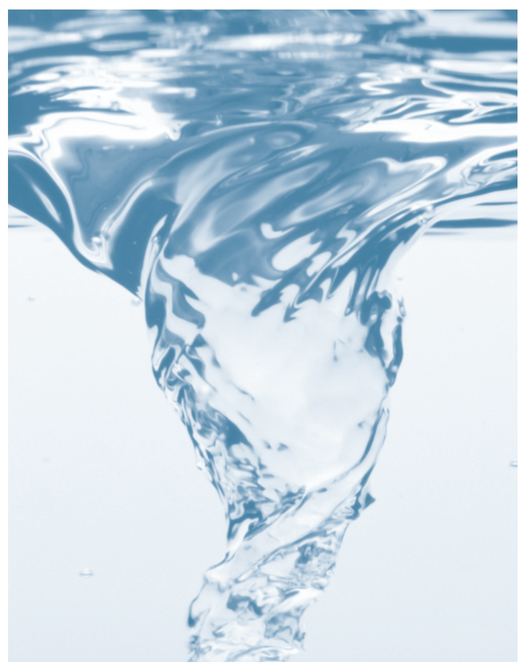
Chapter 2
Why Stormwater Matters: The Impacts of Urbanization



Volume 1: Background

Chapter 2

Why Stormwater Matters: The Impacts of Urbanization

2.1 What is Urban Stormwater Runoff?

Stormwater runoff is a natural part of the hydrological cycle, which is the distribution and movement of water between the earth's atmosphere, land, and water bodies. Rainfall, snowfall, and other frozen precipitation send water to the earth's surfaces. Stormwater runoff is surface flow from precipitation that accumulates in and flows through natural or man-made conveyance systems during and immediately after a storm event or upon snowmelt. Stormwater runoff eventually travels to surface water bodies as diffuse overland flow, a point discharge, or as groundwater flow. Water that seeps into the ground eventually replenishes groundwater aquifers and surface waters such as lakes, streams, and the oceans. Groundwater recharge also helps maintain water flow in streams and wetland moisture levels during dry weather. Water is returned to the atmosphere through evaporation and transpiration to complete the cycle. A schematic of the hydrologic cycle is shown in **Figure 2-1**.

Traditional development of the landscape with impervious surfaces such as buildings, roads, and parking lots, as well as storm sewer systems and other man-made features, alters the hydrology of a watershed and has the potential to adversely affect water quality and aquatic habitat. As a result of development, vegetated and forested land that consists of pervious surfaces is largely replaced by land uses with impervious surfaces. This transformation increases the amount of stormwater runoff from a site, decreases infiltration and groundwater recharge, and alters natural drainage patterns. This effect is shown schematically in **Figure 2-2.** In addition, natural pollutant removal mechanisms provided by on-site vegetation and soils have less opportunity to remove pollutants from stormwater runoff in developed areas. During construction, soils are exposed to rainfall, which increases the potential for erosion and sedimentation. Development can also introduce new sources of pollutants from everyday activities associated with residential, commercial, and industrial land uses. The development process is known as "urbanization." Stormwater runoff from developed areas is commonly referred to as "urban stormwater runoff."

