Guidance Manual For The Surface And Stormwater Rules Of The District

Volume 1

PARTNERS FOR A CLEANER ENVIRONMENT

The District's mission is to cost-effectively protect public health and the environment, prevent pollution and enhance the quality of area waterways.

INTRODUCTION

Milwaukee Metropolitan Sewerage District's Role in Stormwater Management

The Milwaukee Metropolitan Sewerage District (District) is a state-chartered agency serving all cities and villages (except South Milwaukee) in Milwaukee County and all or part of 10 municipalities in surrounding Racine, Waukesha, Washington and Ozaukee Counties. **Figure 1-1** shows the District's 411-square-mile planning area. The District's mission is to cost-effectively protect public health and the environment, prevent pollution and enhance the quality of area waterways.

The District is charged by section 200.31 of the Wisconsin Statutes with the function and duty of planning, designing, constructing, maintaining, and operating a sewerage system for the collection, transmission, and disposal of all sewage and drainage generated within its planning area. Specifically, that function and duty includes the provision and management of a system of facilities for the collection, transmission, and disposal of stormwater and groundwater, as well as of sanitary sewage.

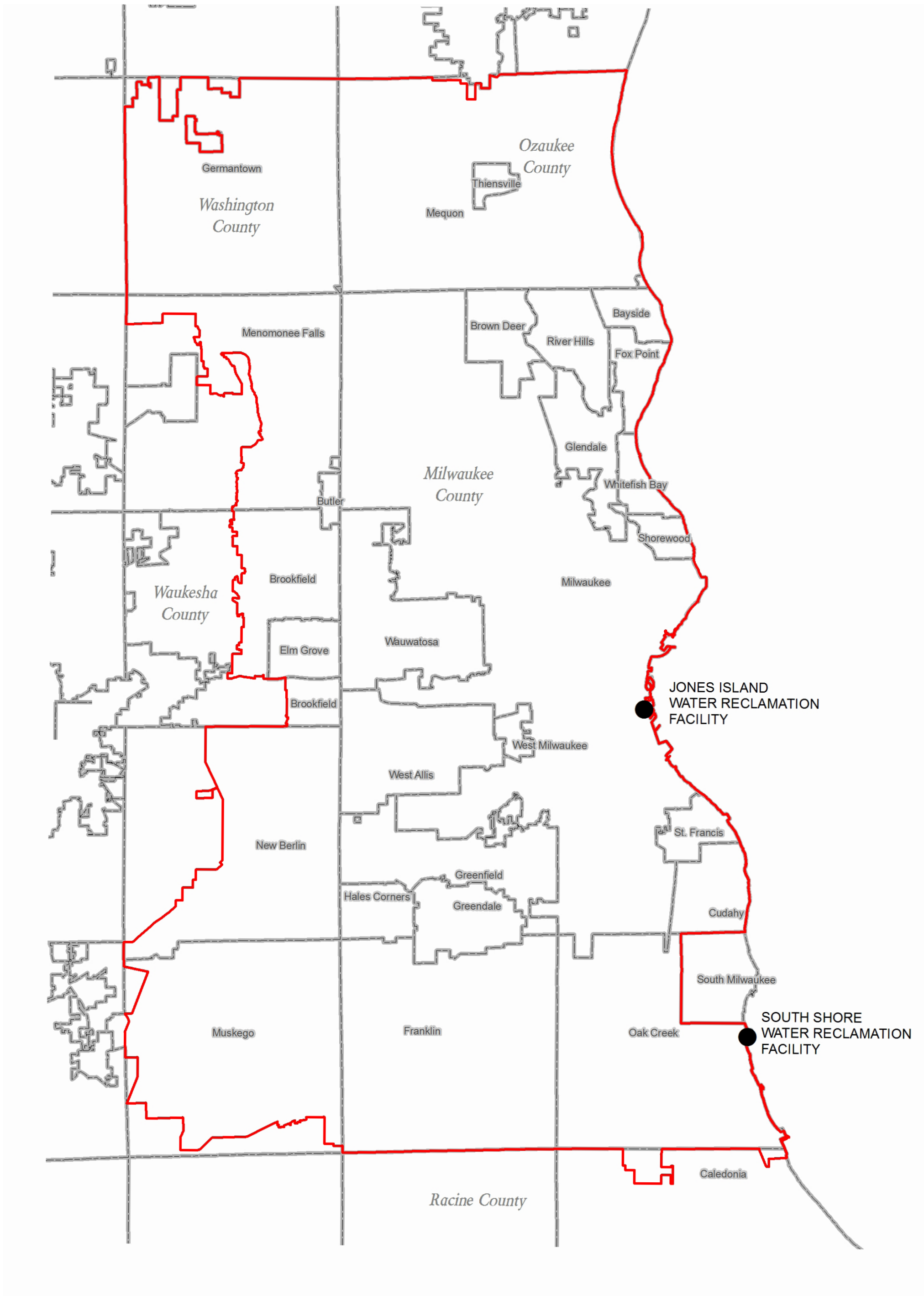


Figure 1-1
The District's 411-square-mile Planning Area.

A state statute gives the District broad responsibilities for sewerage and drainage.

Wisconsin Statutes, section 200.35 authorizes the District to plan, design, construct, maintain, and operate storm sewers and other facilities and structures for the collection and transmission of stormwater and is authorized to improve certain watercourses within the District by constructing regional storage or deepening or widening channels needed to carry off surface or drainage waters, subject to certain reviews and approvals by state and federal regulatory agencies. The District is also authorized to make such improvements outside the geographic limits of the District on any watercourses that flow out of the District and may divert stormwater from surface watercourses into drains, conduits, and storm sewers (SEWRPC, 1986).

In keeping with its mission, the District, working with various stakeholders, plans and oversees projects that reduce flooding risks and prevent pollution that is conveyed by rainfall and snowmelt runoff. More specifically, the District is involved in stormwater management (SWM) for two principal reasons:

1. To manage existing flooding problems and prevent new problems.

2. To reduce entry of stormwater conveyed pollution. The District has an interest in preventing water quality violations and SWM is an important tactic.

Specifically, the rationale for District involvement is defined in the "purpose" section of its Chapter 13 Surface Water and Stormwater Rules, as follows:

- Reduce the unsafe conditions, property damage, economic losses, and adverse health effects caused by flooding;

- Maximize the effectiveness of flood abatement facilities and watercourse improvements;

- Reduce the number and magnitude of releases of sewage to the environment from sanitary and combined sewers and to protect sewage collection and treatment facilities from high flows;

- Promote comprehensive watershed planning and intergovernmental cooperation; and

- Restore and enhance opportunities to use and enjoy watercourses.

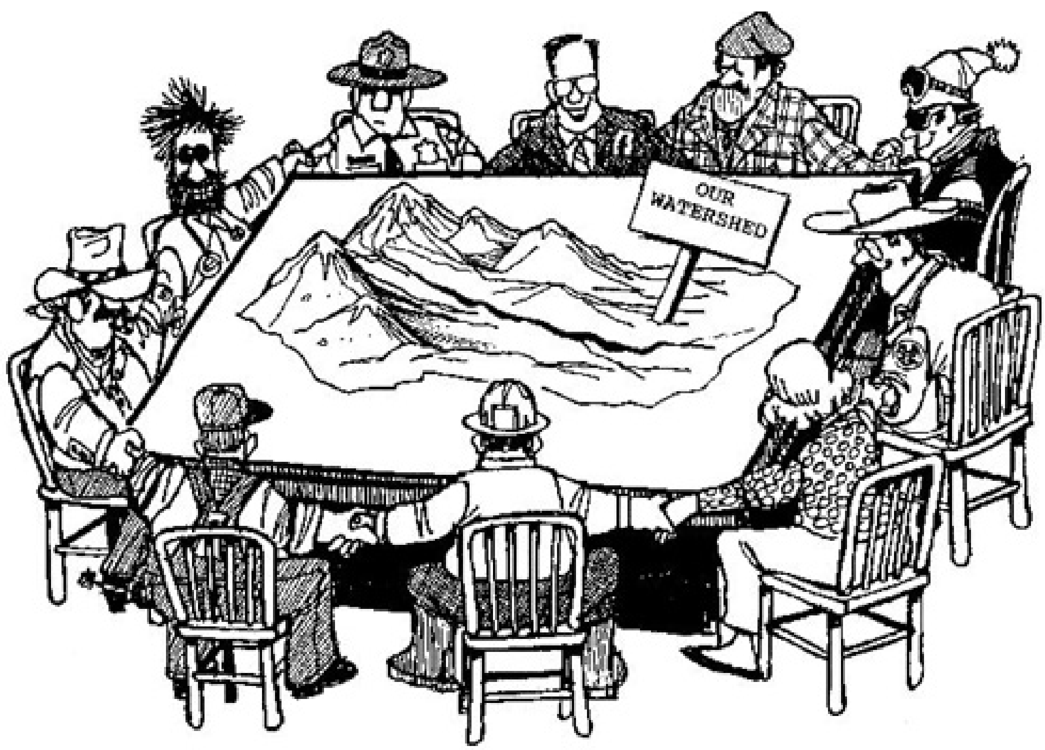


Figure 1-2
Stakeholders are individuals who are affected by and could affect a stormwater program (USEPA, 1997).

SWM is everything done to remedy existing stormwater-related flooding and pollution problems and to prevent the occurrence of new problems. From a functional perspective, SWM involves planning, design, construction and operation. SWM is an interdisciplinary effort carried out by a team that should include different but complementary specialists. When performed most effectively, the SWM Program and project teams include planners, engineers, biologists, chemists, economic and finance experts, regulators, attorneys and policy makers (**Figure 1-2**).

Interested, knowledgeable stakeholders can partner with the District.

