INTRODUCTION

Background

Many areas of Tennessee have been experiencing significant land development. Human activities, particularly urbanization and agriculture, can alter natural drainage patterns and add pollutants to rivers, lakes, and streams (See Figure 1). Typical pollutants in stormwater include elevated concentrations of sediment, oils and grease, heavy metals, salts, pesticides, nutrients, bacterial and other pollutants. Recent studies have shown that stormwater runoff is a significant source of water pollution, causing declines in aquatic health and restrictions on swimming, and limiting our ability to enjoy many of the other benefits that water provides (USEPA, 1992).

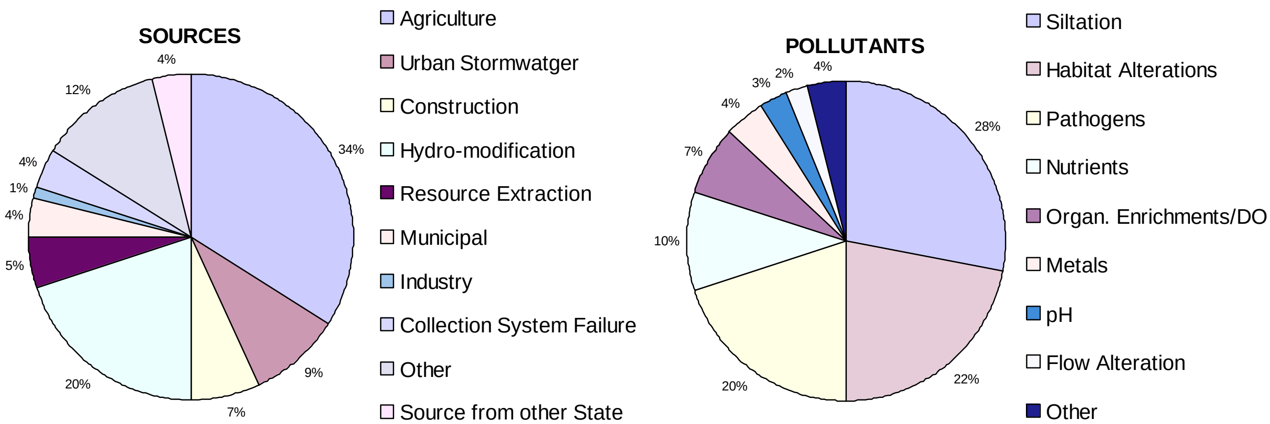

Figure 1. Relative Percentage of Pollutants and Sources for Rivers and Streams in Tennessee (Adapted from SWQT, 2000).

Much of this development can be generally characterized as urban (residential, commercial, industrial, and transportation) and is greatly affecting the way the developed land behaves hydrologically and environmentally. In addition to adding pollution, typical urban development increases both the quantity (volume) of stormwater runoff and the rate or concentration (peak flow) at which it enters receiving waters or flows to adjacent lands. The timing of this runoff is also typically affected and is capable of producing negative downstream consequences.

Many communities across Tennessee do not currently have the technical and regulatory tools, expertise and knowledge to ensure that local development is progressing in a hydrologically and environmentally compatible manner. This manual has been developed to provide general guidance in developing and implementing the best management practices (BMPs) for inclusion in local municipal and county stormwater management programs. As mentioned elsewhere in this manual, federal regulations require municipalities to develop stormwater management programs to reduce the discharge of pollutants to the maximum extent practicable (MEP). It is not the intent of this manual to dictate the actual selection of BMPs (this will be done by the municipality), but rather to provide the framework for an informed selection of BMPs for municipal programs. In selecting and implementing BMPs that will achieve MEP, it is important to remember that municipalities will be responsible to reduce the discharge of pollutants in stormwater to the maximum extent practicable. This means choosing effective BMPs, and rejecting BMPs that would not be technically feasible, or the cost would be prohibitive. The following factors are considered in deciding if a BMP is practicable:

1. Pollutant Removal – Will the BMP address the pollutant of concern?

2. Water Quantity – Will the BMP be an effective facility for managing and controlling water runoff flow and volume?

3. Regulatory Compliance – Is the BMP compatible with stormwater regulations as well as other regulations for air, hazardous wastes, solid waste disposal, etc.?

4. Public Acceptance – Does the BMP have public support?

5. Implementation – Is the BMP compatible with land uses, facilities, or development activity in question?

6. Cost – Will the cost for implementing the BMP exceed the pollution control and flow management benefits expected to be achieved?

7. Technical Feasibility – Is the BMP technically feasible considering soils, geography, water resources, maintenance and special site considerations?