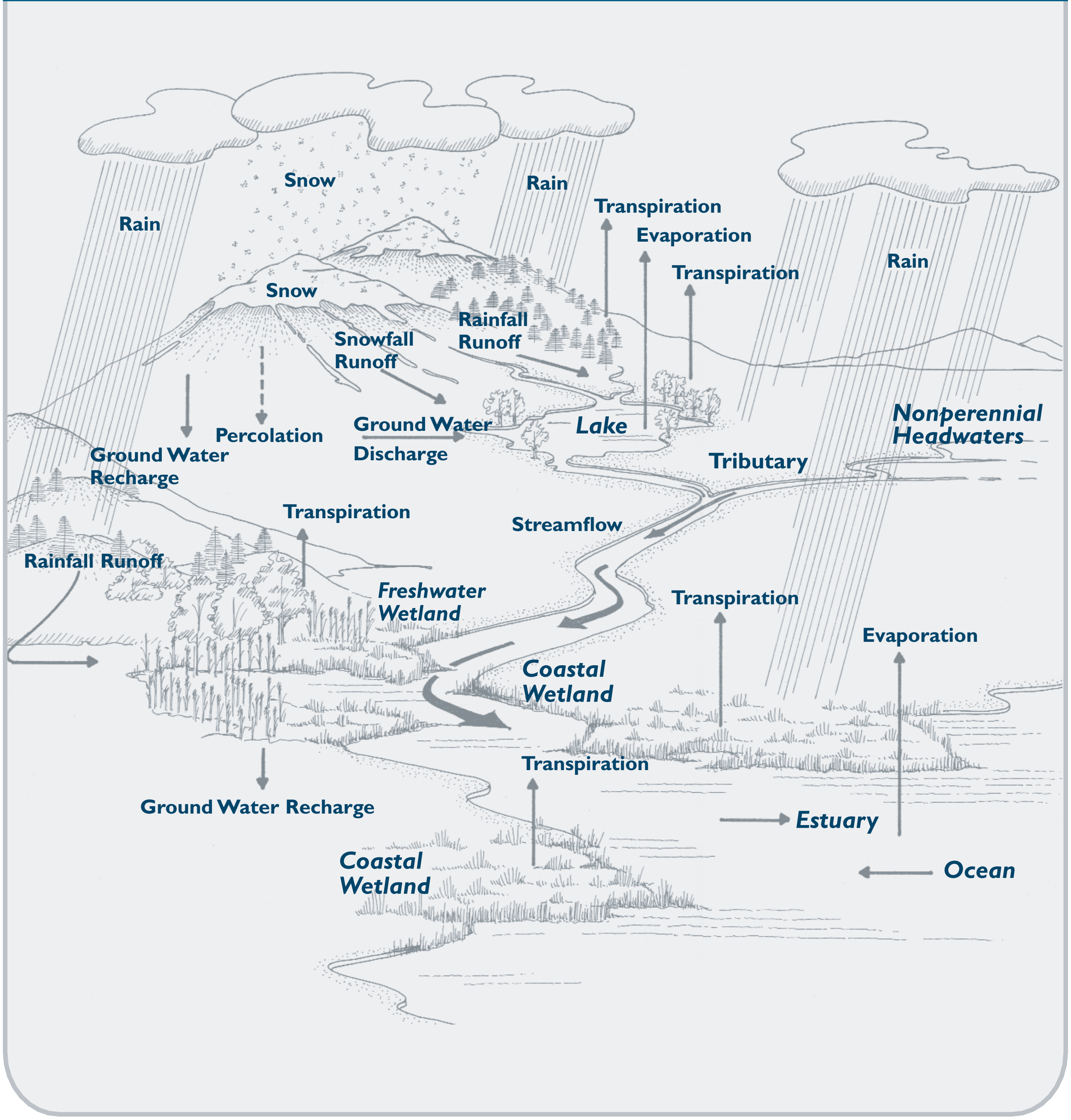
Urban stormwater runoff can be considered both a point source and a nonpoint source of pollution. Stormwater runoff that flows into a conveyance system and is discharged through a pipe, ditch, channel, or other structure is considered a point source discharge under EPA's National Pollutant Discharge Elimination System (NPDES) permit program, as administered by DEP. Stormwater runoff that flows over the land surface and is not concentrated in a defined channel is considered nonpoint source pollution. In most cases stormwater runoff begins as a nonpoint source and becomes a point source discharge (MADEP, 1997). Both point and nonpoint sources of urban stormwater runoff have been shown to be significant causes of water quality impairment (EPA, 2000).

According to the draft 2004 Connecticut list of impaired waters ("303(d)") list prepared pursuant to Section 303(d) of the Federal Clean Water Act), urban runoff and stormwater discharges were a significant cause of aquatic life and contact recreation (e.g. swimming and boating) impairment to approximately one-quarter of the state's 893 miles of major rivers and streams. Urban runoff is also reported as a contributor to excessive nutrient enrichment in numerous lakes and ponds throughout the state, as well as a continued threat to estuarine waters and Long Island Sound (EPA, 2001). **Table 2-1** summarizes impaired Connecticut water bodies (i.e., those not meeting water quality standards) for which urban runoff, stormwater discharges, or other wet-weather sources are suspected causes of impairment (DEP, 2004 draft). This list does not include water bodies impaired as a result of other related causes such as combined sewer overflows (CSOs) and agricultural runoff or unknown sources.

Impervious cover has emerged as a measurable, integrating concept used to describe the overall health of a watershed. Numerous studies have documented the cumulative effects of urbanization on stream and watershed ecology (See, e.g., Schueler et al., 1992; Schueler, 1994; Schueler, 1995; Booth and Reinelt, 1993, Arnold and Gibbons, 1996; Brant, 1999; Shaver and Maxted, 1996). Research has shown that when impervious cover in a watershed reaches between 10 and 25 percent, ecological stress becomes clearly apparent. Beyond 25 percent, stream stability is reduced, habitat is lost, water quality becomes degraded, and biological diversity decreases (NRDC, May 1999). **Figure 2-3** illustrates this effect.

To put these thresholds into perspective, typical total imperviousness in medium density, single-family home residential areas ranges from 25 to nearly 60 percent (Schueler, 1995). **Table 2-2** indicates typical percentages of impervious cover for various land uses in Connecticut and the Northeast

