Urbanization and Water Quality

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Abstract

The United States Environmental Protection Agency now considers pollution from all diffuse sources to be the most important source of contamination in the nation's waters (USEPA, 1997). These pollutants cause dramatic changes in hydrology and water quality that result in a variety of problems. Hydrologic impact due to urbanization is reported to cause water quality problems such as sedimentation, increases temperatures, habitat changes, and loss of fish population. There is widespread recognition that these problems are caused by increased runoff volumes and velocities from urbanization and associated increases in watershed imperviousness. Imperviousness represents the imprint of land development on the landscape. The second aspect of urbanization that contributes to urban stormwater pollution is the increased discharge of pollutants. Oil, grease, landscape practices, construction, illicit connection, leaking sanitary sewers and countless other aspects of daily life in urban areas contribute to polluted runoff (NRDC, 1999, Chap. 2). The degradation caused by urban stormwater pollution is serious, and affects a significant proportion of the nation's population. The most dramatic consequence of increases in the volume and rate of stormwater runoff is flooding, property damage and erosion.

With the spread of development and intensified agricultural practices across watersheds, pollutant runoff, nonpoint source pollution and unmanaged development have become the greatest threats to drinking water sources (TPL, 1997, p.5). From small towns to big cities to entire states, there is a growing recognition that land conservation may be the best and cheapest way to guarantee drinking water supplies. Watershed development does not necessarily have to be synonymous with the degradation of aquatic resources. When new growth is managed in a watershed context, homes and businesses can be located and designed to have the smallest possible impact on streams, lakes, wetlands and estuaries. In the watershed protection approach, communities can apply basic tools that guide where and how new development occurs. Watershed planning has provided several municipalities the opportunity to consider all the resources in the watershed as a single, interrelated system.

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Runoff pollution occurs every time rain or snowmelt flows across the ground and picks up contaminants. It occurs on farms or other agricultural sites, where the water carries away fertilizers, pesticides and sediment from cropland or pastureland. It occurs during forestry operations (particularly along timber roads) where water carries away sediment, nutrients and other materials associated with that sediment, from land which no longer has enough living vegetation to hold soil in place. This portion of the discussion however, will focuses on urban runoff pollution (NRDC, 1999, Chap 2).

Stormwater carries away a wide variety of contaminants as it runs across rooftops, roads, parking lots, baseball diamonds, construction sites, golf courses, lawns and other surfaces in our cities and suburbs. The United States Environmental Protection Agency now considers pollution from all diffuse sources, including urban stormwater pollution, to be the most important source of contamination in the nation's waters (USEPA, 1997). EPA ranks urban runoff and storm sewer discharges together as the second most prevalent source of water quality impairment in the nation's estuaries, after industrial discharges, and the fourth most prevalent source of impairment in lakes after agriculture, unspecified nonpoint sources and atmospheric deposition of pollutants (USEPA, 1998, ES-13). Uncontrolled urban runoff also contributes to hydrologic and habitat modification, two important sources of river impairment identified by the EPA (USEPA, 1998, ES-13). Unlike industrial or municipal wastewater treatment plant discharges, most stormwater pollution is derived from more diffuse sources that are closely related to everyday municipal and personal activities. While these characteristics pose some challenges, they also provide the opportunity for many approaches to address the problem.

The problem of polluted stormwater runoff has two main components: 1) the increased volume and rate of runoff from impervious surfaces; and 2) the concentration of pollutants in the runoff. Both components are highly related to development in urban and urbanizing areas. Everyday activities, including driving and maintaining vehicles, maintaining lawns and parks, disposing of waste and even walking pets, often cover these impervious surfaces with a coating of various harmful materials. Construction sites, power plants, failed septic systems, illegal discharges and improper sewer connections also contribute substantial amounts of pollutants to runoff. Sediments, toxic metal particles, pesticides and fertilizers, oil and grease, pathogens, excess nutrients and trash are common stormwater pollutants. Many of these constituents end up on roads and parking lots during dry weather only to be washed into waterbodies when it rains or when snow melts. Together, these pollutants and the increased velocity and volume of runoff cause dramatic changes in hydrology and water quality that result in a variety of problems. Urban stormwater is not alone in causing these impacts. Industrial and agricultural runoff are equal or greater contributors. But the environmental, aesthetic and public health impacts of diffuse pollution will not be eliminated until urban stormwater pollution is controlled (NRDC, 1999, Chap. 3).

Increased Volume and Velocity: The Importance of Imperviousness

Hydrologic impact due to urbanization is reported to cause water quality problems such as sedimentation, increased temperatures, habitat change and loss of fish population. There is widespread recognition that these problems are caused by increased runoff volumes and velocities from urbanization and associated increases in watershed imperviousness. Increased imperviousness leads to increases in volume of water, increased peak flow and duration and changes in sediment load. All these effects can result in flooding, habitat loss, erosion, channel widening and streambed alteration. Habitat loss can also result from increased stream temperature and decreased base flow, which are also effects of increased imperviousness.

Imperviousness is defined as the sum of roads, parking lots, sidewalks, rooftops and other impermeable surfaces of the urban landscape. This variable can be easily measured at all scales of development, as the percentage of the area that is not "green." Imperviousness is a very useful indicator with which to measure the impact of land development on aquatic systems. Scientific evidence relates imperviousness to specific changes in the hydrology, habitat structure, water quality and biodiversity of aquatic systems. Stream degradation occurs at relatively low levels of imperviousness (10 percent to 20 percent). Most importantly, imperviousness is one of the few variables that can be explicitly quantified, managed and controlled at each stage of land development (Schueler, 1994, p.100-111). Imperviousness represents the imprint of land development on the landscape. It is composed of two primary components, which include rooftops and the transportation system. The transportation component now often exceeds the rooftop component, in terms of total impervious area created (City of Olympia, 1994).