For the BMPs selected, the municipality must demonstrate a “good faith” effort to implement and provide for long-term maintenance for them. Both publicly and privately-owned facilities require regular inspection and maintenance to ensue effective stormwater water quality and quantity management as intended by the designer. Finally, the municipality should prepare and adhere to a schedule for implementation.

Users of the Manual

The primary users of this manual are the municipalities and counties responsible for selecting BMPs as part of their overall stormwater management program. Such users include municipal engineers, public works officials, planners and environmental specialists. In addition, consulting/design engineers and developers will find the manual useful in their work.

Purpose and Scope of Manual

The purpose of this manual is to provide guidance to listed Phase II Tennessee stormwater program communities for selecting and implementing the best management practices (BMPs) for post-development activities. The BMPs presented in this manual are organized into *Non-structural* and *Structural* sections and applicable to managing either or both water quantity and quantity as shown in the matrix table below:

BMP	Symbol	Category	
		Water Quantity	Water Quality
NON-STRUCTURAL			
Comprehensive Planning, Zoning, Ordinances, and Codes	NS-01	X	X
Landscaping and Vegetative Control Practices	NS-02	X	X
Public Outreach and Education Awareness	NS-03	X	X
Good Housekeeping	NS-04		X
Urban Stormwater Pollution Prevention Plans	NS-05		X
Non stormwater Discharges to Storm Drains	NS-06		X
STRUCTURAL			
Detention (Dry) Basin	P-01	X	X
Retention (Wet) Basin	P-02	X	X
Alternative Storage Measures	P-03	X	X
Constructed Wetlands	W-01	X	X
Infiltration/Percolation Trench	I-01	X	
Infiltration Basin	I-02	X	X
Underground Drainage Systems	I-03		X
Porous Pavement	I-04	X	
Catch Basin Inserts/Media Filter	F-01		X
Oil/Water Separator	F-02		X
Filter and Buffer Strips	F-03	X	X
Filter/Adsorption Bed	F-04		X
Bioretention Basins (Rain Gardens)	F-05	X	X
Swale (Open Channel Systems)	O-01	X	X

Table 1. Matrix of structural and non-structural Best Management Practices (BMPs) for water quality and water quantity management for applications intended for post-construction development.

Organization of the Manual

The overall goal of stormwater management is to reduce the discharge of pollutants while controlling the quantity of runoff from a development site. This manual is organized to assist the user in planning, developing, and implementing such a program. The manual contains the following elements, with applicable references:

?? Forward - Basis and Context for Manual: Water Quality and Quantity Issues

- ?? Background: Choosing BMPs, Purpose and Scope of Manual, Organization, Effects of Urbanization, including Sources and Effects of Pollutants
- ?? Non-structural BMPs:
  - o Description
  - o Selection Criteria
- ?? Structural BMPs:
  - o Description
  - o Selection Criteria
  - o Design and Sizing Considerations
  - o Construction /Inspection Considerations
  - o Maintenance
  - o Cost Considerations
  - o Limitations of Use
  - o Additional Information
  - o References
  - o Rating of targeted (pollutant) constituent benefits
    - ✍ Sediment
    - ✍ Heavy metals
    - ✍ Floatable materials
    - ✍ Oxygen demanding substances
    - ✍ Nutrients
    - ✍ Toxic materials
    - ✍ Oil & grease
    - ✍ Bacteria & viruses
    - ✍ Construction wastes
  - o Rating of Implementation Requirements
    - ✍ Capital costs
    - ✍ O & M costs
    - ✍ Maintenance
    - ✍ Training

Effects of Urbanization

There are two main environmental impacts that typically result from urbanization. First, the hydrology of the area is changed. This change typically consists of increased runoff volumes, flows, and velocities, while at the same time reduced groundwater recharge. The timing of this runoff and base flow are also typically affected and may have negative downstream consequences. Second, urbanization increases a variety of human activities that generate pollutants within a watershed. The pollutants are transported in runoff and subsequently discharged to our streams and lakes. These activities may range from construction itself to automobile use and to various types of private and public development and pedestrian uses after construction is completed.

Hydrologic Changes

When an undeveloped area changes to support urban land uses, dramatic impacts in the local hydrology result as illustrated in Figure 2. Urbanization typically changes the natural hydrology of a watershed through increased imperviousness there by increasing direct runoff and decreasing evapotranspiration, deep infiltration, and shallow infiltration. When an area is developed, natural drainage patterns are modified as runoff is channeled into road gutters, culverts and storm drains, and paved channels. The results of these modifications typically produce an increase in runoff volume and velocity, and a shorter time for the runoff to leave the watershed, causing higher peak flows.