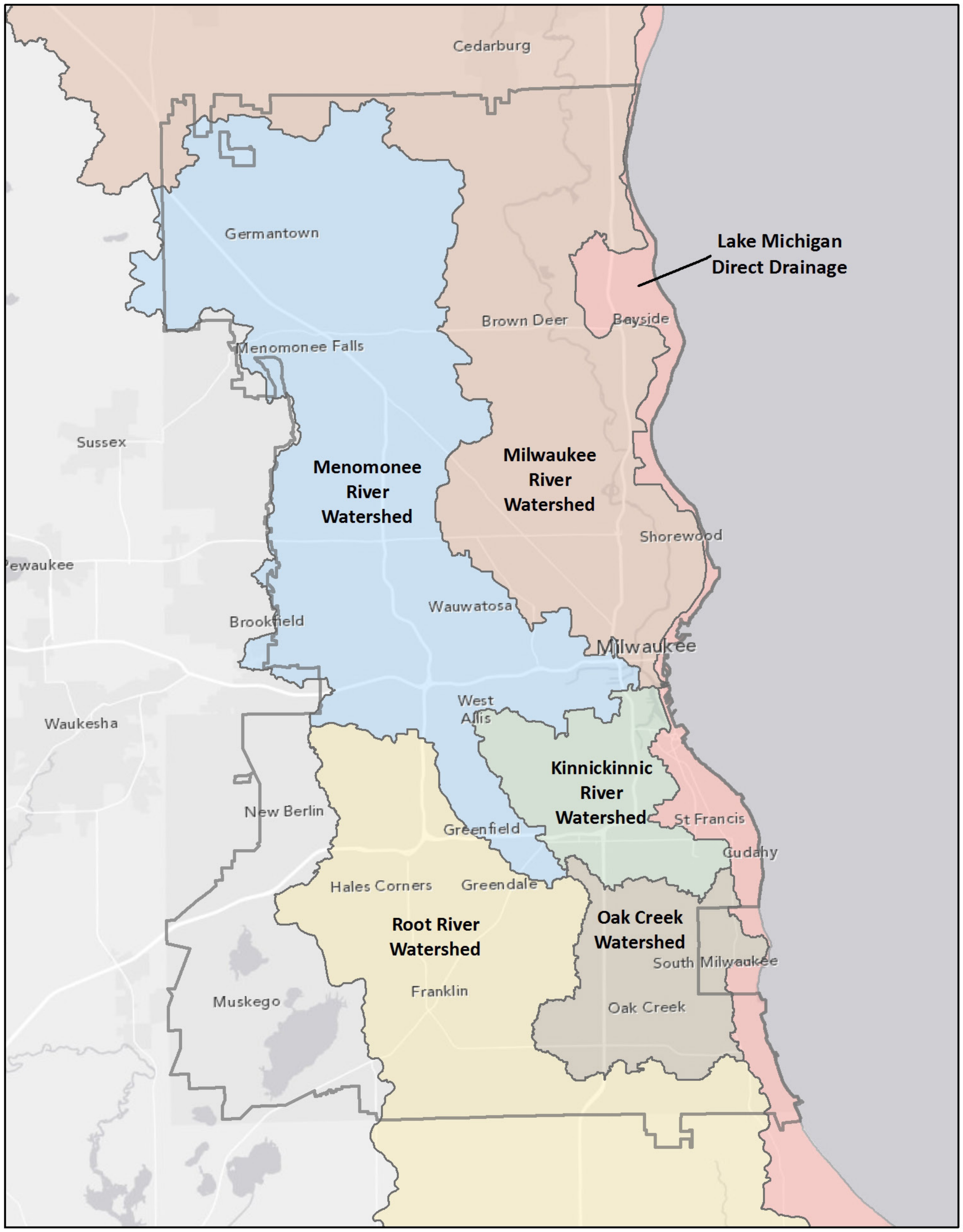


Figure 1-3

The Watercourse Management Plans manage current and future flooding problems in six watersheds.

To facilitate flood risk reduction and pollution prevention, the District maintains Watercourse Management Plans (WMPs) for rivers and streams in six watersheds. The watersheds, as shown in **Figure 1-3**, are the Kinnickinnic River, Lake Michigan Direct Drainage, the Menomonee River, the Milwaukee River, the Oak Creek, and the Root River.

Your Potential Role in the Stormwater Management Program

The District's SWM Program has many and varied stakeholders. These are individuals who are affected by and could affect the program. **Figure 1-2** illustrates the concept of watershed stakeholders. Typical stakeholders in the District's SWM Program are shown in **Figure 1-4**.

Stormwater education for stakeholders is the purpose of Volume 1 of this manual.

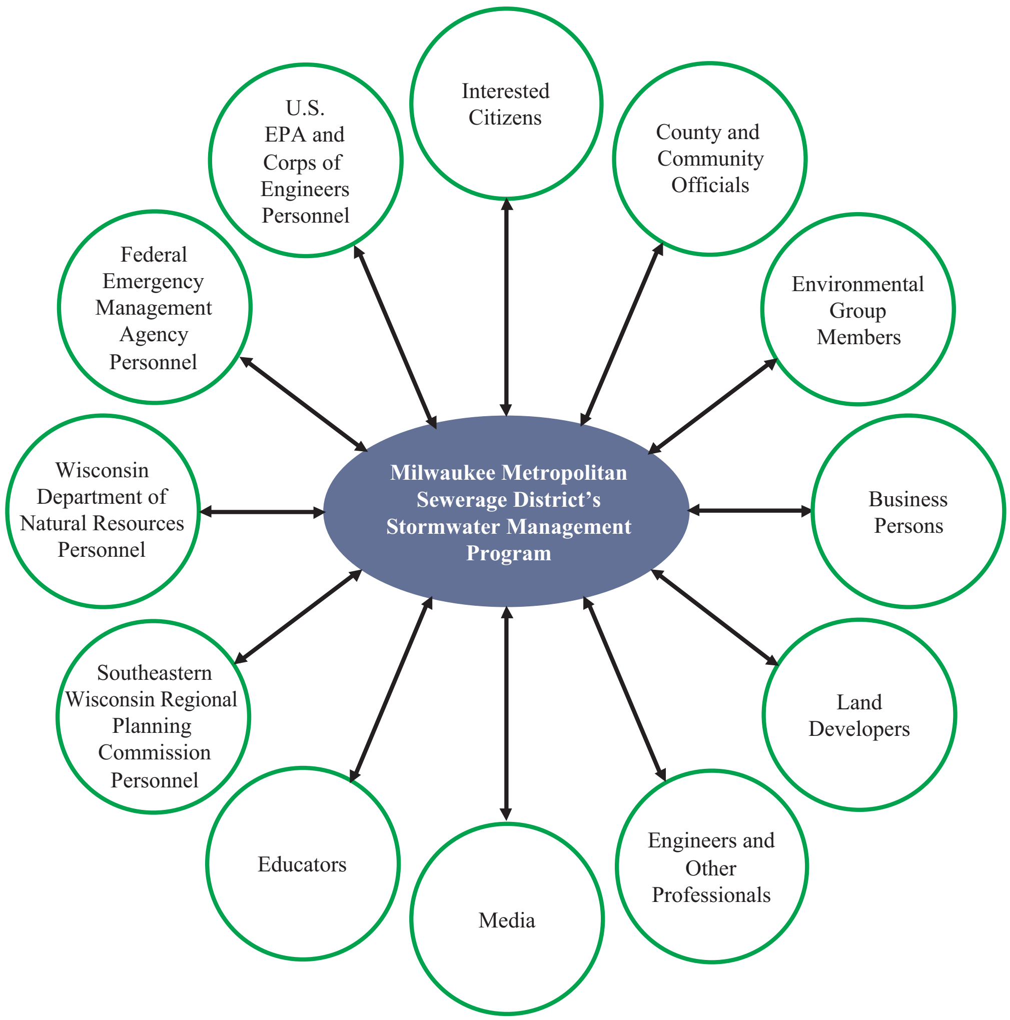


Figure 1-4
The District's Stormwater Management Program (SWM) has many stakeholders.

Perhaps you are one of the illustrated stakeholders. Your reading of Volume 1 of this Guidance Manual suggests that you recognize your stake in the District's SWM Program and may want to become even more informed and involved. The District needs and actively seeks your help and the assistance of other interested and knowledgeable stakeholders. Examples of ways in which you and others can partner with the District to improve stormwater management are:

- Asking questions;
- Studying issues;
- Offering suggestions;
- Properly disposing of potential pollutants such as motor oil, and leftover paint and solvents; not dumping them down stormwater inlets;
- Carefully storing hazardous materials;
- Avoiding excessive application of lawn fertilizers;
- Cleaning up after pets;
- Adhering to subdivision, building, erosion and sediment control and other codes;
- Avoid blocking or altering stormwater system components on or near your property; and
- Reducing vehicle trips.

Interest and knowledge are the keys to being an effective stakeholder. This leads to the purpose of Volume 1 of the Guidance Manual for the Surface and Stormwater Rules of the District. Volume 1 is intended to be a stormwater primer, that is, a short document that introduces SWM to the District's interested, non-technical stakeholders.

To assist you in reading Volume 1, definitions of technical and other terms are presented in Appendix B and a list of abbreviations is included as Appendix C. Appendix D includes a list of representative stormwater manuals and guidelines and websites are listed in Appendix E.

Although most apparent during and immediately after rainfall or snowmelt, the hydrologic cycle is always in motion.

The hydrologic cycle is a given; we can choose to work with or against it.

STORMWATER CONCEPTS

Hydrologic Cycle

The hydrologic cycle is most apparent to the casual observer during and immediately after rainfall or snowmelt because we can see, feel and hear the moving water. However, the hydrologic cycle is always functioning. As illustrated in **Figure 1-5**, the hydrologic cycle is the continuous circulation of water from the atmosphere (e.g., when it rains) onto, over, through and under the land surface; into creeks, rivers, ponds and lakes; and back into the atmosphere. Hydrology is the study of the hydrologic cycle and our interactions, positive and negative, on it.

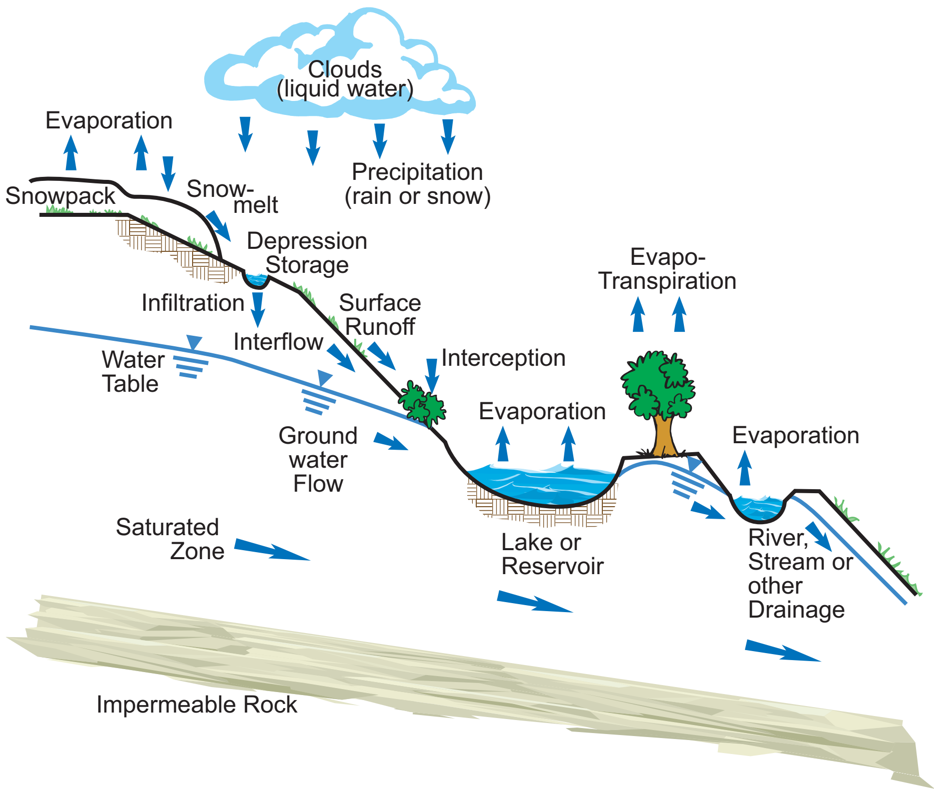


Figure 1-5
The Hydrologic Cycle (Walesh, 1989).

Working With Or Against the Hydrologic Cycle

Hydrologic studies reveal that we can dramatically impact the hydrologic cycle, often negatively. If not carefully planned, development and redevelopment, such as construction of buildings, roads, parking lots, and paved or unpaved storage areas, are likely to create serious flooding and pollution problems.