The relationship between imperviousness and runoff may be widely understood, but it is not always fully appreciated. It should be noted that the transportation-related imperviousness often exerts a greater hydrological impact than the rooftop-related imperviousness. In residential areas, runoff from rooftops can be spread out over pervious areas, such as backyards, and are not always directly connected to the storm drain system. This may allow for additional infiltration of runoff. Roads and parking lots on the other hand, are usually directly connected to the storm drain system (Schueler, 1994, p. 100-111).

Impervious surfaces collect and accumulate pollutants deposited from the atmosphere, leaked from vehicles or derived from other sources. During storms, accumulated pollutants are quickly washed off and are rapidly delivered to aquatic systems. Monitoring and modeling studies have consistently indicated that urban pollutants are directly related to watershed imperviousness (Schueler, 1987). Impervious surfaces also both absorb and reflect heat. During the summer months, impervious areas can have local air and ground temperatures that are 10 degrees to 12 degrees warmer than the fields and forests that they replace. The trees that could have provided shade to offset the effects of solar radiation are absent as well. Water temperature in headwater streams is strongly influenced by local air temperatures. Stream temperatures throughout the summer are increased in urban watersheds, and the degree of warming appears to be directly related to the imperviousness of the contributing watershed (Galli, 1991).

Many independent lines of research converge toward one common conclusion: it is extremely difficult to maintain predevelopment stream quality when watershed development exceeds 10 percent to 15 percent impervious covers. The obvious question then becomes should low-density or high-density development be encouraged. At first, it seems appropriate to limit watershed development to no more than 10 percent total impervious cover. While this approach may seem wise for an individual "sensitive" watershed, it is not practical as a uniform standard. Only low-density development would be feasible under a 10 percent zoning scenario, perhaps one acre lot residential zoning, with a few widely scattered commercial clusters. At the regional scale, development would be spread over a much wider geographic area than it would otherwise have been. At the same time, additional impervious areas (in the form of roads) would be needed to link the community together. Paradoxically, the best way to minimize the creation of additional impervious area at the regional scale is to concentrate it in high-density clusters or centers. The corresponding impervious cover in these clusters is expected to be very high (25 percent to 100 percent), making it virtually impossible to maintain predevelopment stream quality. A watershed manager must then confront the fact that to save one stream's quality it may be necessary to degrade another (Schueler, 1994, p.100-111).

Sources of Urban Nonpoint Pollution

The second aspect of urbanization that contributes to urban stormwater pollution is the increased discharge of pollutants. As human activity increases in a given area, the amount of waste material deposited on the land and in drainage systems increases. Driving a car or truck for instance contributes a number of different types of pollutants to urban runoff. Pollutants are derived from automotive fluids, deterioration of parts and vehicle exhaust. Once these pollutants are deposited onto road and parking surfaces, they are available for transport in runoff to receiving waters during storm events (NRDC, 1999, Chap. 2). One landmark study estimated that cars and other vehicles contributed 75 percent of the total copper load to the lower San Francisco Bay through runoff (SCNSPCP, 1992, p. 3-2). Brake pad wear contributed 50 percent of the total load, and 25 percent came from atmospheric deposition – the eventual settling of metals from tailpipe emissions onto the ground (SCNSPCP, 1993, p.48). Other car and truck related sources of metals include tire wear, used motor oil and grease, diesel oil and vehicle rust. Tire ware is a substantial source of cadmium and zinc; concentrations at outfalls often exceed acute toxicity levels. Engine coolants and antifreeze containing ethylene glycol and propylene glycol can also be toxic and contribute high biological oxygen demand (BOD) to receiving waters (Barth, 1995, p. 239-246, 241-242).

Oil, grease and other hydrocarbons related to vehicle use and maintenance also contaminate our waters. These come from disposal of used oil and other fluids on the ground or into storm drains, spills of gasoline or oil, and leaks from transmissions or other parts of automobiles and trucks. The stormwater discharge from one square mile of roads and parking lots can yield approximately 20,000 gallons of residual oil per year (AbTech Industries). Runoff from residential car washing also contributes oil, grease, grit and detergents to the stormwater system. Even gas vapor emitted when filling tanks can subsequently mix with rain, contributing significantly to polluted runoff (National Academy of Science, 1985).

Landscaping practices are another potential source of pollutants in urban runoff. Turf management chemicals including fertilizers used at home and on golf courses, cemeteries and public parks can add nutrients to runoff (Arnold, 1994, p.100). Monitoring has shown a direct link between the chemicals found in lawn care products and urban water quality (Schueler, 1995, p.252). While there remain questions on some details of the contribution of turf management to receiving water quality, it is clear that the type, quantity and timing of materials used make a significant difference.

Construction activity is the largest direct source of human-made sediment loads (Vice, 1969, p.1591-E). Results from both field studies and erosion models indicate that erosion rates from construction sites are typically an order of magnitude larger than row crops and several orders of magnitude greater than rates from well-vegetated areas, such as forest or pastures (63 Federal Register, 1998, p.1540). Since erosion rates are much higher for construction sites relative to other land uses, the total yield of sediment and nutrients is higher (Novotny, 1994, p.564). Studies indicate that poorly managed construction sites can release seven tons to 1,000 tons of sediment per acre during a year, compared to one ton or less from undeveloped forest or prairie land (USEPA, 1993, p. 4-64). Construction activity can also result in soil compaction and increased runoff.

Illicit connections from toilets to storm sewer pipes can be a source of pathogens to stormwater (Haile, 1996, p.7-8). Pathogens are viruses, bacteria and protozoa that can be harmful to human health. Illicit sanitary connections can also add nutrients such as nitrogen and phosphorus to stormwater (USEPA, 1995, p.3-42). Businesses that illicitly connect pipes containing wastewater from industrial processes to the storm sewer system rather than to the sanitary sewers can add metals, solvents or other contaminants to stormwater. In Seattle, one industrial facility's discharge of lead to the storm sewer system resulted in sediment so contaminated that it could be sent to a smelter to be refined (USEPA, 1995, p. 3-44). Floor drains, dry wells and cesspools are also frequent sources of illicit industrial discharges and connections.