Figure 2-1 Hydrologic Cycle



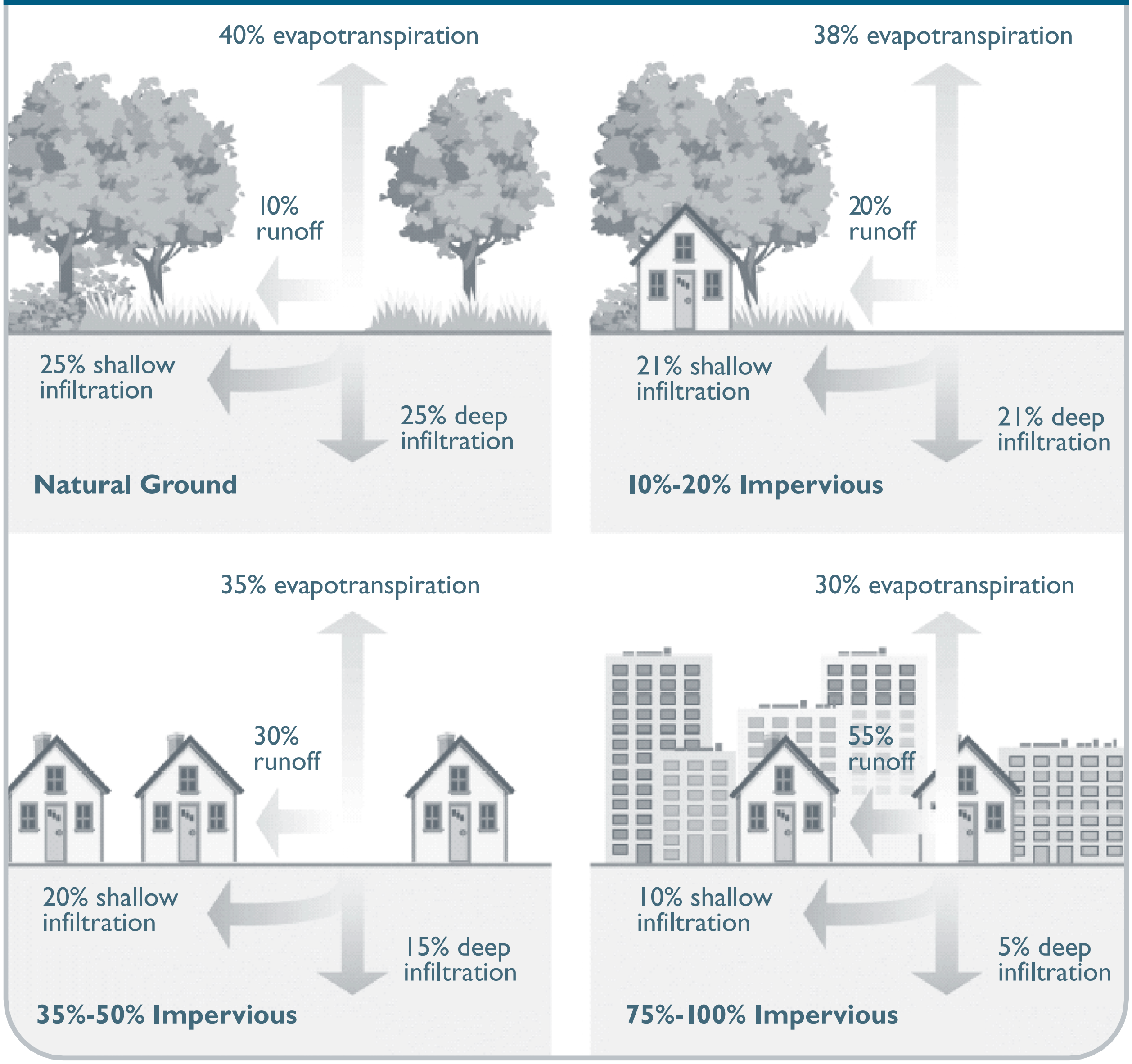
Source: National Water Quality Inventory, U.S. EPA, 1998.

Table 2-1 Connecticut Water Bodies Impaired by Urban Stormwater Runoff

Major Basin	Water Body	Major Basin	Water Body
Pawcatuck River Basin	Pawcatuck River Estuary	Thames River Basin	Thames River Estuary Eagleville Brook Quinebaug River
Southeast Coastal Basins	Fenger Brook Stonington Harbor West and Palmer Coves Mumford Cove Alewife Cove Long Island Sound East Niantic Bay: upper bay, river and offshore Wequetequock Cove Copps Brook Estuary/Quiambog Cove Mystic River Estuary Pequonock River Estuary/Baker Cove Jordan Cove Pattagansett River Estuary Fourmile River	Housatonic River Basin	Housatonic River Housatonic River Estuary Hitchcock Lake Ball Pond Still River Kenosia Lake Padanaram Brook Sympaug Brook Naugatuck River Naugatuck River, West Branch Steele Brook Mad River Hop Brook Lake
Southwest Coastal Basins	Bridgeport Harbor Blackrock Harbor Sherwood Mill Pond/Compo Cove Westcott Cove Greenwich Cove Byram Beach Captain Harbor Rooster River Ash Creek Upper/Lower Mill Ponds Sasco Brook/Estuary Saugatuck River Estuary Norwalk River and Harbor Ridgefield Brook Five Mile River/Estuary Darien Cove Holly Pond/Cove Harbor Stamford Harbor Cos Cob Harbor Byram River/Estuary Long Island Sound West: Southport Harbor	South Central Coastal Basins	Oyster River Tributary Madison Beaches Island Bay/Joshua Cove Thimble Islands Plum Bank Indiantown Harbor Patchogue River Clinton Harbor Guilford Harbor Cedar Pond Linsley Pond Branford Harbor Hanover Pond Quinnipiac River New Haven Harbor Tenmile River Sodom Brook Harbor Brook Wharton Brook Mill River Edgewood Park Pond West River Milford Harbor/Gulf Pond Long Island sound Central Menunnketesuck River Hammonasset River Indian River Hammock Riber Branford Supply Pond West Pisgah River Pine Gutter Brook Allen Brook
Connecticut River Basin	Pequabuck River Birge Pond Pine Lake Park River, South Branch Batterson Park Pond Piper Brook Trout Brook Park River, North Branch Hockanum River Union Pond Mattabesset River Willow Brook Pocotopaug Creek Connecticut River Estuary	Crystal Lake John Hall Brook Little Brook Spruce Brook Coles Brook Miner Brook Belcher Brook Webster Brook Sawmill Brook	

Source: 2004 List of Connecticut Waterbodies Not Meeting Water Quality Standards (draft 5/14/02). The impaired waters list is updated by DEP every two to three years.