Flooding Problems

Development may replace cropland with roadways, pasture with parking lots, and woodlands with rooftops. As a result of the increase in impervious surface, as shown in **Figure 1-6**, more and more of the rainfall or snowmelt runs off rather than infiltrating into the ground. Not only can the runoff volume increase, but it may also occur in

Planning and designing developments should function in harmony with the hydrologic cycle and not cause off-site flooding and pollution problems.

much less time because the runoff paths in a development offer much less resistance to surface flow. For example, rough cropland furrows may be replaced with smooth curb and gutter, and natural, meandering stream channels and floodplains may be replaced with straight, smooth concrete-lined channels. The net effect of more runoff volume occurring in less time is a great increase in peak flow rates as illustrated in **Figure 1-7**.

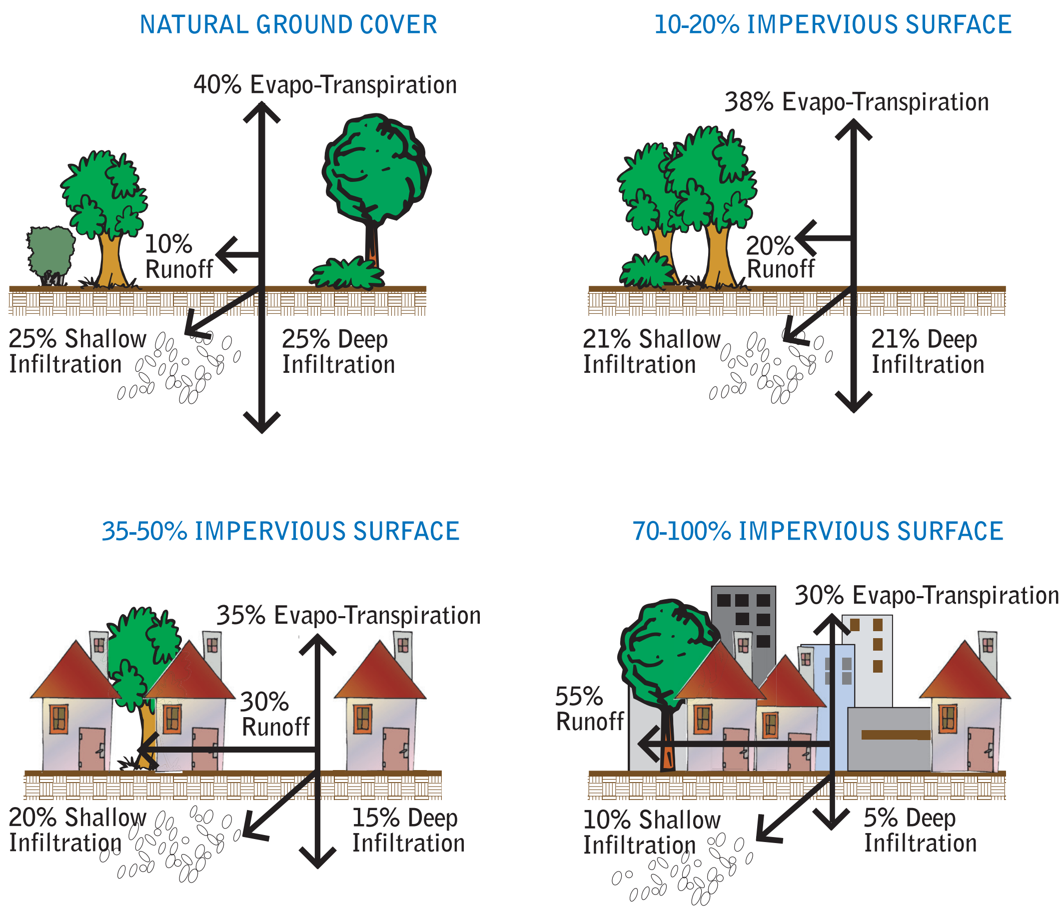


Figure 1-6
Development increases impervious surface which, in turn, increases the volume of surface runoff (USEPA, 1993).

Poorly planned development can cause or aggravate downstream flooding problems.

Hydrologists typically present flow rates in cubic feet per second (cfs); that is, the volume of water in cubic feet that passes a point in a second. The faucet in your kitchen sink has a flow of roughly 0.007 cfs, the average flow of the Milwaukee River just before it joins the Menomonee and Kinnickinnic Rivers is about 500 cfs, and the highest flow ever recorded on the Milwaukee River is 15,100 cfs.

As peak flow rates increase downstream of poorly planned developments, creeks and streams flow higher and wider, more roadways are overtopped, additional land is flooded, erosion and sedimentation increase, and additional buildings and properties are damaged. Even more important, deeper and faster moving water increases personal hazards, especially to children.

Pollution Problems

Pollutants can enter area creeks, rivers, ponds, and lakes from many sources including industrial discharges, overflow from sanitary and combined sewers, atmospheric deposition and stormwater runoff. All sources must be addressed to find a balanced approach to reducing pollutant loads so that surface water standards are met. "Urban and rural nonpoint sources are Wisconsin's greatest cause of water quality problems, degrading or threatening about 40% of the streams, about 90% of the inland lakes, much of the Great Lakes harbors and coastal waters, and substantial groundwater wetland areas (WDNR, 1994)."

Potential pollutants that can be carried away by stormwater runoff are available all over the urban area.

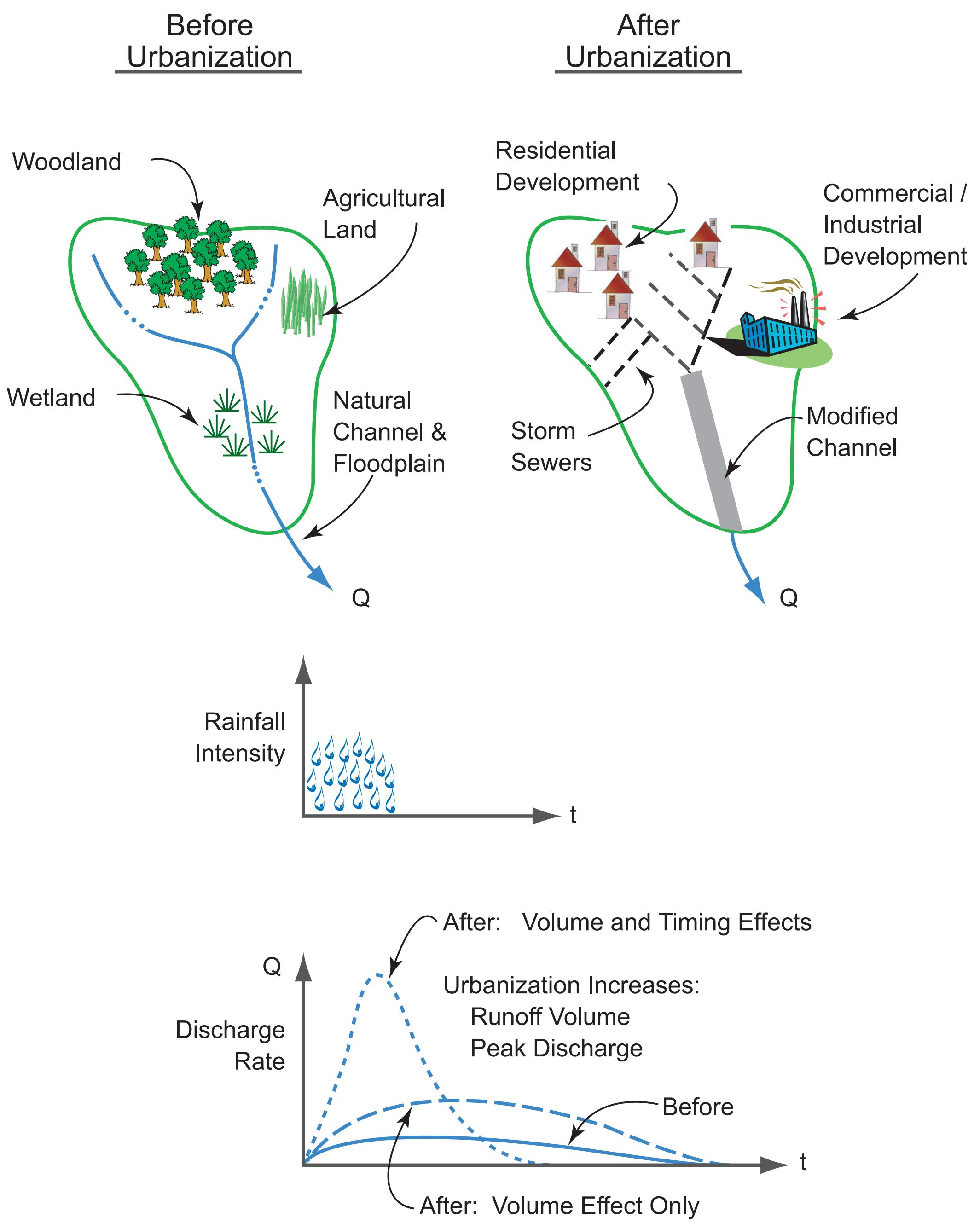


Figure 1-7
Development that ignores hydrologic effects is likely to greatly increase downstream fow rates (Walesh, 1989).

The last listed pollutant-source stormwater runoff may be a surprise to some readers because of the misconception that stormwater is "clean." However, stormwater runoff can easily be a major source of pollution. Activities typically occurring in an urban area generate, expose, and otherwise make available potential pollutants. This effect is magnified if the urban area is undergoing development. As illustrated in **Figure 1-8**, substances having toxic, organic, nutrient, pathogenic, sediment, and aesthetic pollution potential are present in urban areas. When it rains, these substances can be picked up and carried away by the resulting stormwater runoff. Furthermore, urbanization tends to increase the temperature of runoff and surface waters, which, in turn, has adverse effects, one of which is reduced oxygen concentration.

A watershed is a basin within which all land and water areas flow toward a point at a lower elevation.

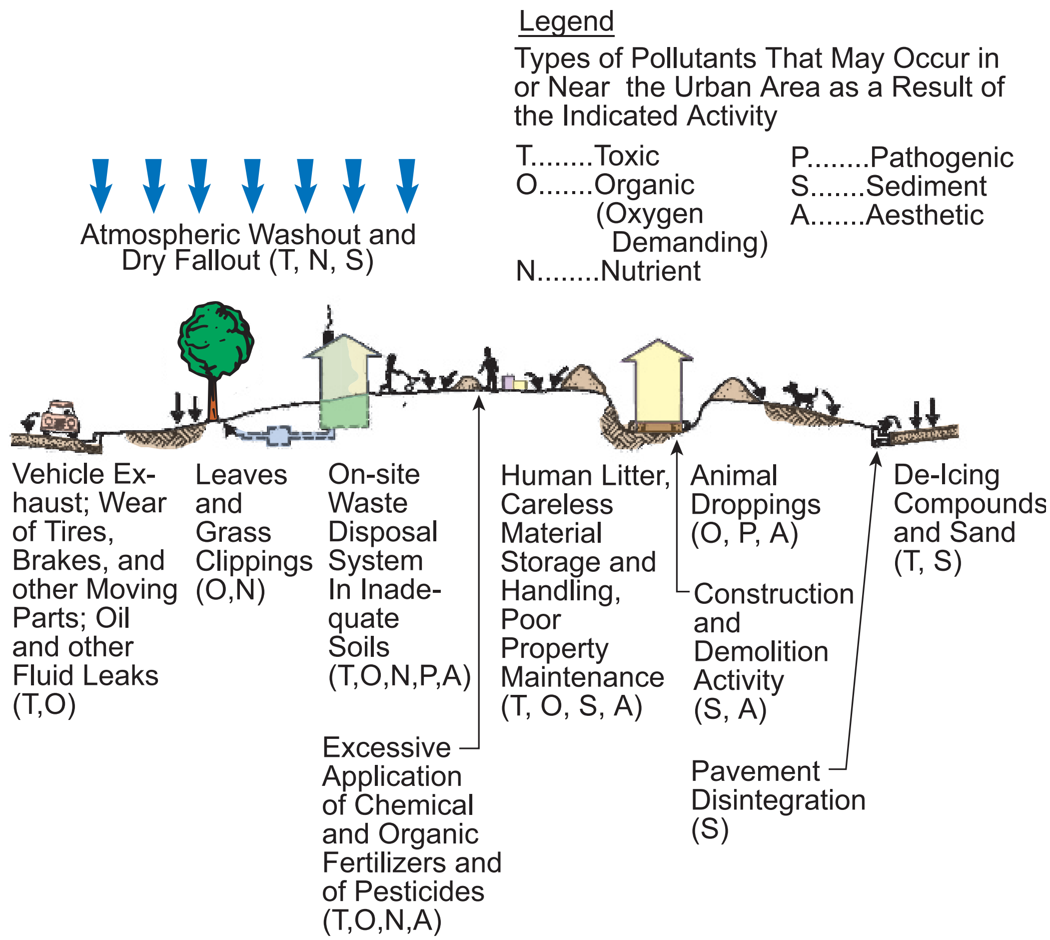


Figure 1-8
The variety of potential pollutants typically available in urban and urbanizing areas may be carried by stormwater into nearby creeks, streams, rivers and lakes (Walesh, 1989).