Leaking sanitary sewer lines located near storm sewer lines can pose the same problems as illicit connections. Effluent from poorly maintained or failing septic systems can rise to the surface and contaminate stormwater (USEPA,1995, 3-42). Septic systems can be important sources of pathogens and nutrients, especially nitrogen, that are not effectively removed from the waste stream. Bathing beach and shellfish bed closures are frequently the result of septic system effluent. One study found that 74 percent of the nitrogen entering the Buttermilk Bay estuary in Massachusetts originated from septic systems (Ohrel, 1995, p.267)

Rain or melting snow can erode piles of bulk material, such as sand, loose topsoil or road salt if left uncovered adding sediment, salts or other pollutants to nearby waterbodies. Likewise, precipitation can wash contaminants off leaking or dirty objects left outdoors. For example, water quality monitoring showed that untreated runoff collected from auto recycling facilities near Los Angeles frequently exceeded EPA benchmark figures, for BOD, nitrogen, oil, grease, phosphorus and sediment (Swamikannu, 1994, p.59).

In colder parts of the country, salts used to keep roads, parking lots and sidewalks free of ice often drain into our waterbodies as snow and ice melt and spring rain falls. Some municipalities spread sand to maintain road traction on snow and ice, and this sand eventually may increase sediment loads. While some salt and ice treatment is necessary to keep roads safe in winter, measures can be taken to reduce or prevent the impacts from de-icing. Airports de-ice runways and planes, usually with glycol mixtures that can be toxic to fish, wildlife and humans and exert high BOD on receiving streams (Public Sector Consultants, Inc., 1993, p.13-23).

One more source of sedimentation can be attributed to landfills. Because the soil cover on landfills is not stabilized with vegetation or other retaining cover while the landfill is operational, soil can erode from landfills as it does from construction sites. Additionally, improperly maintained hazardous-waste landfills can allow toxic contaminants to reach or stay on the surface of the landfill, allowing stormwater to carry these pollutants to nearby waterbodies (NRDC, 1999, Chap. 2).

Unbelievable as it may seem, waste from domestic and wild animals is a source of pathogens, nutrients and BOD in stormwater (USEPA, 1995, p.3-42). The Northern Virginia Soil and Water Conservation District estimates that each day, dogs leave 180,000 pounds of waste on the ground in Fairfax County, Virginia, alone (Northern Virginia Soil & Water Conservation District). Waste from birds such as pigeons, geese and gulls that are attracted to human activity can also be a problem. Wild geese that congregate in large numbers on cultivated turf adjacent to bodies of water also contribute to pathogen, nutrient and BOD loading (Manny, 1974, p. 1949).

Not only does stormwater frequently receive no treatment; it often does not have the benefit of simple filtering or screening for visible objects. As a result, on top of all those thing already mentioned paper cups, cigarette butts, styrofoam products, newspaper and other materials that people toss on the ground are carried into storm sewer systems and eventually into lakes, streams and oceans. This list, exhaustive as it is, is incomplete. Galvanized roofs, unpaved roads, the dust that collects on paved streets and countless other aspects of daily life in urban areas contribute to polluted runoff (NRDC, 1999, Chap 2).

Urban Runoff and Streams

Urban areas, covering less than 5 percent of land in the continental United States, traditionally have not been recognized as important contributors to pesticide contamination, especially when compared to agricultural land, which covers more than 50 percent of the United States. The National Water-Quality Assessment program findings show a widespread occurrence of some insecticides commonly used around homes and gardens and in commercial and public areas. In fact, these insecticides occurred at higher frequencies, and usually at higher concentrations, in urban streams than in agricultural streams. Most common were diazinon, carbaryl, chloropyrifos and malathion. As in agricultural areas, insecticides were detected in groundwater less frequently than in streams. Some herbicides – including atrazine, simazine and prometon – which are used to control weeds in lawns, golf courses, roadsides and right-of-ways, also occurred frequently in samples collected from streams and shallow ground water in urban areas. Presented here are some of the findings (USGS, 1999, p.10-11).

- *Complex mixtures of pesticides commonly occur in urban streams*. Similar to agricultural pesticides, urban pesticides commonly occurred in mixtures. More than 10 percent of the urban streams sampled during the NAWQA study contained a mixture of the insecticide diazinon and chlorphyrifos, along with at least four herbicides. Two of the most common herbicides in these mixtures were simazine and prometon (USGS, 1999, p.10-11).
- *Concentrations of phosphorous were elevated in urban streams*. Concentrations of total phosphorous in streams generally were higher in urban areas than in agricultural areas; concentrations commonly exceeded the USEPA desired goal (0.1 milligram per liter) to control excessive growth of algae and other nuisance plants in streams. Elevated concentrations of phosphorous are, in part, due to effluent from wastewater treatment plants, despite some long-term decreases in phosphorous resulting from improved treatment technology. The highest concentrations of total phosphorous were in streams in semiarid western and southwestern cities, where discharges from wastewater treatment plants may account for a significant proportion of streamflow. Concentrations of phosphorous also were high in urban areas in the east (USGS, 1999, p.10-11).
- *Nitrogen levels have remained nearly unchanged in rivers downstream from wastewater treatment plants*. Although NAWQA focused mostly on nonpoint sources of nutrients, sampling of some rivers downstream from wastewater treatment plants showed that total nitrogen levels have remained stable since the 1970s. Improvements in wastewater treatment have kept pace with urban population growth in major metropolitan areas. However, wastewater treatment has resulted in changes in the form of nitrogen in the water; specifically, nitrogen in the form of ammonia commonly is converted to nitrate during the treatment process. This conversion makes the discharge less toxic to fish, but is may not help to resolve problems with excessive growth of algae (USGS, 1999, p.10-11).