Figure 2-2 Impacts of Urbanization on the Hydrologic Cycle



Source: Federal Interagency SRWG, 2000.

United States. It is important to note that these tabulated values reflect impervious coverage within individual land uses, but do not reflect overall watershed imperviousness, for which the ecological stress thresholds apply. However, in developed watersheds with significant residential, commercial, and industrial development, overall watershed imperviousness often exceeds the ecological stress thresholds.

Table 2-2
Typical Impervious Coverage of Land Uses in the Northeast U.S.

Land Use	% Impervious Cover
Commercial and Business District	85-100
Industrial	70-80
High Density Residential	45-60
Medium Density Residential	35-45
Low Density Residential	20-40
Open Areas	0-10

Source: MADEP, 1997; Kauffman and Brant, 2000; Arnold and Gibbons, 1996; Soil Conservation Service, 1975.

The impacts of development on stream ecology can be grouped into four categories:

1. Hydrologic Impacts
2. Stream Channel and Floodplain Impacts
3. Water Quality Impacts
4. Habitat and Ecological Impacts

The extent of these impacts is a function of climate, level of imperviousness, and change in land use in a watershed (WEF and ASCE, 1998). Each of these impacts is described further in the following sections.

2.2 Hydrologic Impacts

Development can dramatically alter the hydrologic regime of a site or watershed as a result of increases in impervious surfaces. The impacts of development on hydrology may include:

- *Increased runoff volume*
- *Increased peak discharges*
- *Decreased runoff travel time*
- *Reduced groundwater recharge*
- *Reduced stream baseflow*
- *Increased frequency of bankfull and overbank floods*
- *Increased flow velocity during storms*
- *Increased frequency and duration of high stream flow*

Figure 2-4 depicts typical pre-development and post-development streamflow hydrographs for a developed watershed.

2.3 Stream Channel and Floodplain Impacts

Stream channels in urban areas respond to and adjust to the altered hydrologic regime that accompanies urbanization. The severity and extent of stream adjustment is a function of the degree of watershed imperviousness (WEF and ASCE, 1998). The impacts of development on stream channels and floodplains may include:

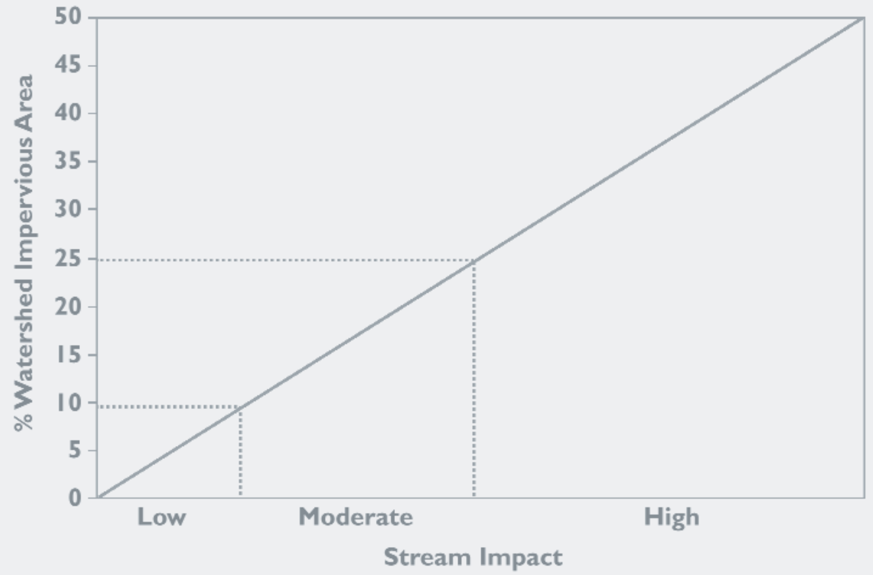
- *Channel scour, widening, and downcutting*
- *Streambank erosion and increased sediment loads*
- *Shifting bars of coarse sediment*
- *Burying of stream substrate*
- *Loss of pool/riffle structure and sequence*
- *Man-made stream enclosure or channelization*
- *Floodplain expansion*

2.4 Water Quality Impacts

Urbanization increases the discharge of pollutants in stormwater runoff. Development introduces new sources of stormwater pollutants and provides impervious surfaces that accumulate pollutants between storms. Structural stormwater collection and conveyance systems allow stormwater pollutants to quickly wash off during storm or snowmelt events and discharge to downstream receiving waters. By contrast, in undeveloped areas, natural processes such as infiltration, interception, depression storage, filtration by vegetation, and evaporation can reduce the quantity of stormwater runoff and remove pollutants. Impervious areas decrease the natural stormwater purification functions of watersheds and increase the potential for water quality impacts in receiving waters.

Urban land uses and activities can also degrade groundwater quality if stormwater with high pollutant loads is directed into the soil without adequate treatment. Certain land uses and activities, sometimes referred to as stormwater "hotspots" (e.g., commercial parking lots, vehicle service and maintenance facilities,

Figure 2-3
Relationship Between Watershed Imperviousness and Stream Health



Source: Adapted from Schueler, 1992 and Prince George's County, Maryland, 1999.

and industrial rooftops), are known to produce higher loads of pollutants such as metals and toxic chemicals. Soluble pollutants can migrate into groundwater and potentially contaminate wells in groundwater supply aquifer areas.