As explained earlier, development can cause more runoff volume to occur in less time. Larger amounts of faster moving stormwater provide an effective means of carrying substances from the land surface to creeks, rivers, ponds and lakes.

When these stormwater-borne substances enter area creeks, rivers, ponds and lakes, as shown in **Figure 1-9**, they can contribute to various pollution problems. Example problems are algae blooms, fish kills, blocked culverts, odors and objectionable appearance.

Sufficient Knowledge Exists

If wisely planned and designed using current hydrologic principles and methodologies, urban development can occur in harmony with the hydrologic cycle. When development results in flooding and pollution problems, lack of knowledge is not the cause. Failure to apply available knowledge is the cause. Heavy rainfalls are inevitable. Damage and pollution are not inevitable. Application of available knowledge is the deciding factor.

Engineering, science, and other professions involved in land development have access to sufficient knowledge. Problems occur when that knowledge is not used. You, as an interested and informed stakeholder, should be prepared to seek assurances that only qualified professionals are involved in planning and designing developments in the same way that one seeks qualified individuals when needing medical, financial and legal advice.

Watersheds are the framework used by engineers and others in planning and designing urban development, recognizing the realities of the hydrologic cycle.

Figure 1-9
When a community takes a "shower", various potential pollutants are picked up by stormwater rumoff and carried in creeks, rivers, ponds and lakes.

A solution to flooding that is feasible for one community may be unacceptable from a watershed perspective because of adverse effects it would have on other communities.

Local communities and the District share responsibility for stormwater management.

The Watershed

A watershed is an area or basin within which all land and water areas drain or flow toward a point on a creek, stream, river or lake at a lower elevation. Refer again to **Figure 1-3**, showing the six watersheds that drain the entire planning area.

The boundary of a watershed is called the watershed divide. If you stand at any point on a watershed's divide and look into the watershed, the land will slope downward from you. Behind you, the land surface will slope downward into the adjacent watershed.

Assume that a watershed surface is smooth. If you dropped a ball anywhere within the watershed it would roll to the watershed outlet, that is, its lowest point. In an actual watershed, all surface water flow paths lead to the outlet.

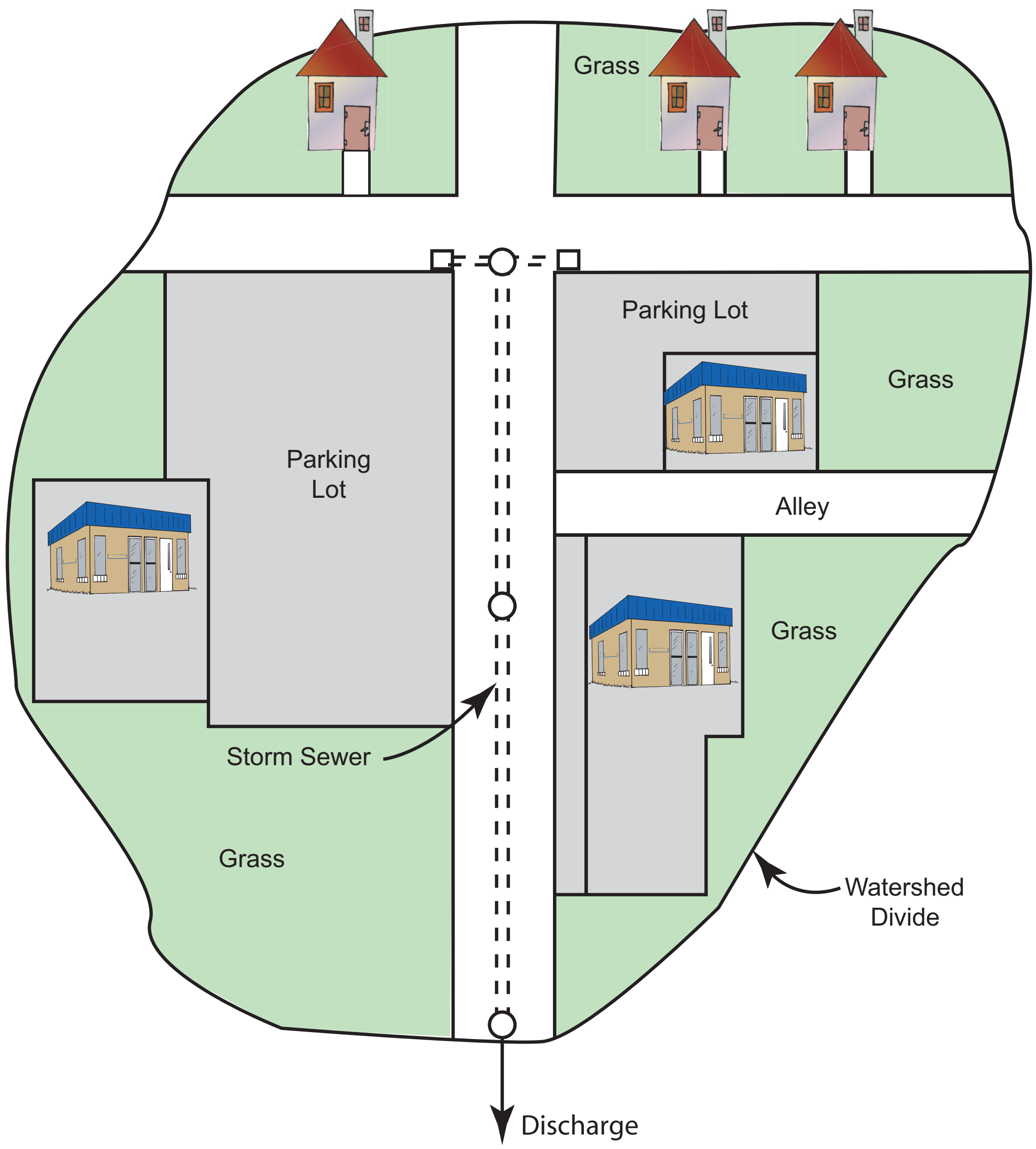


Figure 1-10
Depending on the purpose of a study, watersheds can vary in size (Walesh, 1989).

Watersheds can be almost any size. The area upstream of the outlet point selected on a creek, stream, river or lake determines watershed size. The Menomonee River watershed, as shown in **Figure 1-3**, covers 135 square miles. The hypothetical neighborhood watershed shown in **Figure 1-10**, covers only about 10 acres.

Essentially every member of the watershed community is upstream and downstream of other members.

Watersheds are the framework of hydrologic studies. All hydrologic processes within a watershed are interconnected. For example, snow that melts near the divide affects the volume of stream flow at the watershed outlet. Development in upstream portions of a watershed can influence peak flood elevations in downstream portions. Erosion occurring in a subdivision being developed along a tributary stream in a watershed can destroy fish habitat in the watershed's major river.

Given the interconnectiveness of the watershed, a flooding or pollution solution that could solve a local problem might not be implementable because of adverse downstream or upstream effects. For example, a channel straightening and lining project could solve a particular community's flooding problem. However, when viewed in the context of the entire watershed, moving water more quickly from that flood-prone community may cause increased flooding in a downstream community. Additionally, channel modifications produce extreme impacts to the local watercourse ecosystem.

The 1986 Policy Plan identified those streams in the Milwaukee area for which the District assumed jurisdiction for the resolution of drainage and flood management problems. In this case, jurisdiction is defined to mean those streams and watercourses for which the District is recommended to act as the primary management agency with respect to the construction and maintenance of needed drainage and flood management works (SEWRPC, 1986). The District has assumed "jurisdiction" for a number of major watercourses in the Milwaukee area. A list of watercourses for which the District has jurisdiction is found attached to its Chapter 13 Surface Water and Stormwater Rule. Responsibility for both jurisdictional and non-jurisdictional streams and the local storm drainage systems rests with adjacent property owners and the local municipalities.

Another way of viewing the interconnectiveness of a watershed is to say that essentially every member of the watershed community is both upstream and downstream of other members. Therefore, fairness and liability considerations require determination of possible off-site effects of potential flooding and pollution solutions.

In summary, watersheds are the most logical unit to use for SWM and flood managment. Accordingly, each of the District's WMPs focus on one of the six watersheds, and some plans focus on smaller subwatersheds within those six.

Components of a Stormwater System

A modern urban stormwater system consists of various components designed to function together for the purpose of preventing flooding and pollution. Many of these components are illustrated in **Figure 1-11**, which is a hypothetical small urban watershed. Examples of stormwater system components shown in **Figure 1-11**, are inlets, swales, curb and gutter, roadways, roadside ditches, culverts, storm sewers, manholes and detention/wet detention facilities. A well designed stormwater system may also include Low Impact Development components (see Appendix L).

The stormwater system includes inlets, swales, curb and gutter, roadside ditches, culverts, storm sewers, detention/retention facilities, channels and floodplains.

A well-designed stormwater system may be viewed as two functionally and physically superimposed systems. One, the convenience or "minor" system, includes those components that convey runoff from small, frequent rainfall and snowmelt events. The convenience system is sometimes referred to as the "minor" system because it accommodates runoff from small or "minor" rainfalls. The disadvantage of the "minor" label is that it may suggest that the convenience system is unimportant. Typical convenience system components are inlets, curb and gutter, and storm sewers. They are sized so that little or no disruption or inconvenience occurs during small runoff events.