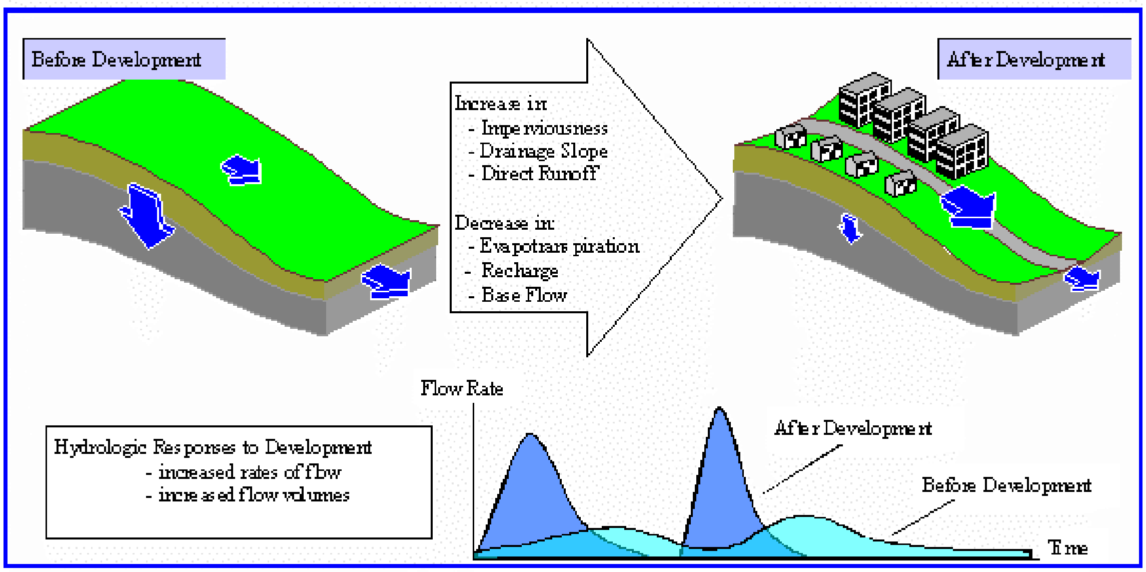

Figure 2. Changes in watershed hydrology resulting from urbanization.

In addition higher flows cause flooding and adverse effects on natural streams. Before development, at bankfull capacity, natural streams can handle a flow approximately equal to the 2-year frequency peak discharge. After development this bankfull capacity can be exceeded several times per year. The new flow regime also can lead to channel and bank erosion and unwanted meandering and widening (Minnesota PCA, 1989).

The box below summarizes the typical impacts that urbanization has on both water quantity and water quality in water bodies such as lakes and streams.

Typical Effects of Urbanization

Hydrologic Changes

?? Increased runoff volumes
?? Reduced times of concentration for the contributing drainage areas, resulting in higher flow velocities and peak flows
?? Increased frequency of flows for given storm events
?? Decreased groundwater recharge
?? Habitat destruction from flow changes, channel erosion, and channel improvements

Pollutant Generation

?? Human activities create several types of biological, chemical and physical pollutants which are transported to receiving waters

Urban Storm Water Pollutants

Pollutants most frequently associated with stormwater include construction sediment and post-construction nutrients, bacteria, oxygen-demanding substances, oil and grease, heavy metals other toxic chemicals (e.g., pesticides and herbicides), and floatables (e.g., fast-food litter and debris from traffic litter and fly away). In addition, urban runoff usually has a higher water temperature resulting from natural land being converted to paved areas and removal of stream shade.

Stormwater Pollutants of Concern

?? Sediment
?? Nutrients
?? Bacteria and Viruses
?? Oxygen Demanding Substances
?? Oil and Grease
?? Metals
?? Toxic Pollutants
?? Floatables
?? Temperature

These pollutants and their impacts on water quality and aquatic habitat are described as follows:

?? *Sediment* is a common component of storm water and is a pollutant in its own right. Excessive erosion and sediment, especially generated during construction activities, can be detrimental to aquatic life (primary producers, benthonic invertebrates and fish) by interfering with photosynthesis, respiration, growth, and reproduction. In addition, the sediment can transport other pollutants that are attached to it including nutrients, trace metals, and hydrocarbons (AWPA, 1981). Sediment that leaves a site, whether during or after construction, has the potential for clogging downstream drainways, thereby reducing flow capacity, and causing flooding.