More Consequences of Urban Nonpoint Pollution

The degradation caused by urban stormwater pollution is serious and affects a significant proportion of the nation's population. The most dramatic consequence of increases in the volume and rate of stormwater runoff is flooding and property damage. One study estimated that because of the increase in impervious cover in a watershed a flood event that should be expected once in 100 years could occur once every five years when the impervious cover reaches 25 percent, and could become an annual event when imperviousness reaches 65 percent (NRDC, 1999, Chap 3).

The increased volume and rate of urban stormwater runoff erodes streambanks and streambeds, dislodging and suspending sediment that might otherwise have remained in place. Erosion can be gradual, or can occur rapidly through a sudden collapse of a streambank (Booth, 1990, p.407, 410-411). Changes in hydrology also affect the shape and dimension of river channels, thereby altering aquatic habitat and channel stability (Rosgen, 1993, p. 783-790). Rapidly flushing stormwater can increase erosion from all land, not just streambanks and streambeds. Stormwater then transports the eroded sediment downstream into the receiving waters. Eventually, when sediment-laden water is stilled, that sediment settles to the bottom of the stream, river, lake or estuary. When sediments settle out, they may cover or destroy important habitat such as spawning beds or submerged aquatic vegetation. Pollutants such as phosphorus attach to sediment particles and become suspended or dissolved in receiving waters (Schueler, 1997, p.443-444)

The magnitude of the sedimentation problem is staggering. One study estimates that each year erosion from construction sites puts 80 million tons of sediment into receiving waters (Shueler, 1997, p. 443-444). Urban runoff can harm aquatic life in many ways due to changes in water chemistry and habitat loss (USEPA, 1997). The metals and organics that stormwater carries are toxic to fish and other forms of aquatic life (Swamikannu, 1994, p. 112-113). Urban stormwater is also often toxic to several species of aquatic insects, on which fish, frogs and other higher life forms feed (Jones, 1987, p. 1047-1055). Stormwater can also bring toxic levels of road salt to urban waters. Pathogens in stormwater also contaminate shellfish beds, and this contamination, along with pollution from other sources, causes closure of shellfish beds nationwide (USEPA, 1995, p.134). The harm to fish leads quickly to harm to fisheries. Sport fishing is a big business in the United States, and many of the species that are most sensitive to degraded water conditions, such as brown trout and salmon, are the species angler's prize most. Quality fisheries can be an important economic asset to the surrounding communities (Vaughan, 1982, p.460-461). The U.S. Fish and Wildlife Service estimates that in 1996, over 35 million anglers spent over $38 billion in pursuit of their pastime – money that would not be spent if there were no fish to catch (USF&WS, 1997, p.4-5).

Stormwater runoff can also carry disease-causing bacteria, viruses and protozoa. Swimming in polluted waters can make you sick. A study in Santa Monica Bay found that swimming in the ocean near a flowing storm sewer drain during dry weather conditions significantly increased the swimmer's risk of contracting a broad range of health effects. Comparing swimming near flowing storm-drain outlets to swimming at a distance of 400 yards from the outlet, the study found a 66 percent increase in an group of symptoms indicative of respiratory disease and a 111 percent increase in a group of symptoms indicative of gastrointestinal illness within the next nine to 14 days (Vaughan, 1982, p.460-461). Increased sediment in receiving water is also related to human illness – sediment prolongs the life of pathogens and makes it easier for them to reproduce.

In urbanized areas, runoff pollution is a serious concern for water supply agencies. Over 90 percent of the people in the United States rely on public supplies of drinking water. Of that 90 percent, 19 percent are served by systems with reported health violations (USEPA, 1998, p.147). A nationwide survey of surface drinking water supply utilities found that with an increase in urbanization there arose an increased concern among managers over runoff pollutants, particularly nutrients, bacteria and toxic organic chemicals (Robbins, 1991). The costs can be astronomic. For example, runoff pollution from suburban and agricultural sources is one of the largest threats to New York City's currently unfiltered drinking water supply. If this pollution cannot be prevented, New York City may need to filter its water supply at a capital cost of perhaps $5 billion or more (Marx, 1999).

Protecting the Source

Now that a few of the consequences of urban nonpoint pollution have been discussed, lets focus on some communities that have opted to protect their watershed from these types of problems. From small towns to big cities to entire states, there is a growing recognition that land conservation may be the best and cheapest way to guarantee drinking water supplies. This is revolutionizing the way America's watersheds are managed. Production of quality drinking water depends on three things, watershed protection, filtration and disinfection. With the spread of development and intensified agricultural practices across watersheds, pollutant runoff, nonpoint source pollution and unmanaged development have become the greatest threats to drinking water sources (TPL, 1997, p.5).

Rising levels of organic material entering treatment plants are pushing treatment technology to its limits. Many treatment plants have had to increase levels of chlorination to meet EPA disinfection requirements. Chicago, for instance, has increased its level of chlorine by 30 percent since 1965. Not only is the taste affected, but chloroform is created as a by-product. Trihalomethanes (THMs) such as chloroform, once formed, are not removable by filtration and are thought to cause more than 10,000 rectal and bladder cancers nationwide each year (TPL, 1997, p.6).