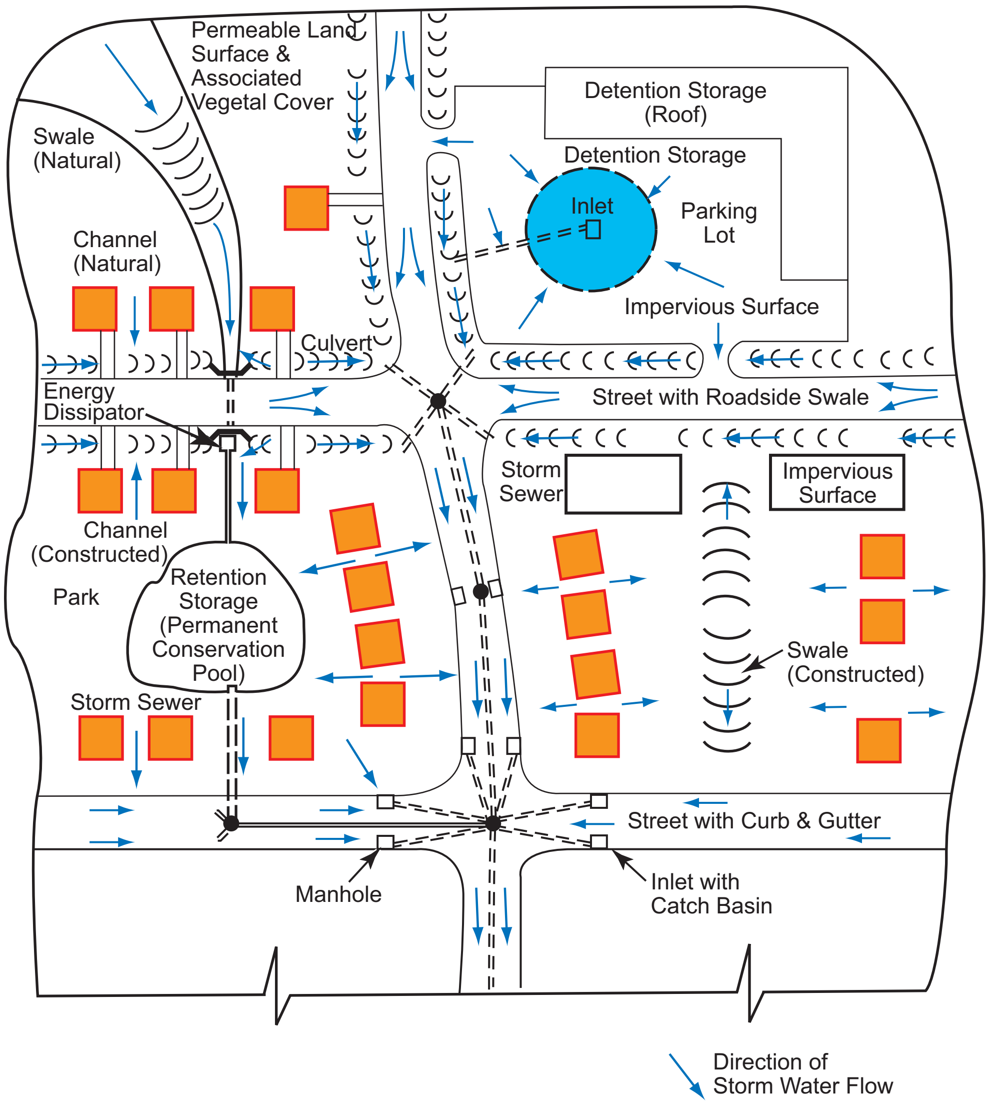


Figure 1-11
Many interconnected components comprise a well-designed urban stormwater system (Walesh, 1989).

The other system is the emergency or "major" system. It includes components that control runoff from large, infrequent events. Typical emergency system components are streets, large swales and major storage facilities. While temporary disruption is likely to occur during major runoff, a carefully designed emergency system will prevent damage.

As innocuous as some of the stormwater system components illustrated in **Figure 1-11**, may appear (e.g., inlets, culverts), they are all important. If inlets or culverts are blocked or altered, localized flooding or pollution may occur. Stormwater inlets, if used for disposal of hazardous materials, such as crank case oil and left over paint and solvents, send these pollutants, via the stormwater system, directly to nearby creeks, rivers, ponds and lakes. As noted later in Volume 1, stormwater system components are primarily the responsibility of local municipalities.

The stormwater system typically shares street right-of-ways and other areas with various utilities and facilities. Examples are sanitary sewers which collect and convey wastewater, combined sewers which collect and convey both wastewater and stormwater runoff, and electric and gas lines.

Channels and floodplains are often the spine of primary environmental corridors which offer flood control, pollution prevention, wildlife habitat, recreation and aesthetic benefits.

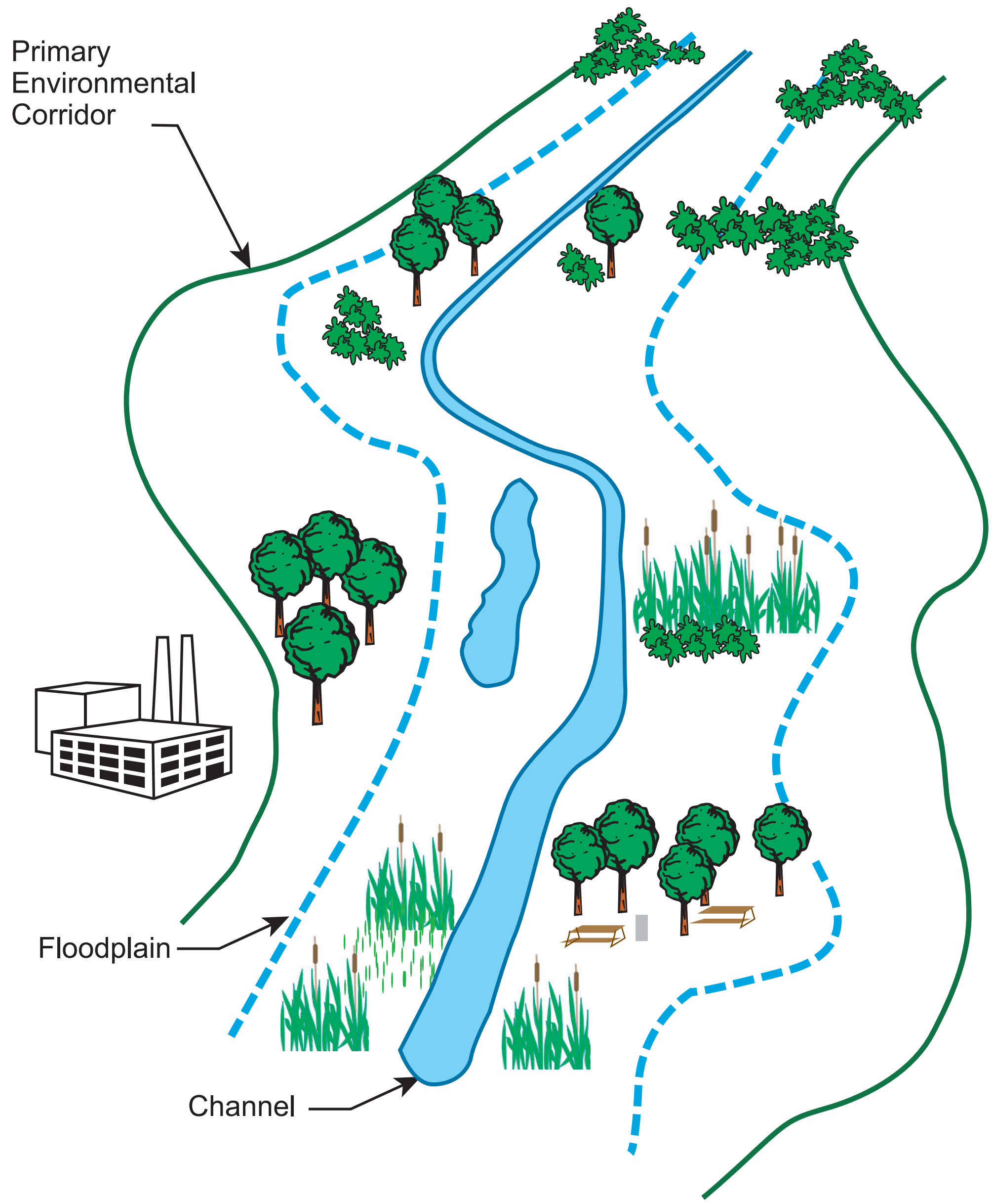


Figure 1-12
The channel and floodplain are often part of a primary environmental corridor which offers flood management, pollution prevention, wildlife habitat, recreation and aesthetic values.

Channels and floodplains, preferably natural but sometimes reconstructed, are also important elements of the stormwater system. The channel, as shown in **Figure 1-12**, is the long, narrow, and continuous low-lying area that, except in instances of moderate or more rainfall or snowmelt, carries all the flow of a creek or river. The floodplain, as also shown in **Figure 1-12**, is usually much wider than the channel and lies along both sides of the channel. The floodplain is vital to the overall hydrologic cycle because it temporarily conveys and stores stormwater runoff from moderate and greater rainfall and snowmelt events. Prudence suggests that houses, businesses and other flood-prone structures and facilities should not be built in floodplains. Furthermore, floodplains should not be filled for development or other purposes, because the stormwater previously conveyed and stored there must then be accommodated somewhere else, possibly to the detriment of others.

The channel and floodplain are often the spine of primary environmental corridors. As shown in **Figure 1-12**, these are elongated stretches of important natural resource features such as channels, floodplains, wetlands, woodlands, and wildlife habitats. Primary environmental corridors, which typically contain and extend laterally beyond the floodplain, are sometimes referred to as "blue-green corridors" because of the dominance of water and vegetation.

Primary environmental corridors, and the channel floodplains within them, offer flood management, pollution prevention, wildlife habitat, recreation and aesthetic benefits (Walesh, 1976). The Milwaukee area pioneered the corridor concept (Katz, 1976) and, as noted later in Volume 1, preserving primary environmental corridors is one of the policies used by the District in making decisions. Primary environmental corridors are complex, valuable and vulnerable ecosystems the protection of which greatly enhances the quality of life for District residents.

EVOLUTION OF DISTRICT STORMWATER MANAGEMENT POLICIES

Watercourse Policy Advisory Group

The District's involvement in regional flood abatement began in 1959. As a result of the community's concern with flooding caused by major storms, in 1998 the District initiated a comprehensive approach to its role in stormwater management and flood abatement that involved both remedial and preventive measures.

In 1998 the Commission approved the development of Watercourse Management Plans that address flood management in six watersheds. At that time the Commission Chair also formed a Watercourse Policy Advisory Group to develop policy recommendations for the implementation of the District's watercourse projects.

The Advisory Group presented its recommendations to the Commission in April 1999. The recommendations addressed the following issues:

- The appropriate relationship between municipal stormwater management and the District's flood management activities;
- Funding responsibilities and cost-sharing for the system plan;
- Acceptable benefit-cost ratios;
- Project prioritization and policy for potential interim projects; and
- Riparian management.

Policies adopted by the District, guide stormwater management decision- making in accordance with the District's mission.

In large measure, the Advisory Group's recommendations built on the Stormwater Drainage and Flood Control Policy Plan that the Commission adopted in 1986. However, the Advisory Group took a more specific position regarding stormwater management by proposing three guiding principles:

- Flood management and stormwater management must focus on watershed-based, not solely local, solutions;
- The watershed perspective is important both for avoiding increases to peak flows downstream and for environmental protection; and
- Proper stormwater management in future development is a necessary condition for investing in projects to reduce existing flood exposure.

In April 1999 the Commission adopted a Watercourse Policy based on the Advisory Group's recommendations. At the same time, the Commission directed District staff to develop a stormwater rule that would prevent flood risk from increasing as a result of development or redevelopment. In 2007 and 2015, the Policy received minor modifications related to the District's stream jurisdiction.