?? *Nutrients* including nitrogen and phosphorous are found in stormwater. These nutrients can result in excessive or accelerated growth of vegetation or algae resulting in impaired use of water in lakes and other sources of water supply. In addition, un-ionized ammonia (one of the nitrogen forms) can be toxic to fish.

?? *Oxygen demanding substances* including plant debris (such as leaves and lawn trimmings), animal excrement, street litter, and organic matter are commonly found in stormwater (USEPA, 1992; Woodward-Clyde, 1990). Such substances depress the dissolved oxygen levels in streams, lakes, and other water bodies, thereby depriving aquatic life of needed oxygen.

?? *Oil and grease* contain a wide array of hydrocarbon compounds, some of which are toxic to aquatic organisms at low concentrations (Woodward-Clyde, 1990). The main sources of oil and grease are leakage from engines in parking lots and streets, spills at fueling stations, overfilled tanks, restaurant grease traps, and waste oil disposal (Berman, et al, 1991).

?? *Lead, zinc, cadmium, and copper* are the most commonly found *heavy metals* in stormwater. Chromium and nickel are also frequently present (USEPA, 1983). Heavy metals are of concern because they are toxic to aquatic organisms, can be bio-cumulative, and have the potential to contaminate drinking water supplies.

?? *Other toxic materials (priority pollutants)* may be found in stormwater in low concentrations. Pesticides, herbicides, phenols, and polynuclear or polycyclic aromatic hydrocarbons (PAHs) are the organics most frequently found in stormwater (City of Seattle, 1989).

?? *Floatables* in stormwater are pollutants that may contain significant amounts of heavy metals, pesticides, and bacteria. Typically, resulting from street refuse, commercial areas, or industrial yards, floatables also create “eyesores” along waterways, street inlets, and in detention basins.

?? *Temperature* of post-development runoff water tends to increase when natural land use areas are converted to paved or roofed areas. Also, water temperature in streams, formerly shaded with riparian trees and plants, tends to increase as the vegetation is removed. Increased runoff temperature can be detrimental to aquatic life both on the development site as well as in downstream waterways.

Sources of Pollutants

The primary sources of stormwater pollution in urban areas include automobiles and activities associated with automobile use (including pavement), inadequate housekeeping and landscaping practices, industrial activities, construction, non-stormwater connections to the drainage system, accidental spills, and illegal dumping. Table 2 summarizes the relationship of pollutant sources with the pollutants they generate.

Pollutant	Automobile/Atmospheric Deposit	Urban Housekeeping/Landscaping Practices	Industrial Activities	Construction Activities	Non-stormwater Connections	Accidental Spills & Illegal Dumping
SEDIMENTS	X	X	X	X		
NUTRIENTS	X	X	X	X	X	X
BACTERIA & VIRUSES		X		X	X	X
OXYGEN DEMANDING SUBSTANCES		X	X	X	X	X
OIL & GREASE	X	X	X	X	X	X
Anti-freeze	X	X		X	X	X
Hydraulic fluids	X	X	X	X	X	X
Cleaners & solvents	X	X		X	X	X
HEAVY METALS	X	X	X	X	X	X
Chromium	X	X	X			
Copper	X	X	X			
Lead	X	X	X			
Zinc	X	X	X			
Iron	X		X			
Cadmium	X		X			
Nickel	X		X			
Manganese	X		X			
Paint		X		X	X	X
Wood preservatives		X		X	X	X
TOXIC MATERIALS	X	X	X	X	X	X
Fuels	X		X	X	X	X
PCBs	X				X	X
Pesticides	X	X	X	X	X	X
Herbicides	X		X	X	X	X
FLOATABLES		X	X	X		X

References: Minnesota PCA (1989); Berman, L., et al. (1991); Woodward-Clyde (1990); USEPA (1991); Schuler (1987); Beaton, J., et al. (1972); Camp Dresser & McKee (1993); and Oberts, G. (1986).

Table 2. Common Sources of Pollutants in Urban Stormwater Runoff

AUTOMOBILE AND RELATED ACTIVITIES

Sediment

Significant post-construction sediment-borne pollutants associated with highway and street runoff come from pavement wear, vehicles, atmospheric deposition, and road maintenance (USEPA, 1991). Atmospheric deposition contains appreciable quantities of sulfur, toxic and heavy metals, pesticides, organic compounds, fungi, pollen, and sol (Novatny and Chesters, 1981). Asbestos in runoff can occur from wear of clutch and brake linings (Berman, et al., 1991).