The failure to protect recharge zones can also be disastrous. From the hamlet of Katonah, New York, where artesian wells were contaminated by dry-cleaning chemicals, to California's San Gabriel Valley, where one public well in four is tainted with industrial toxins, countless municipal and private wells across the nation have had to be closed and capped. In 1983, leaking underground gasoline storage tanks contaminated one of five wells in Thurmont, Maryland. Thirteen years and countless cleanup efforts later, the well remains contaminated. The Maryland Rural Water Association, which assist communities with wellhead protection, says the rule of thumb is that one gallon of leaked gasoline can contaminate one million gallons of water. More recently, Santa Monica, California was forced to shut down wells providing half its normal water supply when leaking gasoline tainted them. The Congressional Research Service estimates that 140,000 underground storage tanks are leaking at local gas stations across the country. Development that includes the storage and use of chemical contaminants like gas and dry-cleaning fluids within a watershed is a critical concern (TPL, 1997, p. 8-9)

There are a number of recent examples of communities protecting their watersheds. One fantastic example is that of the New York watershed. For the past century, New York City residents have obtained 90 percent of their drinking water from reservoirs and streams in the Catskill's region. Much of this water flows through farmland, and area farmers have long had to accommodate downstate water demands. From 1907 to 1964, the New York City Board of Water Supply acquired more than 57,000 acres of Catskill land. Streams and rivers were dammed to create six new reservoirs. Houses were razed, farms flooded and entire villages raised. The city had created the largest surface drinking water supply in the country, encompassing more than 1,900 square miles of reservoirs and waterways. For years, that drinking water was treated with only the addition of chlorine. In 1989, however, the federal Safe Drinking Water Act ordered New York City to filter its water to reduce the possibility of contamination. A filtration plant for the city water could cost between $3 billion and $8 billion to build and hundreds of millions of dollars per year to operate. The EPA rules also offered an alternative: watershed protection. This was a much less costly option, and the city officials decided to protect their water supply at the source rather than treat the water just prior to its dispersal. After evaluating land uses in the watershed, the city released a draft protection plan in 1990. The draft, which contained new updated rules and regulations for the watershed and outlined ways to protect the water supply, proposed banning such practices as applying manure or fertilizer within 100 feet of a waterway (AFT, 1998, 31-34).

A 1990 study determined that the average farm would be forced to retire 35 percent of its land in order to comply with the regulations. The farmers surveyed said that such a loss of productive farmland would cause them to sell land to developers. Further development of the watershed, however, was not what the city wanted. Since agricultural enterprises are considered low-density land uses, with less potential to pollute surface waters than dense urban areas, watershed farmers contended that it would be to the city's advantage to keep farmland in farming. In 1991, the city and watershed farmers started working together to develop whole-farm plans that protect water quality and enhance agricultural viability. After months of negotiations, New York City agreed in 1998 to fund an agricultural easement program. The first of its kind "Whole-Farm Easement" program will integrate water quality and farmland protection. Whole-farm plans would account for soil erosion, management of livestock waste and use of chemicals, pesticides and fertilizer. To implement the plans, farmers would utilize "best management practices" that help reduce a farm's potential to degrade the environment. Whole-farm management, with the city paying for the costs, allowed upstate farmers and the city to share the responsibility for protecting the water resources (AFT, 1998, 31-34).

Colorado and New Jersey have also done a great job protecting their watersheds. In Colorado, the city of Gunnison, population 6,000, spent over a half-million dollars to buy a ranch sitting on top of its aquifer. The amount spent on this project equaled the cities entire annual drinking water budget. Water used to irrigate the 460-acre Van Tuly Ranch's hay crop filters through the soil to recharge the aquifer that supplies the town with water. Development would not only curtail vital recharge, but related pollution, from lawn chemical runoff to septic system leaching, would directly threaten drinking water quality. Protecting the ranch preserves the quality and quantity of the water available to the residents, as well as preserving open space (TPL, 1997, p. 5-6).

When the state of New Jersey revised its 1996 master plan for water management, it completely revised the priorities of the 1980s. Gone were any considerations of increased capacity. Initiatives were instead directed at water resource protection, water management and water conservation. The plan noted that water management concepts are changing, and concluded that more emphasis on water-based pollution control was absolutely necessary (TPL, 1997, p. 5-6).

In 1998, the Trust for Public Land helped the state of New York acquire Sterling Forest, a 16,000-acre watershed on the new York/New Jersey border. The land's owners had proposed 13,000 homes, 8 million square feet of commercial and light-industry development, and three golf courses on the site. The forest was protected by $55 million in federal, state and foundation funds. New Jersey officials had calculated that development would have so polluted the watershed that a new $160 million filtration plant would have been required (Smart Growth Network, 1999, p.1-2).

Other examples include Austin and other comminutes in Texas which are working to protect land above the shallow Edwards Aquifer, which supplies drinking water to 1.5 million Texans. Communities around Charlotte, North Carolina have launched a cooperative effort to protect the watershed around Mountain Island Lake, the source of drinking water for 600,000 people. Some of the money for these acquisitions is coming from North Carolina's Clean Water Management Trust Fund, the nation's only state program that sets aside funds specifically for water quality protection, including watershed acquisition. Other communities are protecting floodplains to avoid recurring property losses from floods, which average $4.3 billion each year. For example, in the Napa Valley of California, engineers are purchasing homes and businesses and acquiring land along the Napa River, restoring the river's floodplain to avert an average $10 million a year in property damages (Smart Growth Network, 1999, p.1-2).

The Economic Benefit of Watershed Protection

Watershed development does not necessarily have to be synonymous with the degradation of aquatic resources. When new growth is managed in a watershed context, homes and businesses can be located and designed to have the smallest possible impact on streams, lakes, wetlands and estuaries. In the watershed protection approach, communities can apply basic tools that guide where and how new development occurs. The watershed protection tools highlighted are designed to protect water quality while increasing the value of existing and developable land. If used correctly, these tools can protect the rights of individual property owners as well as those of the entire community (Schueler, 1995).