Table 2-3 lists the principal pollutants found in urban stormwater runoff, typical pollutant sources, related impacts to receiving waters, and factors that promote pollutant removal. **Table 2-3** also identifies those pollutants that commonly occur in a dissolved or soluble form, which has important implications for the selection and design of stormwater management practices described later in this manual. Chapter Three contains additional information on pollutant removal mechanisms for various stormwater pollutants.

Excess Nutrients

Urban stormwater runoff typically contains elevated concentrations of nitrogen and phosphorus that are most commonly derived from lawn fertilizer, detergents, animal waste, atmospheric deposition, organic matter, and improperly installed or failing septic systems. Nutrient concentrations in urban runoff are similar to those found in secondary wastewater effluents (American Public Works Association and Texas Natural Resource Conservation Commission). Elevated nutrient concentrations in stormwater runoff can result in excessive growth of vegetation or algae in streams, lakes, reservoirs, and estuaries, a process known as accelerated eutrophication. Phosphorus is typically the growth-limiting nutrient in freshwater systems, while nitrogen is growth-limiting in estuarine and marine systems. This means that in marine waters algal growth usually responds to the level of nitrogen in the water, and in fresh waters algal growth is usually stimulated by the level of available or soluble phosphorus (DEP, 1995).

Nutrients are a major source of degradation in many of Connecticut's water bodies. Excessive nitrogen loadings have led to hypoxia, a condition of low dissolved oxygen, in Long Island Sound. A Total Maximum Daily Load (TMDL) for nitrogen has been developed for Long Island Sound, which will restrict nitrogen loadings from point and non-point sources throughout Connecticut. Phosphorus in runoff has impacted the quality of many of Connecticut's lakes and ponds, which are susceptible to eutrophication from phosphorus loadings. Nutrients are also detrimental to submerged aquatic vegetation (SAV). Nutrient enrichment can favor the growth of epiphytes (small plants that grow attached to other things, such as blades of eelgrass) and increase amounts of phytoplankton and zooplankton in the water column, thereby decreasing available light. Excess nutrients can also favor the growth of macroalgae, which can dominate and displace eelgrass beds and dramatically change the food web (Deegan et al., 2002).

Table 2-3 Summary of Urban Stormwater Pollutants

Stormwater Pollutant	Potential Sources	Receiving Water Impacts	Removal Promoted by[1]
Stormwater Pollutant Excess Nutrients Nitrogen, Phosphorus (soluble)	Animal waste, fertilizers, failing septic systems, landfills, atmospheric deposition, erosion and sedimentation, illicit sanitary connections	Algal growth, nuisance plants, ammonia toxicity, reduced clarity, oxygen deficit (hypoxia), pollutant recycling from sediments, decrease in submerged aquatic vegetation (SAV)	Phosphorus: High soil exchangeable aluminum and/or iron content, vegetation and aquatic plants Nitrogen: Alternating aerobic and anaerobic conditions, low levels of toxicants, near neutral pH (7)
Sediments Suspended, Dissolved, Deposited, Sorbed Pollutants	Construction sites, streambank erosion, washoff from impervious surfaces	Increased turbidity, lower dissolved oxygen, deposition of sediments, aquatic habitat alteration, sediment and benthic toxicity	Low turbulence, increased residence time
Pathogens Bacteria, Viruses	Animal waste, failing septic systems, illicit sanitary connections	Human health risk via drinking water supplies, contaminated swimming beaches, and contaminated shellfish consumption	High light (ultraviolet radiation), increased residence time, media/soil filtration, disinfection
Organic Materials Biochemical Oxygen Demand, Chemical Oxygen Demand	Leaves, grass clippings, brush, failing septic systems	Lower dissolved oxygen, odors, fish kills, algal growth, reduced clarity	Aerobic conditions, high light, high soil organic content, low levels of toxicants, near neutral pH (7)
Hydrocarbons Oil and Grease	Industrial processes; commercial processes; automobile wear, emissions, and fluid leaks; improper oil disposal	Toxicity of water column and sediments, bioaccumulation in food chain organisms	Low turbulence, increased residence time, physical separation or capture techniques
Metals Copper, Lead, Zinc, Mercury, Chromium, Aluminum (soluble)	Industrial processes, normal wear of automobile brake linings and tires, automobile emissions and fluid leaks, metal roofs	Toxicity of water column and sediments, bioaccumulation in food chain organisms	High soil organic content, high soil cation exchange capacity, near neutral pH (7)
Synthetic Organic Chemicals Pesticides, VOCs, SVOCs, PCBs, PAHs (soluble)	Residential, commercial, and industrial application of herbicides, insecticides, fungicides, rodenticides; industrial processes; commercial processes	Toxicity of water column and sediments, bioaccumulation in food chain organisms	Aerobic conditions, high light, high soil organic content, low levels of toxicants, near neutral pH (7), high temperature and air movement for volatilization of VOCs
Deicing Constituents Sodium, Calcium, Potassium Chloride Ethylene Glycol Other Pollutants (soluble)	Road salting and uncovered salt storage. Snowmelt runoff from snow piles in parking lots and roads during the spring snowmelt season or during winter rain on snow events.	Toxicity of water column and sediments, contamination of drinking water, harmful to salt intolerant plants. Concentrated loadings of other pollutants as a result of snowmelt.	Aerobic conditions, high light, high soil organic content, low levels of toxicants, near neutral pH (7)
Trash and Debris	Litter washed through storm drain network	Degradation of aesthetics, threat to wildlife, potential clogging of storm drainage system	Low turbulence, physical straining/capture
Freshwater Impacts	Stormwater discharges to tidal wetlands and estuarine environments	Dilution of the high marsh salinity and encouragement of the invasion of brackish or upland wetland species such as Phragmites	Stormwater retention and volume reduction
Thermal Impacts	Runoff with elevated temperatures from contact with impervious surfaces (asphalt)	Adverse impacts to aquatic organisms that require cold and cool water conditions	Use of wetland plants and trees for shading, increased pool depths