Commission Watercourse Policy

Commission Policy 1-01.15 establishes a Watercourse Policy for the District. This policy directs the activities of District personnel with respect to the construction and maintenance of flood management measures. Key elements of the policy are as follows:

1. Jurisdiction refers to the streams and watercourses for which the Commission has determined the District should serve as the primary management agency with respect to the construction and maintenance of flood abatement measures. The exercise of jurisdiction is completely discretionary, provided it is consistent with the relatively broad permissive authority granted by state statutes.

   The Watercourse Policy provides that the District may exercise jurisdiction over perennial streams within the District that meet at least one of the following criteria:

   - Streams where flooding poses potential major damage;
   - Streams with tributary drainage in more than one municipality; or
   - Streams on which the District has completed channel improvements.

   The policy also provides for District jurisdiction over intermittent streams that meet at least two of those criteria.

The District's stormwater policies are hydrologically sound and reflect a desire to partner with stakeholders.

2. The Watercourse Policy provides for the District to play the lead funding role for capital improvements pertaining to jurisdictional watercourses by allowing the District to fund up to 100% of the cost of construction and operation and maintenance of a variety of structural and non-structural measures designed to remediate existing problems. District funding of storage facilities is limited to projects that receive the flows from two or more upstream municipalities, and/or manage the flows moving toward two or more downstream municipalities.

   - The Policy reflects a concern with the environmental impacts of watercourse projects by declaring that river lowering is the least preferred alternative for flood management and may be used only when other alternatives are not feasible.
   - The Watercourse Policy does not provide for District involvement in storage facilities that pertain to flows originating from or received by a single municipality, or that manage runoff from new development, or redevelopment that occurs in the future.

3. The Policy limits District watercourse maintenance activities to those streams and stream reaches over which the Commission has chosen to assume jurisdiction for flood abatement purposes. The policy is geared to resolving problems from obstructions that would cause an increase to the number of structures exposed to flooding during the 1% probability (100-year) storm, compared to baseline conditions.

Chapter 13, District Rules

1. State law establishes Commission authority to adopt the Rules both necessary and proper to promote the best results from the construction, operation, and maintenance of the sewerage system, to prevent damage to the system or to prevent surcharging, or to limit discharges that interfere with the process of sewage treatment. Under Rule making authority the Commission may enact rules and regulations to enable any of the District's flood management facilities to achieve their best results and limit the potential for surcharging the facilities.

2. Chapter 13 clearly establishes local government responsibility for stormwater management. The District's role is to remediate flooding problems in existence at the time the Watercourse System Management Plan was adopted in 1998. The Rules assign local governments with a preventive duty to ensure that future development and redevelopment do not create the potential for additional flood risk.

3. The Rule's key concept is to preserve current conditions by preventing increases to peak flows during the 1% (100-year) and 50% (2-year) probability storms for development or redevelopment that involves an increase of 1/2 acre or more of impervious surface, porous pavement, or vegetated roof.

   Chapter 13 does not intend to guarantee flood protection under all circumstances, nor does it require local governments to remediate problems that existed prior to the Rule's effective date of January 1, 2002.

4. The Rule also addresses demolition or construction during redevelopment that will disturb an area larger than 2 acres. Governmental units shall reduce the runoff release rate by a percentage dictated by the area of disturbance for the 1% (100-year) and 50% (2-year) probability storms.

5. Prior to the adoption of Chapter 13, stormwater management ordinances and practices varied significantly among municipalities in the District's planning area. This resulted in development having variable impacts on future flood risks, depending on where the project occurred. A minimum standard applicable throughout the planning area ensures a consistent level of protection for all communities and their residents. The Rules will also protect regional wastewater treatment and flood abatement infrastructure, which ensures that taxpayers' investments in these facilities will serve their purpose.

6. The Rules incorporate a watershed perspective. Standards developed with only local conditions in mind cannot provide adequate protection for downstream neighbors.

These District stormwater policies build on the foundation of stormwater concepts (e.g., hydrologic cycle, the watershed and impact of development) as discussed earlier in this manual. The District's policies also reflect a desire to partner with various stakeholders.

Stormwater management measures are the "tools" used to prevent or remedy flooding and pollution problems.

The challenge in stormwater management is finding the optimum mix of non-structural and structural measures.

STORMWATER MANAGEMENT MEASURES

Non-Structural and Structural Management Measures

Recall the definition of SWM presented at the beginning of this volume. It included "...everything done to remedy existing stormwater-related flooding and pollution problems and to prevent the occurrence of new problems."

SWM measures are the "tools" used in SWM. They are the actions that are taken and the facilities that are built to prevent flooding and pollution. "Actions" may also be called "non-structural management measures." Similarly, the "facilities" may also be called "structural management measures." Lists of available non-structural and structural measures are presented in **Table 1-1**. For each measure, the table indicates whether the measure is intended for flood management, pollution prevention, or both.

Storm Water Management Measure	Purpose	
	Flood Management	Pollution Prevention
Non-Structural		
1. Education and involvement	●	●
2. Appropriate land use	●	●
3. Flood Insurance	●	
4. Floodproofing	●	
5. Relocation and/or demolition of structures	●	
6. Inspection and maintenance	●	●
7. Emergency action program	●	●
Structural		
1. Channel modification or enclosure	●	●
2. Channel rehabilitation	●	●
3. Levees and floodwalls	●	
4. On-line and off-line storage	●	
5. Bridge and culvert alteration, replacement or removal	●	
6. Sedimentation basin		●
7. Sedimentation basin - wetland system		●
8. Sedimentation basin - wetland - detention / retention system	●	●
9. Low impact development system	●	●

Table 1-1
Many structural and non-structural measures are available to manage stormwater flooding and pollution.

Structural SWM measures are typically major public works projects. As such, they typically require moderate to major planning and design efforts, formal approval by one or more government entities, letting of construction contracts and moderate to large capital investments and operation and maintenance commitments.

In contrast, non-structural SWM measures typically involve little or no construction. Individuals, businesses and other private entities and government units can often implement them quickly, sometimes unilaterally. Non-structural measures, relative to structural measures, usually entail small to moderate capital investments and operation and maintenance expenses.

Very broadly speaking, non-structural SWM measures tend to be more readily applied to areas undergoing development. In already developed areas that are experiencing growing stormwater problems, structural measures are often the only recourse. Stated differently, non-structural measures tend to be preventive whereas structural measures tend to be remedial.

Structural measures, used in a remedial mode, are usually the only option once urban development has occurred.

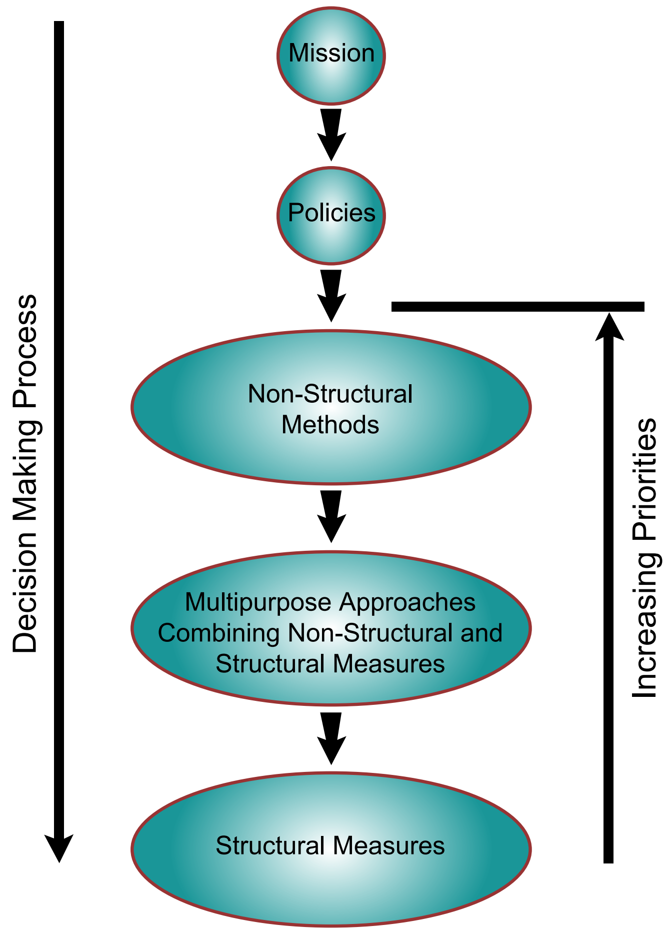


Figure 1-13
The District uses a hierarchical approach to selecting stormwater management measures.

Recall the significantly higher capital and operation and maintenance costs of structural SWM measures. Accordingly, fiscal prudence suggests applying primarily non-structural measures in a preventive mode prior to and during development rather than waiting until development is well underway or complete to introduce the more costly structural measures in a remedial mode.

Stakeholder knowledge is a prerequisite for effective stakeholder involvement.

Non-structural stormwater management measures are most effective when applied in a preventive mode to areas as they are being developed.

Hierarchal Approach to Selection of Stormwater Management Measures

Many structural and non-structural SWM measures are available to the District and its stakeholders. The challenge in SWM planning and design is to find, for each existing or potential flooding and/or pollution situation, the best combination of actions and facilities and apply them as an integrated whole.

For guidance in optimizing management measures, the District and its stakeholders turn to the previously discussed District's mission and policies. Favoring non-structural over structural measures is explicitly set forth in those policies. Multipurpose SWM facilities are also strongly endorsed by the District's policies. **Figure 1-13** illustrates the District's hierarchical approach to selecting and tailoring SWM measures to particular situations.

Descriptions of Non-Structural Measures

Education and Involvement

As noted earlier in this volume, knowledge is a key to effective involvement by stakeholders in SWM. Education can take many forms including the preparation and wide dissemination of educational publications such as this Guidance Manual. Self-directed means of SWM education include websites, videos, and kits (See Appendix E). The District provides water quality presentations and tours. Water quality data and research can be found on the District's website. The District also partners with schools giving students the opportunity to learn more about the environment, especially its water resources.

For examples of ways in which informed citizens and other stakeholders can be involved largely at the individual level in SWM, refer to the section of this volume of the Guidance Manual titled "Your Potential Role in the Stormwater Management Program."

Appropriate Land Use

As explained in the earlier Stormwater Concepts section of this volume of the Guidance Manual, the manner in which SWM is matched to land development determines if flooding and pollution will occur. Stormwater runoff from improperly planned and constructed development (poor land use) will, as suggested in **Figure 1-14**, cause disruptive and damaging flooding and pollute surface waters. In contrast, and also illustrated in **Figure 1-14**, intelligent SWM can prevent new flooding and pollution problems and even remedy existing problems.

Sufficient knowledge exists and methodologies are available to plan and design urban development, to use the land in harmony with the hydrologic cycle. Wise land use can facilitate development and redevelopment that avoids flooding and pollution problems, while gaining amenities. Appropriate land use choices accomplish objectives as shown in **Table 1-2**.

