulp mill effluents (Solomon, 1998).

Role of lake associations

Education is an important component of the solution to the problems of chemical pollution in lakes and streams. Lake association projects could include distribution of booklets on proper disposal methods and cooperating with community hazardous waste cleanup days. Homeowners should be discouraged from pouring unused chemicals down the drain or into the backyard. They should be encouraged to deal responsibly with household chemical wastes by doing the following:

- Not disposing of paints, automobile fluids and similar chemicals by pouring them down the drain, and by filtering turpentine and brush cleaners for reuse;
- Taking used motor oil and antifreeze to a gas station for recycling;
- Finishing all medications or disposing of them properly; some pharmacies have periodic programs where they will accept leftover medicines for proper disposal;
- Supporting use of organic meats that were not grown with food supplements;
- Reading labels when purchasing chemicals to become familiar with potential hazards;
- Using alternative, less harmful products and biodegradable products whenever possible and never buying more than necessary; and
- Discarding unused products and empty containers safely into the trash to be buried in sanitary landfills but never near a lake or poured into a backyard.

Natural-areas management

Management of the natural areas of forests and streams is everybody's job, not just the job of professional park rangers. Nearly 70 percent of the New York State landscape is currently forested, and the majority of these forests are owned by non-industrial, private landowners. Informed management of these landscapes will have direct benefits to the lakes located downslope and downstream.

Forestry Best Management Practices

Nonpoint source pollution from silviculture activities is a minor contributor to overall sources of pollution, but it can cause severe local damage to streams and lakes. Most degradation is associated with erosion and sedimentation due to:

- clearcut or excessive harvesting;
- the design, location, construction, use, maintenance and abandonment of logging roads, skid trails, log landings; and
- direct disturbance of streams.

Thermal effects on water due to the removal of streambank vegetation may also affect the quality of the fishery.

The Cooperative Forest Management Program and the state Cooperative Forestry Program are administered by DEC and relate to the proper management and harvesting of forest resources in New York State. These programs provide technical advice and assistance to forest landowners and primary wood-using industries. County Soil and Water Conservation Districts (SWCDs) also prepare management plans for agricultural woodlots in cooperation with DEC. The Timber Harvest Guidelines provide the basis for management practices to prevent water-quality impacts from harvesting operations. These guidelines are administered through DEC programs and contracts between the county SWCD and rural landowners and loggers. Some silviculture BMPs includes the following:

- Road and skid trail management involves the appropriate design, location and use of roads and skid trails. These roads and trails should be located away from poorly drained areas and restricted primarily to shallow slopes, except during dry summer logging. They should be at least 150 feet from streams, ponds and marshes. This BMP benefits from water diversion and reseeding of vegetative ground cover after logging.
- Diversion of water, through the use of water bars located at regular intervals along dirt roads, helps prevent gullying and reduces erosion along logging roads. Water bars are small berms constructed of soil that are perpendicular to the road surface to capture water and divert it downhill. Tractors and other logging equipment should not be driven through streams. Instead, bridges should be erected over streams and culverts used to divert the flow. The culvert diameter should be at least 15 inches for maximum possible flow, and should be properly designed to facilitate upstream migration of fish.
- Ground cover maintenance for silviculture activities is similar to vegetative-cover measures used at construction sites. Maintenance of a vegetative cover will help reduce sediment and nutrient runoff from the activity site. Leaving treetops, branches and other logging residue scattered on the ground also reduces erosion. Such coarse debris has been shown to provide refuge and habitat for wildlife and reduce deer herbivory of young tree seedlings. Special precautions should be taken to maintain vegetative cover within 50 feet of any streambanks adjacent to the forestry site.

Streamside erosion control

Streambank erosion is estimated to account for more than 20 percent of the annual soil loss in New York State, nearly 75 tons of soil for each mile of streambank in the state (USDA Soil Conservation Service, 1975). These sediments pose a serious threat to water quality and fish habitat in streams and lakes. The problem of streambank erosion has increased as changes in land use have resulted in greater runoff volumes and peak rates of discharge. Some of these changes include forests cleared for agricultural land and later converted to urban development. Each change has resulted in higher rates of surface-water runoff that causes erosion and widening of streams. Removal of riparian (streambank) vegetation for farming and unlimited access of livestock to streams exacerbates the problem of streambank erosion.

Buffer strips or greenbelts

Buffer strips can be grasses, shrubs or trees planted or allowed to grow at the water's edge to protect streams from land-use activities adjacent to streams or lakes. Depending on the slope, soil and adjacent land uses, the buffer strip can range from 25 to 450-feet wide. Its functions include:

- stabilizing a streambank to minimize erosion;
- filtering out sediment and other substances (nutrients, pesticides, heavy metals);
- maintaining stream integrity by retaining a natural vegetative corridor;
- enhancing recreational stream use;
- preserving trees and shrubs that shade the stream; and
- keeping water cooler (and better) for fish and restoring degraded fish and wildlife habitat.

The U.S. Department of Agriculture (USDA) currently recommends a 100-foot vegetated buffer consisting of three zones to maximize the streamside's functions for flood reduction (Zone 1), nutrient uptake (Zone 2), and filtering of overland runoff (Zone 3).

Streambank and roadbank stabilization and management

This BMP includes the use of hardening or armoring banks and adding vegetative stabilization to reduce erosion along streambanks and roadbanks susceptible to stormwater runoff. Hardening is now being discouraged with the growing recognition of the multiple benefits of vegetated buffer strips. Hardening may be necessary, however, where residences, roads or other existing structures are threatened by eroding streambanks. Several methods are used to harden stream banks.

- **Rip-rap** is rock and stone rubble used as a blanket or liner to prevent erosion in highly susceptible areas. This practice is used to stabilize sites that are subjected to large volumes of water and cannot be stabilized with less expensive vegetative measures. Rip-rap usually is installed with heavy equipment because the stones must be large enough to resist displacement by high water or strong currents.
- **Log cribbing** is effective in reducing streambank erosion, and spaces between the logs can provide an excellent fish habitat. Once the crib has been constructed, usually along the outside bend of a stream, it is filled with rocks to hold it in place. Construction and maintenance costs of log cribbing are expensive.
- Non-vegetative and **vegetative stabilization** reduces soil and streambank erosion by stabilizing exposed soils and slopes with materials such as straw, hay or commercially processed materials. This cover can be temporary, prior to reseeding, or permanent. Vegetative stabilization also can include cover crops or even reforestation. Forested lands normally retain more precipitation than agricultural and urban lands. Reforestation, therefore, reduces both the volume of runoff and peak discharge. Streamflow is reduced, resulting in less flow pressure on embankments, which minimizes channel erosion.

Summing it up

A lake, including both its physical and biological health, is intimately connected with the surrounding landscape. A sustainable, long-term protection program for a lake will be successful only if watershed management is a significant part of the plan. This chapter provided an overview of the process of watershed management, and a framework of diverse strategies available to address both nonpoint and point source pollution. The next chapter provides an in-depth discussion of the legal framework available to implement a regulatory system for lake protection and management.