Source: Adapted from DEP, 1995; Metropolitan Council, 2001; Watershed Management Institute, Inc., 1997.

1 Factors that promote removal of most stormwater pollutants include:
- Increasing hydraulic residence time
- Low turbulence
- Fine, dense, herbaceous plants
- Medium-fine textured soil

Sediments

Sediment loading to water bodies occurs from washoff of particles that are deposited on impervious surfaces such as roads and parking lots, soil erosion associated with construction activities, and streambank erosion. Although some erosion and sedimentation is natural, excessive sediment loads can be detrimental to aquatic life including phytoplankton, algae, benthic invertebrates, and fish, by interfering with photosynthesis, respiration, growth, and reproduction. Solids can either remain in suspension or settle to the bottom of the water body. Suspended solids can make the water cloudy or turbid, detract from the aesthetic and recreational value of a water body, and harm SAV, finfish, and shellfish. Sediment transported in stormwater runoff can be deposited in a stream or other water body or wetland and can adversely impact fish and wildlife habitat by smothering bottom dwelling aquatic life and changing the bottom substrate. Sediment deposition in water bodies can result in the loss of deep-water habitat and can affect navigation, often necessitating dredging. Sediment transported in stormwater runoff can also carry other pollutants such as nutrients, metals, pathogens, and hydrocarbons.

Pathogens

Pathogens are bacteria, protozoa, and viruses that can cause disease in humans. The presence of bacteria such as fecal coliform or enterococci is used as an indicator of pathogens and of potential risk to human health (DEP, 1995). Pathogen concentrations in urban runoff routinely exceed public health standards for water contact recreation and shellfishing. Sources of pathogens in stormwater runoff include animal waste from pets, wildlife, and waterfowl; combined sewers; failing septic systems; and illegal sanitary sewer cross-connections. High levels of indicator bacteria in stormwater have commonly led to the closure of beaches and shellfishing beds along coastal areas of Connecticut.

Organic Materials

Oxygen-demanding organic substances such as grass clippings, leaves, animal waste, and street litter are commonly found in stormwater. The decomposition of such substances in water bodies can deplete oxygen from the water, thereby causing similar effects to those caused by nutrient loading. Organic matter is of primary concern in water bodies where oxygen is not easily replenished, such as slower moving streams, lakes, and estuaries. An additional concern for unfiltered water supplies is the formation of trihalomethane (THM), a carcinogenic disinfection byproduct generated by the mixing of chlorine with water high in organic carbon (NYDEC, 2001).

Hydrocarbons

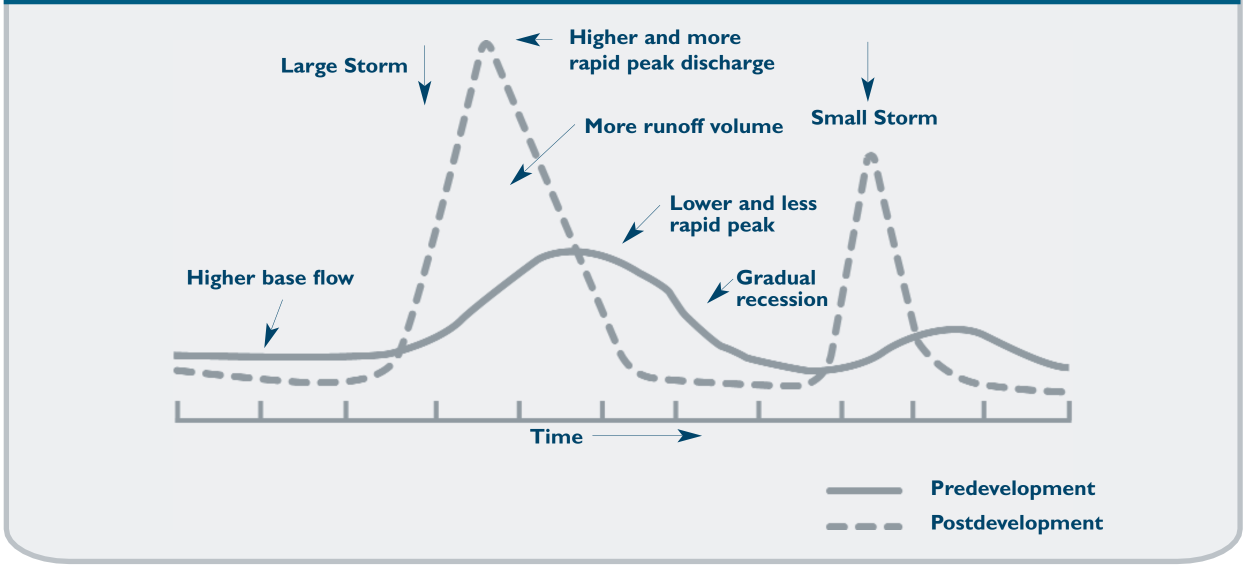
Urban stormwater runoff contains a wide array of hydrocarbon compounds, some of which are toxic to aquatic organisms at low concentrations (Woodward-Clyde, 1990). The primary sources of hydrocarbons in urban runoff are automotive. Source areas with higher concentrations of hydrocarbons in stormwater runoff include roads, parking lots, gas stations, vehicle service stations, residential parking areas, and bulk petroleum storage facilities.