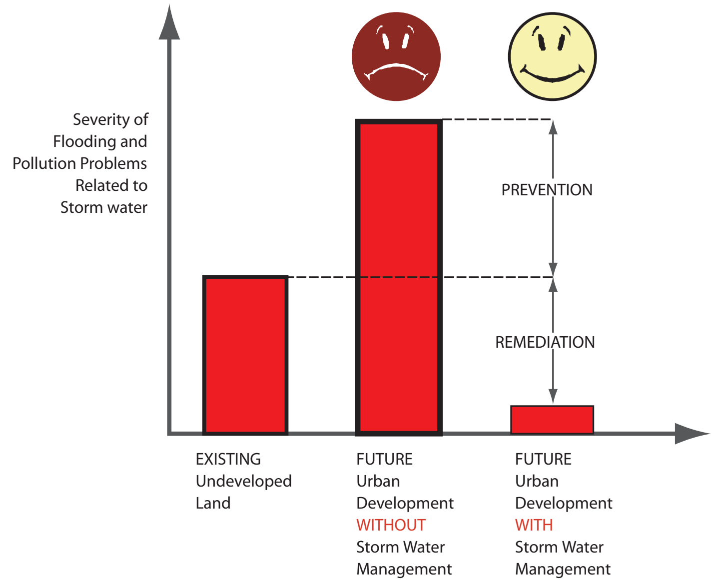


Figure 1-14
The manner in which stormwater management is matched to land development determines if flooding or pollution problems will occur.

Non-structural measures usually cost less than structural measures and can be implemented faster.

Land Use Choices	Objective
Avoid placing residential, commercial, industrial and other structures and facilities in flood-prone areas (e.g., on floodplains).	Greatly reduces potential flood disruption and damage.
Preserve natural storage, conveyance and infiltration areas.	Natural storage, conveyance and infiltration that is removed must eventually be replaced, typically at high costs.
Preserve environmental corridors and other natural areas for their stormwater storage and conveyance benefits and also for their habitat, recreation and aesthetic values.	Reinforces the second objective and adds more value for area residents and visitors.
Respect the rights of individual landowners.	Property owners should not be unfairly burdened with the cost of achieving appropriate land use.

Table 1-2
Objectives for better land use choices.

Many means are available to encourage wise land use. Four key methods are land use planning, land acquisition, conservation easements, and land use regulations. Each is briefly discussed.

Land Use Planning: A land use plan for a municipality, a watershed, a proposed development or some other geographic unit can serve many infrastructure and environmental purposes. One of these is SWM. The SWM aspect of the land use planning process delineates floodplains; identifies stormwater storage, conveyance and infiltration areas; and describes primary environmental corridors and other natural areas. Furthermore, a land use plan recommends ways to protect the SWM functions of those land features.

Many SWM-related land use plans have been or are being prepared within the District's planning area. An example is SEWRPC's 2020 Land Use Plan (PR No. 45), which promotes urban development adjacent to or within existing urban areas or in areas physically suited for the development with existing infrastructure such as sewer systems, a water supply and public transit systems. The plan also seeks to preserve environmentally sensitive areas and productive farmland and recommends residential lot sizes of 1/4 acre for most new residential development. This land use plan was the basis for the 2020 land use condition used as future conditions in District planning efforts. All municipalities completed a Comprehensive Master Plan in 2009 that addressed land use, natural resources, housing, transportation and more.

Land Acquisition: Land needed for SWM and related purposes can be purchased by a public entity. An example of this definitive approach is gradual acquisition, by Milwaukee County, of what are now continuous parklands along the Milwaukee, Menomonee and Kinnickinnic Rivers. By including channels and floodplains, these land acquisitions have preserved storage and conveyance capacity. These purchases have also created a highly valued recreation and aesthetic amenity.

Conservation Easements: Rather than outright purchase of land having a SWM function, a government entity can acquire a conservation easement. This is a legal agreement between a landowner and a government agency that permanently protects the environmentally valuable aspects of a parcel of land, while maintaining the landowner's restricted use of the land as defined by the agreement. An "environmentally valuable aspect" might be stormwater storage, conveyance or infiltration.

Owners and renters of flood-prone buildings should consider purchasing flood insurance.

The District has acquired easements on significant acreage of critical property. These efforts are continuing.

Land Use Regulations: Use of private land is often regulated in the public interest. Various types of land use regulations can be used to support effective SWM (Walesh, 1989). For example, a floodplain zoning ordinance can use overlay provisions to regulate land use and even the type and placement of structures in floodplains. A land division ordinance typically regulates the division and transfer of land. It could require dedication of a stormwater storage and infiltration area for public parks and open space use. A sanitary or health ordinance could prohibit use of septic tank systems near certain creeks, rivers, ponds and lakes. Finally, a building ordinance typically regulates the construction, alteration, expansion or conversion of buildings. It could include provisions to control potentially polluting erosion and sedimentation during construction.

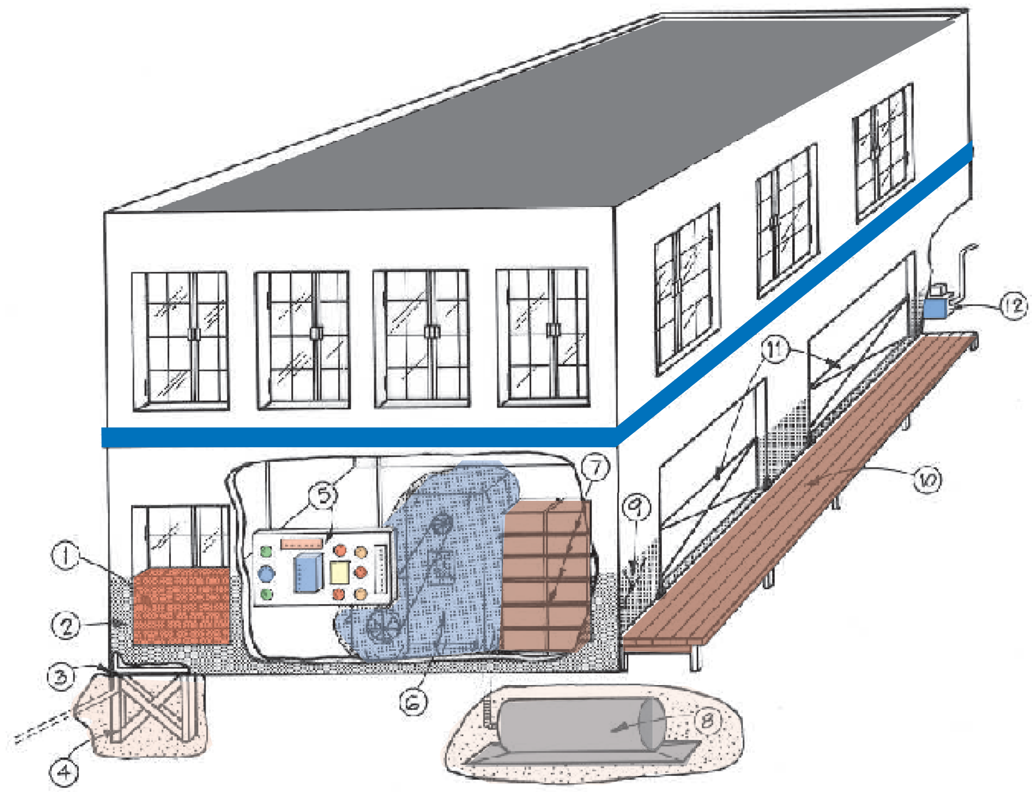
Flood Insurance

One purpose of the National Flood Insurance Program (NFIP) is to distribute federal emergency funding by subsidizing flood insurance premiums. Another purpose of the NFIP is to encourage implementation of floodplain regulations. To receive more information about the NFIP, visit the website at **http://www.fema.gov/business/nfip**.

Assume you own or rent a building in or near a floodplain. You should consider purchasing flood insurance as protection against large monetary losses as a result of flooding. That is, acquiring flood insurance will not reduce the threat of flooding, but it will reduce your potential financial impact by providing some monetary compensation for damage to your structure and its contents. For information about flood insurance, including premiums and coverage in your area, contact your personal insurance agent.

Floodproofing

Floodproofing means making structural and use changes to existing or new buildings to reduce flood threats. Floodproofing may be applied to individual residential, commercial, industrial buildings or other single facilities or to groups of contiguous buildings or facilities. Even when successfully applied to individual buildings or facilities, overland flooding and related disruption will continue to occur in flood-prone areas. That is, floodproofing focuses on protecting the building or facility, not the site.



LEGEND

1. Permanent closure of opening with masonry
2. Coating to reduce seepage
3. Valve on sewer line
4. Underpinning
5. Instrument panel raised above expected flood level
6. Machinery protected with polyethylene covering
7. Strips of polyethylene between layers of cartons
8. Underground storage tank properly anchored
9. Cracks sealed with hydraulic cement
10. Rescheduling has employed the loading dock
11. Steel bulkheads for doorways
12. Sump pump and drain to eject seepage

Figure 1-15
A combination of permanent and temporary measures is another approach to floodproofing (Adapted from Sheaffer et al., 1967).

An entire existing or new building can be elevated above flood stage by constructing it on columns, by raising the foundation, or by placing it on fill. Another floodproofing approach, as illustrated in **Figure 1-15**, is to employ a combination of permanent and temporary measures. Many other floodproofing techniques are available.

> A word of caution is in order. Many floodproofing methods appear simple. Accordingly, well-intentioned building owners and tenants may apply floodproofing in a way that inadvertently increases the threat to a structure or facility. For example, sealing basement windows and installing backwater valves in basement floor drains may appear effective to a homeowner frequently flooded by overland flow and sewer back up. However, the "solution" may have catastrophic consequences in the form of uplifted basement floors and collapsed basement walls. Building owners and tenants interested in floodproofing are urged to use services of a licensed engineer.

Relocation and/or Demolition of Structures

In certain cases, floodproofing may not be technically or economically feasible. Prohibitive factors could include poor structural condition of buildings and high flood stages relative to the buildings.

Reducing flooding and pollution is one way the District carries out its mission.

As options, structurally sound buildings may be moved to nearby high ground or buildings may be purchased and demolished. In both cases the site would be converted to a flooding-compatible use. An example of acquisition and use conversion is the District's participation in the purchase of over 50 properties along the Menomonee River in the Hart Park area (MMSD, 1999).

A potential negative aspect of structure relocation or demolition is loss in property tax base. However, some of the lost property tax revenue may be offset by reduced costs of providing municipal services including flood response or, because of increased open space, by increased property values in the surrounding area. Furthermore, some former residents of the flood prone area may construct new buildings or relocate their structures within the municipality. These actions would help maintain the tax base.

Inspection and Maintenance

Stormwater systems include many components. Blocking or otherwise altering them can cause localized flooding or pollution. The primary issue is not the physical integrity of the components of the stormwater system, that is, whether or not they will be damaged, but rather their ability to convey or store stormwater. Accordingly, an ongoing inspection and maintenance program is essential if a stormwater system is to function as intended.

The District and local municipalities collectively inspect and maintain the stormwater system throughout the District's planning area although these activities may be limited by lack of funding and resources. Examples of inspection and maintenance tasks are:

- Inspecting and cleaning catch basins and inlets;
- Inspecting and cleaning trash and safety racks or grates, sluice gates, and other control devices, motors and pumps;

- Inspecting and cleaning storm sewers, combined sewers, channels, and detention/retention facilities;
- Removing settled and floating solids and debris from sedimentation basins;
- Revegetating; and
- Mowing and controlling weed, brush, and tree growth.

Emergency Action Plan

An emergency action plan (EAP) is a proactive way to mitigate the flood damage and pollution typically accompanying inevitable heavy rainfalls and large snowmelts. The EAP lays out the coordinated steps taken by a municipality or a group of communities before, during and after flooding events.