The first tool that can be utilized is watershed-based zoning. This is a local planning process for identifying key watershed uses, and then directing the appropriate level of new growth to those subwatersheds that can best afford and accommodate it (Schueler, 1995). Watershed planning involves an assessment of stream conditions and development of strategies to maintain or restore their condition. It directs proposed development to the least sensitive area and attempts to control the amount and location of impervious cover in a watershed. Some subwatersheds are designated as growth areas, while others are partly or fully protected from future development (Schueler, 1995).

Conserving trees also saves money on energy bills and treatment of runoff. Studies by the American Forest Association have shown that homes and businesses that retain trees save 20 percent to 25 percent in their energy bills for heating and cooling, compared to homes where trees are cleared. The urban forest canopy also helps to reduce the volume of stormwater runoff. A modeling study by Henson and Rowntree (1988) reported that stormwater decreased by 17 percent due to forest cover in a Utah development during a typical one-inch rainstorm. Protecting coastal wetland areas can also contribute to the local economy through recreation, fishing and flood protection. Various economists have calculated that each acre of coastal wetland contributes from $800 to $9,000 to the local economy (Kirby, 1993).

A shoreline or creek buffer can create many market and non-market benefits for a community, particularly if they are managed as a greenway. These include an increase in the value of adjacent property. For example, housing prices were found to be 32 percent higher if they were located next to a greenbelt buffer in Colorado (Correl et al. 1978). Nationally, buffers were thought to have a positive or neutral impact on adjacent property values in 32 out of 39 communities surveyed (Schueler, 1995).

Forested shoreline and stream buffers situated on the flat soils of the coastal plain have been found to be effective in removing sediment, nutrients and bacteria from stormwater runoff and septic system effluent in a wide variety of rural and agricultural settings along the East Coast (Desbonnet et al. 1994). Buffers provide a critical "right of way" for streams during large floods and storms. When buffers contain the entire 100-year floodplain, they are an extremely cost-effective form of flood damage avoidance for both communities and individual property owners. As an example, a national study of 10 programs that diverted development away from flood-prone areas found that land next to protected floodplains had increased in value by an average of $10,427 per acre (Burby 1988). Homes situated near seven California stream restoration projects had a 3 percent to 13 percent higher property value than similar homes located on unrestored streams (Streiner and Loomis 1996). Most of the perceived value of the restored stream was due to the enhanced buffer, habitat and recreation afforded by the restoration.

One tool developers can employ to increase profits and protect the watershed is cluster development. The concept underlying cluster development is to minimize lot sizes within a compact developed portion of a property while leaving the remaining portion prominently open. Housing can still consist of detached single-family homes as well as multi-family housing or a mix of both. This can reduce the capital cost of subdivision development by 10 percent to 33 percent, primarily by reducing the length of the infrastructure needed to serve the development (NAHB 1986; Maryland Office of Planning 1989; Schueler, 1995). This type of construction can keep from 40 percent to 80 percent of total site area in permanent community open space, which can reduce site impervious cover from 10 percent to 50 percent (depending on the original lot size and layout), thereby lowering the cost for both stormwater conveyance and treatment. These cost savings can be considerable, as the cost to treat the quality and quantity of stormwater from a single impervious acre can range from $2,000 to $50,000. In addition, the ample open spaces within a cluster development provide a greater range of locations for more cost-effective stormwater runoff practices (Schueler, 1995).

In many rural watersheds, new development occurs outside of water and sewer service areas, which means that wastewater must be treated on the site, usually by a septic system. To treat wastewater, septic systems must have appropriate drainage area and soil to function properly. Costs associated with installing septic systems and correcting system failures can be expensive. The average cost of constructing a conventional septic system at a single family home situated on a large lot is around $4,500 approximately equal to the unit cost of municipal wastewater (USEPA, 1993). The cost of more innovative septic systems (that have a higher nutrient removal rate, lower failure rates or that can perform on poor soils) are 25 percent to 75 percent greater than conventional systems, with somewhat higher maintenance costs as well (Ohrel, 1995). The cost to maintain a properly functioning septic system on an individual lot is not inconsequential. For example, the cost to inspect a septic system ranges from $50 to $150 per visit, and each pumpout costs about $150 to $250 (Ohrel, 1995). The recommended pumpout frequency ranges from two to five years for a standard household tank. Over a decade, the total costs of maintaining a septic system can run from $1,000 to $3,000. There are also major costs to landowners when septic systems fail. A failed or failing septic system can decrease property values, delay the issuance of building permits or hold up the purchase settlement. In the event a septic system fails, homeowners can expect to pay from $3,000 to $10,000 for replacement (NSFC, 1995).

Strategies

By far the most important category of stormwater strategies focuses on land use and development. It encompasses a wide range of measures, from regional planning to the use of site-specific structural and nonstructural measures. These measures, with the exception of incentives for infill and redevelopment, apply more in developing and suburban areas than in ultra-urban areas that are already built up. In areas where there is less opportunity for regional or site planning or conservation-oriented design because they are already built up and largely covered by impervious surfaces, municipalities will need to rely more on the other elements of a stormwater program or on stormwater treatment measures (NRDC, 1999, Chap5).

One of the principle causes of urban stormwater pollution is the creation of impervious surfaces. One of the best strategies a municipality can employ is to minimize the aggregate amount of new impervious surfaces, since where impervious surface does increase treatment or control of runoff is needed (NRDC, 1999, Chap5). Some ways to deal with this problem of imperviousness that already exists is to redirect roof drains away from driveways or other impervious surfaces. Since it is the effective imperviousness that counts, unplugging unnecessary hydraulic connection wherever possible can reduce the effective imperviousness. Another option is to keep the parking lots, but plant trees that will provide a canopy all around the lots, in street medians etc. Canopy trees will intercept a percentage of the rainfall. They will reduce a developed site’s runoff peak and volume measurably.