Metals

Metals such as copper, lead, zinc, mercury, and cadmium are commonly found in urban stormwater runoff. Chromium and nickel are also frequently present (USEPA, 1983). The primary sources of these metals in stormwater runoff are vehicular exhaust residue, fossil fuel combustion, corrosion of galvanized and chrome-plated products, roof runoff, stormwater runoff from industrial sites, and the application of deicing agents. Architectural copper associated with building roofs, flashing, gutters, and downspouts has been shown to be a source of copper in stormwater runoff in Connecticut and other areas of the country (Barron, 2000; Tobiason, 2001). Marinas have also been identified as a source of copper and aquatic toxicity to inland and marine waters (Sailer Environmental, Inc. 2000). Washing or sandblasting of boat hulls to remove salt and barnacles also removes some of the bottom paint, which contains copper and zinc additives to protect hulls from deterioration.

In Connecticut, discharge of metals to surface waters is of particular concern. Metals can be toxic to aquatic organisms, can bioaccumulate, and have the potential to contaminate drinking water supplies. Many major rivers in Connecticut have copper levels that exceed Connecticut's Copper Water Quality Criteria. Although metals generally attach themselves to the solids in stormwater runoff or receiving waters, recent studies have demonstrated that dissolved metals, particularly copper and zinc, are the primary toxicants in stormwater runoff from industrial facilities throughout Connecticut (Mas et al., 2001; New England Bioassay, Inc., 2001). Additionally, stormwater runoff can contribute to elevated metals in aquatic sediments. The metals can become bioavailable where the bottom sediment is anaerobic (without oxygen) such as in a lake or estuary. Metal accumulation in sediments has resulted in impaired aquatic habitat and more difficult maintenance dredging operations in estuaries because of the special handling requirements for contaminated sediments.

Figure 2-4 Changes in Stream Hydrology as a Result of Urbanization



Source: Schueler, 1992, in Metropolitan Council, 2001.

Synthetic Organic Chemicals

Synthetic organic chemicals can also be present at low concentrations in urban stormwater. Pesticides, phenols, polychlorinated biphenyls (PCBs), and polynuclear or polycyclic aromatic hydrocarbons (PAHs) are the compounds most frequently found in stormwater runoff. Such chemicals can exert varying degrees of toxicity on aquatic organisms and can bioaccumulate in fish and shellfish. Toxic organic pollutants are most commonly found in stormwater runoff from industrial areas. Pesticides are commonly found in runoff from urban lawns and rights-of-way (NYDEC, 2001). A review of monitoring data on stormwater runoff quality from industrial facilities has shown that PAHs are the most common organic toxicants found in roof runoff, parking area runoff, and vehicle service area runoff (Pitt et al., 1995).

Deicing Constituents

Salting of roads, parking lots, driveways, and sidewalks during winter months and snowmelt during the early spring result in the discharge of sodium, chloride, and other deicing compounds to surface waters via stormwater runoff. Excessive amounts of sodium and chloride may have harmful effects on water, soil and vegetation, and can also accelerate corrosion of metal surfaces. Drinking water supplies, particularly groundwater wells, may be contaminated by runoff from roadways where deicing compounds have been applied or from highway facilities where salt mixes are improperly stored. In addition, sufficient concentrations of chlorides may prove toxic to certain aquatic species. Excess sodium in drinking water can lead to health problems in infants ("blue baby syndrome") and individuals on low sodium diets. Other deicing compounds may contain nitrogen, phosphorus, and oxygen demanding substances. Antifreeze from automobiles is a source of phosphates, chromium, copper, nickel, and cadmium.

Other pollutants such as sediment, nutrients, and hydrocarbons are released from the snowpack during the spring snowmelt season and during winter rain-on-snow events. The pollutant loading during snowmelt can be significant and can vary considerably during the course of the melt event (NYDEC, 2001). For example, a majority of the hydrocarbon load from snowmelt occurs during the last 10 percent of the event and towards the end of the snowmelt season (Oberts, 1994). Similarly, PAHs, which are hydrophobic materials, remain in the snowpack until the end of the snowmelt season, resulting in highly concentrated loadings (Metropolitan Council, 2001).

Trash and Debris

Trash and debris are washed off of the land surface by stormwater runoff and can accumulate in storm drainage systems and receiving waters. Litter detracts from the aesthetic value of water bodies and can harm aquatic life either directly (by being mistaken for food) or indirectly (by habitat modification). Sources of trash and debris in urban stormwater runoff include residential yard waste, commercial parking lots, street refuse, combined sewers, illegal dumping, and industrial refuse.