Accelerated erosion of highway slopes occurs primarily as sheet, gully, or rill erosion. Bridge construction may cause significant erosion and sedimentation (USEPA, 1991). Sand applied to icy roads can also create a significant sediment load.

Nutrients

Nitrogen and phosphorous associated with highway runoff come from atmospheric deposition and roadside fertilizer application (USEPA, 1991). Phosphorous has also been associated with application of sand and salt on roads (Oberts, 1986).

Heavy Metals and Toxic Chemicals

Several heavy metals and other toxic substances found in stormwater are associated with automobile use. Chromium, copper, lead, zinc, iron, cadmium, nickel, and manganese associated with automobiles and highways come from many different sources including auto body rust, bearing and bushing wear, brake lining ear, diesel fuel and gasoline exhaust, metal plating, motor oil (stabilizing additives), steel highway structures (guard rails, lighting, signs, etc.), and tire wear (filler material). Other toxic pollutants occur primarily through the use of products for de-icing, and weed, rodent, and insect control (Beaton, et al., 1972). Hydrocarbons typically come from spills, leaks or blow-by of motor lubricants, antifreeze and hydraulic fluids, and asphalt surface leachate. Hydrocarbon levels are highest from parking lots, roads, and service stations (Schueler, 1987).

Maintenance of transportation structures can result in runoff and direct discharge of lead, rust, paint, particulates, solvents, and cleaners. Runoff from bridges may deliver considerable loadings of heavy metals, hydrocarbons, and toxic substances from cars and de-icing of roads as a result of direct delivery through scupper drains into receiving waters with no overland buffering or treatment (USEPA, 1991).

URBAN HOUSEKEEPING/LANDSCAPING PRACTICES

Sediment

Landscape activities are a source of erosion and subsequent sedimentation, especially along street and road right-of-ways, residential areas and commercial districts.

Nutrients

In urban areas, major sources of nutrients are organic matter such as lawn clippings, leaves, street dirt, automobile exhaust, and excessive use of fertilizers. Areas such as golf courses and cemeteries which receive unusually high fertilizer applications are major sources of nutrients (Schueler, 1987).

Bacteria and Viruses

Improper disposal of fecal material from household pets is a source of bacterial contamination (USEPA, 1991). Other sources include septic tanks and deposits of organic matter that accumulate and decompose in storm inlets, catch basins, storm drains, and drainage channels (Berman, et al., 1991). Sanitary sewer systems may also seep or overflow into the drainage system.

Oxygen Demanding Substances

In urban areas, plant debris (such as leaves and lawn-clippings), animal excrement, street litter, dead animals, and organic matter are common sources of oxygen demanding substances found in storm water (Minnesota PCA, 1989). Fast food garbage thrown along waysides also contributes.

Heavy Metals and Toxic Chemicals

Sources of heavy metals include weathered paint, wood preservations, and pesticides (Woodward-Clyde, 1990). Excessive herbicide or pesticide use contributes toxic chemicals to the stormwater. Household toxics such as oil/grease, antifreeze, paint, household cleaners and solvents are widely used and may be improperly used, stored, and disposed of which can lead to stormwater pollution (Berman, et al., 1991). A national study of suburban stormwater showed few instances of detectable quantities of synthetic organic compounds, with the exception of plasticizing compounds often found in many plastic products. Also found, but less frequently, were wood preservative sand pesticides (USEPA, 1983).

INDUSTRIAL ACTIVITIES

Trace metals (particularly chromium, copper, lead, and zinc) found in stormwater may come from industrial use (Woodward-Clyde, 1990). Pesticides, herbicides, solvents, oils and other synthetic organic compounds are widely used in industrial settings and may be improperly stored and disposed of, leading to contaminated runoff. While the BMPs discussed in this manual are intended for general municipal development activities, some may be applicable to industrial development.

CONSTRUCTION

Construction sites may generate considerable sediment, trace metals, nutrients, oil and grease, pesticides, herbicides, and other synthetic organic compounds. The user is referred to the Tennessee Erosion & Sediment Control Handbook (2002) for detailed construction best management practices.

NON-STORMWATER CONNECTIONS

Inadvertent or deliberate discharge of sanitary sewage and industrial waste to storm drains is a widespread and serious occurrence. Illicit connections of sanitary sewers to storm drain sewers (e.g., floor drains) are a source of storm water contamination.

ACCIDENTAL SPILLS AND ILLEGAL DUMPING

Deliberate dumping of chemicals into storm drains and catch basins (especially used crankcase oils) is a common source of pollutants (USEPA, 1991) and can be a local problem. Virtually any chemical, if not properly stored and handled, can be accidentally spilled or illegally dumped.

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