Another strategy is concentrating development. Concentrating development in certain areas within an entire metropolitan area or region has the same benefits as concentrating development on a particular site. Less imperviousness is created for a given number of residences or businesses, creating fewer disturbances to the water cycle. Locally, however, the concentration of imperviousness will result in greater stormwater runoff and more polluted flows. Therefore, heavily urbanized areas will often require structural management measures of the type to be discussed later (NRDC, 1999, Chap 5).

A number of states including Oregon, Tennessee, Maryland and Washington have enacted growth management regimes. Municipalities that have successfully implemented urban growth boundaries include Portland, Oregon; Boulder, Colorado; Lancaster County, Pennsylvania; and several Bay Area cities. Establishing urban growth boundaries that encircle the current developed area of a particular city or metropolitan area reduces the amount of new development and associated impervious cover (NRDC, 1999, Chap5). Under the UGB concept, local governments estimate the amounts of land needed for are business, housing recreation, etc., for a period of time. They then draw a line around this land. New development can occur within the line but not outside it. UGB's are typically set for 20 years. This is long enough to be taken seriously but short enough to accommodate revision. The value of UBG's is not in drawing a fixed boundary per se, but in the pressure it exerts on municipalities to make a direct reckoning of the long-term cost of unplanned sprawl (Bollier,1998).

In Olympia, Washington, the public works department recommended that reducing impervious cover be incorporated into the city's growth management efforts, with vehicle-oriented pavement offering the greatest opportunity for reduction (City of Olympia, 1995, p. 5). Disincentives that some cities use to discourage development outside these boundaries include large-lot zoning, municipal refusal to pay for sewers, roads or other infrastructure, or concurrency requirements, which forbid development where municipal infrastructure has not yet been provided (Duerksen, 1995, p. 24-35). However, in areas experience high growth pressure, such strategies may not be enough to stop sprawl. In the more successful programs, such disincentives are linked with incentives for infill or brownfield redevelopment to ensure that urban growth boundaries are not a moratorium on development. For example, urban growth boundaries are often coupled with other growth management techniques that encourage higher density development within the boundary, such as transfer of development rights programs. Several communities have used these programs, which allow developers outside the urban growth boundary or other areas of managed growth to sell their development rights to developers wishing to build at a higher density within the boundary (Nelson, 1995, p. 47-51).

Watershed planning has provided several municipalities the opportunity to consider all the resources in the watershed as a single, interrelated system. As the name implies, watershed boundaries, not political boundaries, are the basic units of management often requiring a municipality to work with other local governments or regional organizations. Effective watershed planning focuses on the relationship between land use and water quality. Watershed planning begins with an evaluation of the current and desired condition for each of the relevant waterbodies in the watershed, as well as a comprehensive mapping of current land use practices in the watershed. Armed with these data, planners determine what land uses are consistent with the desired conditions in the waterbodies. Watershed residents and other stakeholders are usually involved in the process. The municipalities then put in place a watershed plan along with land-use ordinances that designate new development and land use changes to appropriate levels, types and locations (Schueler, 1995, p. 37-53).

An alternative way to address stormwater pollution is performance zoning (Duerksen, 1995, p.37-38). Under performance zoning, a municipality does not specify uses for parcels of land as it may under traditional ordinances, but instead sets out performance standards for open space preservation, impervious surface area, maximum pollutant emissions or other criteria that the municipality deems important. Some performance zoning ordinances grade proposed developments on a point scale based on the degree to which the development achieves various ends. Only development proposals with a point total exceeding a certain threshold then receive approval. In Maine, the potential impacts from a proposed development on phosphorus loading to lakes is calculated and compared to an established community goal. If the development causes the goal to be exceeded, the developer must modify the design or add additional control measures (Maine DEP, 1992, p.4).

Many municipalities employ stream and wetland buffer requirements, open space preservation and other laws or programs, as cost-effective means for reducing stormwater runoff and achieving other public goals. These programs are often the specific means of implementing larger growth management goals and are often linked with incentives to aid development in other areas. In addition to zoning-type ordinances, municipalities can also use economic incentives to reduce impervious cover or implement stormwater control through stormwater utilities where the fee is based on amount of impervious cover, inspection and permit fees linked to compliance or dedicated contributions from land developers (NRDC, 1999, Chap5).

Other land acquisition and open space presentation programs have proven popular with local governments and, as judged by election and referendum results, with the electorate. In the 1998 elections, 10 states, at least 22 counties and at least 93 local governments featured open space initiatives on their ballots. Voters approved 87 percent of the measures and a total of $4 billion of spending by their governments to protect open space, in many cases increasing taxes (LTA, 1998). Open space often serves many community needs and can both reduce the stormwater problem and be part of the solution. State assistance appears to be extremely helpful.

Open space is not an expense but an investment that can repay the communities for years to come. Parks, greenways and conserved open spaces provide many benefits. These include attracting tax-paying businesses, jobs and new residents to communities. It can stimulate urban commercial growth and inner-city revitalization, and support important industries such as recreation, tourism and agriculture. These options also offer a relatively inexpensive way to prevent flood damage, safeguard drinking water and prevent the loss of invaluable environmental resources. It is important to understand that no community can grow smart if that growth pollutes drinking water supplies (Smart Growth Network, 1999, p.1-3).

The bottom-line is that while prevention-focused, "nonstructural" BMPs such as planning and design offer many advantages, in densely populated sections some structural BMPs are often needed. Municipalities turn to structural measures where there are highly impervious areas, where there is not enough land available for natural area methods and where extensive quantitative information in needed (Livingston, 1997, p. 7). Four categories of structural management measures are found in these case studies: detention practices, biofiltration practices, infiltration practices and filtration practices.