Freshwater Impacts

Discharge of freshwater, including stormwater, into brackish and tidal wetlands can alter the salinity and hydroperiod of these environments, which can encourage the invasion of brackish or freshwater wetland species such as Phragmites.

Thermal Impacts

Impervious surfaces may increase temperatures of stormwater runoff and receiving waters. Roads and other impervious surfaces heated by sunlight may transport thermal energy to a stream during storm events. Direct exposure of sunlight to shallow ponds and impoundments as well as unshaded streams may further elevate water temperatures. Elevated water temperatures can exceed fish and invertebrate tolerance limits, reducing survival and lowering resistance to disease. Coldwater fish such as trout may be eliminated, or the habitat may become marginally supportive of coldwater species. Elevated water temperatures also contribute to decreased oxygen levels in water bodies and dissolution of solutes.

Concentrations of pollutants in stormwater runoff vary considerably between sites and storm events. Typical average pollutant concentrations in urban stormwater runoff in the Northeast United States are summarized in **Table 2-4.**

Table 2-4
Average Pollutant Concentrations in Urban Stormwater Runoff

Constituent	Units	Concentration
Total Suspended Solids[1]	mg/l	54.5
Total Phosphorus[1]	mg/l	0.26
Soluble Phosphorus[1]	mg/l	0.10
Total Nitrogen[1]	mg/l	2.00
Total Kjeldahl Nitrogen[1]	mg/l	1.47
Nitrite and Nitrate[1]	mg/l	0.53
Copper[1]	µg/l	11.1
Lead[1]	µg/l	50.7
Zinc[1]	µg/l	129
BOD[1]	mg/l	11.5
COD[1]	mg/l	44.7
Organic Carbon[2]	mg/l	11.9
PAH[3]	mg/l	3.5
Oil and Grease[4]	mg/l	3.0
Fecal Coliform[5]	Colonies/100 ml	15,000
Fecal Strep[5]	Colonies/100 ml	35,400
Chloride (snowmelt)[6]	mg/l	116

Source: Adapted from NYDEC, 2001; original sources are listed below.
[1]Pooled Nationwide Urban Runoff Program/USGS (Smullen and Cave, 1998)
[2]Derived from National Pollutant Removal Database (Winer, 2000)
[3]Rabanal and Grizzard, 1996
[4]Crunkilton et al., 1996
[5]Schueler, 1999
[6]Oberts, 1994
mg/l = milligrams per liter
µg/l= micrograms per liter

2.5 Habitat and Ecological Impacts

Changes in hydrology, stream morphology, and water quality that accompany the development process can also impact stream habitat and ecology. A large body of research has demonstrated the relationship between urbanization and impacts to aquatic habitat and organisms (**Table 2-5**). Habitat and ecological impacts may include:

- *A shift from external (leaf matter) to internal (algal organic matter) stream production*
- *Reduction in the diversity, richness, and abundance of the stream community (aquatic insects, fish, amphibians)*
- *Destruction of freshwater wetlands, riparian buffers, and springs*
- *Creation of barriers to fish migration*

2.6 Impacts on Other Receiving Environments

The majority of research on the ecological impacts of urbanization has focused on streams. However, urban stormwater runoff has also been shown to adversely impact other receiving environments such as wetlands, lakes, and estuaries. Development alters the physical, geochemical, and biological characteristics of wetland systems. Lakes, ponds, wetlands, and SAV are impacted through deposition of sediment and particulate pollutant loads, as well as accelerated eutrophication caused by increases in nutrient loadings. Estuaries experience increased sedimentation and pollutant loads, and more extreme salinity swings caused by increased runoff and reduced baseflow. **Table 2-5** summarizes the effects of urbanization on these receiving environments.

Table 2-5 Effects of Urbanization on Other Receiving Environments

Receiving Environment	Impacts
Wetlands	❍ Changes in hydrology and hydrogeology ❍ Increased nutrient and other contaminant loads ❍ Compaction and destruction of wetland soil ❍ Changes in wetland vegetation ❍ Changes in or loss of habitat ❍ Changes in the community (diversity, richness, and abundance) of organisms ❍ Loss of particular biota ❍ Permanent loss of wetlands
Lakes and Ponds	❍ Impacts to biota on the lake bottom due to sedimentation ❍ Contamination of lake sediments ❍ Water column turbidity ❍ Aesthetic impairment due to floatables and trash ❍ Increased algal blooms and depleted oxygen levels due to nutrient enrichment, resulting in an aquatic environment with decreased diversity ❍ Contaminated drinking water supplies
Estuaries	❍ Sedimentation in estuarial streams and SAV beds ❍ Altered hydroperiod of brackish and tidal wetlands, which results from larger, more frequent pulses of fresh water and longer exposure to saline waters because of reduced baseflow ❍ Hypoxia ❍ Turbidity ❍ Bio-accumulation ❍ Loss of SAV due to nutrient enrichment ❍ Scour of tidal wetlands and SAV ❍ Short-term salinity swings in small estuaries caused by the increased volume of runoff which can impact key reproduction areas for aquatic organisms

Source: Adapted from WEF and ASCE, 1998.

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