Detention practices temporarily store runoff, then discharge it through a pipe or other outlet structure into streams or other waterbodies (Watershed Management Institute, 1994 p. 1-5). Use of wet and dry detention ponds are the most common of such practices. Dry ponds release all of their water within a specified time period (generally up to 48 hours), while wet ponds keep some water at all times and retain excess water for a longer period than dry ponds. When designed to be such, wet ponds can be an aesthetic or recreational amenity. Another less common detention practice is the use of cisterns. The fundamental purpose of detention ponds is to reduce peak flows. They also can improve water quality by holding water for a long enough period to allow some sediment and other contaminants to settle out before the water drains. Wet ponds, by virtue of the longer detention times and frequent presence of aquatic plants and other life, can provide additional water quality treatment through biofiltration and chemical processes (NRDC, 1999, Chap. 2).

Biofiltration and bioretention practices are discussed in several case studies. These practices filter stormwater to reduce contaminant loading using plants as an additional filter medium. Plants absorb nutrients and metals to a certain extent and facilitate microbial breakdown, but most of the pollutant removal from these practices occurs when the presence of the plants physically block the stormwater flow, slowing the flow and allowing contaminants to settle out (Horner, 1994, p.119, 124). Bioretention areas, also known as rain gardens, capture runoff and allow it to slowly infiltrate into the ground. Infiltration enhances pollutant removal and allows the water to be cooled. As with other structural BMPs, occasional maintenance to remove the accumulated pollutants that have been taken from the stormwater is required (NRDC, 1999, Chap. 2).

Infiltration practices temporarily store runoff in basins from which the water percolates slowly into the soil below. Like detention practices, they reduce peak flows. However, infiltration practices also recreate, to a greater or lesser extent, the natural pattern of water infiltration into the ground that existed before increased imperviousness covered the land. When designed and installed correctly and maintained regularly, infiltration practices are among the most effective structural BMPs, and often address most of the stormwater impacts previously discussed. Studies have shown that infiltration can get 98 percent of stormwater into the earth, cool stormwater to 55°F, remove up to 83 percent of nitrogen and remove up to 98 percent of copper (Klein, 1999). The principle reason why infiltration is often a preferred method is that runoff is cooled as it flows though the ground, thereby reducing the detrimental thermal effects that runoff has on aquatic ecosystems (NRDC, 1999, Chap. 2).

Filtration practices address water quality problems rather than water quality. Some consist of a chamber containing a filter medium buried at ground level through which stormwater flows, while some are filter inserts for catchbasins in the storm sewer system. As stormwater flows through the filter medium, it removes particulates and other contaminants. The filtering materials most frequently used are sand, peat or compost, although municipalities now use BMP's with synthetic filter media (NRDC, 1999, Chap5).

While construction is just one of many industries with stormwater impacts, its impacts are so significant that it is treated separately under the federal and most state and local programs. Effective local construction site stormwater management strategies aim both to reduce runoff volume to levels that will not cause erosion and to capture as much of the sediment and other pollutants that do wash off. While existing programs rely on a fairly wide variety of erosion and sediment control practices virtually all successful strategies require proper planning and phasing of construction activities to avoid disturbing more land than necessary during construction (NRDC, 1999, Chap5). For example, some portions of the development site should never be cleared and graded or should be sharply restricted. These include stream buffers, wetlands, highly erodible soils, steep slopes and stormwater infiltration areas. Streams and waterways are particularly susceptible to sedimentation, and a designer should always check to see if they are present at a site, and whether construction activities will occur near them. If so, no clearing should be permitted adjacent to the waterway. As a secondary form of protection, a line of silt fence or earthen dik3 can be installed along the perimeter of the waterway buffer (Caraco, 1995).

Mass grading of larger construction sites should be avoided since it maximizes both the time and area that disturbed soils are exposed to rainfall and therefore subject to soil erosion. As an alternative, designers should consider construction phasing whereby only a portion of a construction site is disturbed at any one time to complete the needed building at that phase. Other portions of the construction site are not cleared and graded until the construction of the earlier phase is nearly completed and its exposed soils have been stabilized. Construction phasing is similar to “just-in-time manufacturing” in that earthmoving occurs only when it is absolutely needed. By breaking the construction site into smaller units, the disturbed area is sharply reduced. This is particularly critical for larger residential and commercial projects that may take one, two or even three years to finish. Even when the best erosion and sediment control practices are employed, construction sites will still discharge high concentrations of suspended sediments during larger storms. Therefore, the plans should include some kind of trap or basin to capture sediments and allow time for them to settle out (Caraco, 1995).

Conclusion

One can see there is an exhaustive list of pollution sources from all aspects of our daily lives in urban areas. The increasingly complex mix of urban and rural land uses has natural resource impacts that extend well beyond land use competition. Urbanization brings streets and rooftops that run stormwater directly into drains instead of filtering it naturally through the soil. Hydrologic impacts due to urbanization cause water quality problems such as sedimentation, increased temperatures, habitat changes and many others. New pollutants such as oil leaked from automobiles or chemicals leached from suburban lawns are also the cause of some very serious threats to our nation's waters. It is important to realize what a large-scale problem increases runoff volumes and velocities from urbanization and associated increases in watershed imperviousness can cause. As mentioned earlier, EPA ranks urban runoff and storm sewer discharges together as the second most prevalent source of water quality impairment in the nation’s estuaries, after industrial discharges, and the fourth most prevalent source of impairment in lakes after agriculture, unspecified nonpoint sources and atmospheric deposition of pollutants (USEPA, 1998, ES-13). Watersheds where the maintenance of healthy conditions formerly depend on the land stewardship of a few dozen agricultural managers now often rely on the actions of hundreds of small landowners, making the task of developing effective, cooperative efforts all the more difficult and necessary. It should be a priority to use the available tools to protect watersheds. Watershed based zoning and cluster development are only two of the many tools that were mentioned. These sorts of investments in open space and watershed protection will repay the nation with good health and a healthier environment for years to come.

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