An EAP could consist of the following four phases (Walesh, 1989):

1. **Pre-flood Preparation.** This phase may include mapping flood-prone areas; stockpiling materials such as sandbags, sand, and impermeable membrane; identifying the location of and making arrangements for the use of necessary equipment, such as trucks, front-end loaders, and portable pumps; inspecting and maintaining flood management facilities; and locating and making arrangements for the use of emergency shelters for evacuees.

2. **Monitoring and Warning.** This phase of the EAP may include monitoring of upstream gauges and stage sensors and alarms; patrolling low-lying areas to note the water stage relative to flood stage conditions; listening to National Weather Service flash flood watch and warning bulletins; broadcasting emergency messages over radio and public address systems to warn residents in low-lying areas; and activating a siren warning system which uses a special signal or pattern to indicate that flooding is expected or imminent.

3. **Flood Response.** This phase may include evacuating residents of threatened areas, closing roads according to a preplanned schedule, providing for medical care, reinforcing police protection, using portable pumps to relieve surcharging in sanitary sewers, sandbagging, building temporary earth dikes, activating floodproofing measures, and continuously inspecting flood management facilities.

4. **Post-flood Cleanup.** Activities representative of this phase are removing sand bags and temporary dikes; helping evacuees return to their residences and businesses; repairing damage to public utilities and facilities and restoring service; applying for disaster aid from regional, state, and federal agencies; and critiquing and updating the EAP.

Emergency action planning and services, including flood preparedness, are in effect for Milwaukee County. Responsibility for this program lies with the Milwaukee County Sheriff's Department, Emergency Management Division. The Division coordinates with the 19 municipalities in the county. Milwaukee County's Guide to Management

Structural measures are typically costly and complex public works projects.

Channel modification or enclosure is very costly and is often in conflict with the District's environmental objectives.

of Flooding and Other Emergencies is the document Milwaukee County Emergency Operations Plan. Other counties within the District's planning area also have emergency management services.

Potential for flooding within Milwaukee County is determined partly by real time monitoring via modems at stream gauges on the Milwaukee, Menomonee, and Kinnickinnic rivers. In addition, the Emergency Management Division receives reports from the National Weather Service (NWS).

Descriptions of Structural Measures

Channel Modification or Enclosure

Straightening, enlarging and lining a channel **(Figure 1-16)** or enclosing it in a large underground conduit **(Figure 1-17)** are ways to lower the flood stage of a creek or river where it passes near or through an urban area. While channel lining can be an effective SWM measure, negative features typically include high costs, potential negative downstream effects, and adverse environmental and aesthetic impacts. Securing permits for such projects is very difficult. For these reasons, the District's policies assign a low priority to consider action of channel modification or enclosure.

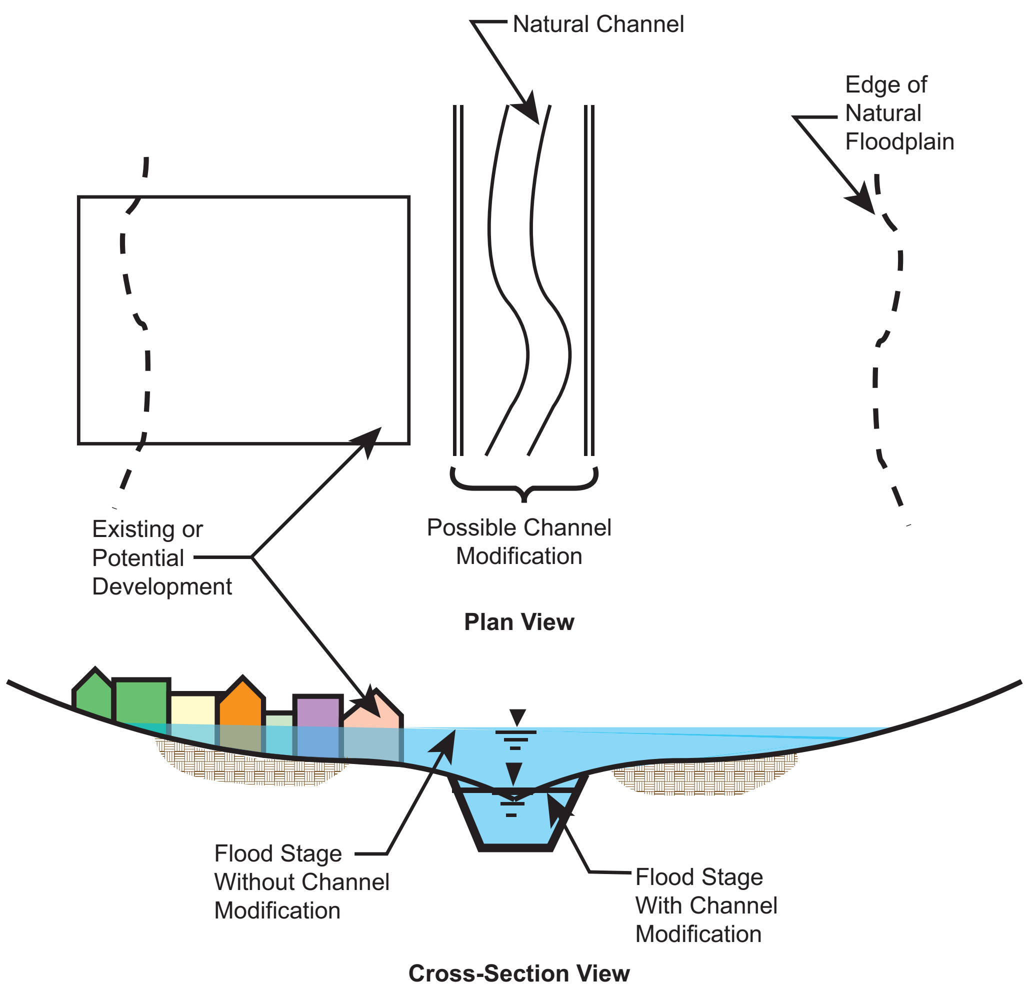
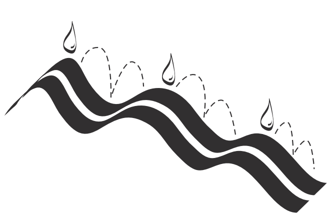


Figure 1-16
Straightening, enlarging and lining a channel can reduce flood stages, but can also cause secondary adverse impacts (Walesh, 1989).



The District constructed a number of channel modifications in the 1950s, 1960s, 1970s and 1980s, which included reaches of the Kinnickinnic River, Honey Creek, Lincoln Creek and Underwood Creek. However, the District's current focus is to rehabilitate and restore channels and drainage ways in order to take advantage of the inherent benefits of a natural water resource, as discussed in the next section.

Channel rehabilitation projects typically have multiple purposes.

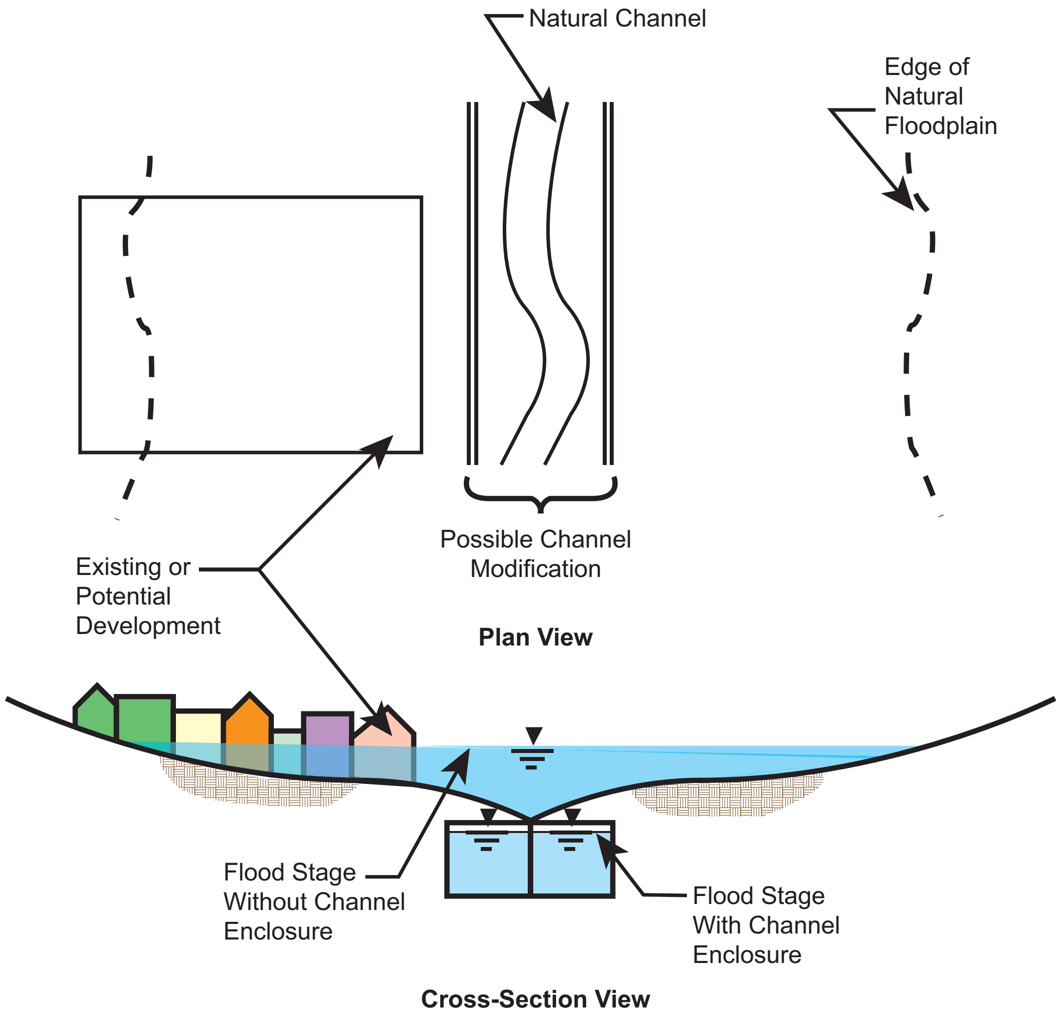


Figure 1-17
Channel enclosure is another way to potentially reduce flood stages (Walesh, 1989).

Channel Rehabilitation

Markedly modified channels are sometimes rehabilitated, that is, shifted in function and appearance back toward natural channel-floodplain configurations. Channel rehabilitation projects typically have multiple purposes such as flood management, pollution abatement, creation of fish and wildlife habitat, provision of recreation opportunities and aesthetic enhancement.

The District's Lincoln Creek Environmental Restoration and Flood Management Project Figure 1-18, is an example of channel rehabilitation. Completed in 2002, the project transformed the 9-mile-long urban waterway into a more natural, winding creek corridor, providing more urban open space. The modifications reduced hazards from flooding to over 2,000 homes and businesses in the floodplains; enhanced the water quality and environment of the Lincoln Creek corridor; rehabilitated, stabilized, and protected eroding banks; and provided suitable habitat for fish and wildlife (MMSD, 2002).

Figure 1-18
Lincoln Creek project, shown here under construction and completed, is a large scale example of channel rehabilitation (MMSD, 1999).

Levees and Floodwalls

Earthen levees and concrete or steel floodwalls can be an effective means of confining a stream and protecting adjacent properties. Typical levees and floodwalls are shown in **Figure 1-19**.

Levees and floodwalls can effectively mitigate flooding, but may be aesthetically objectionable.

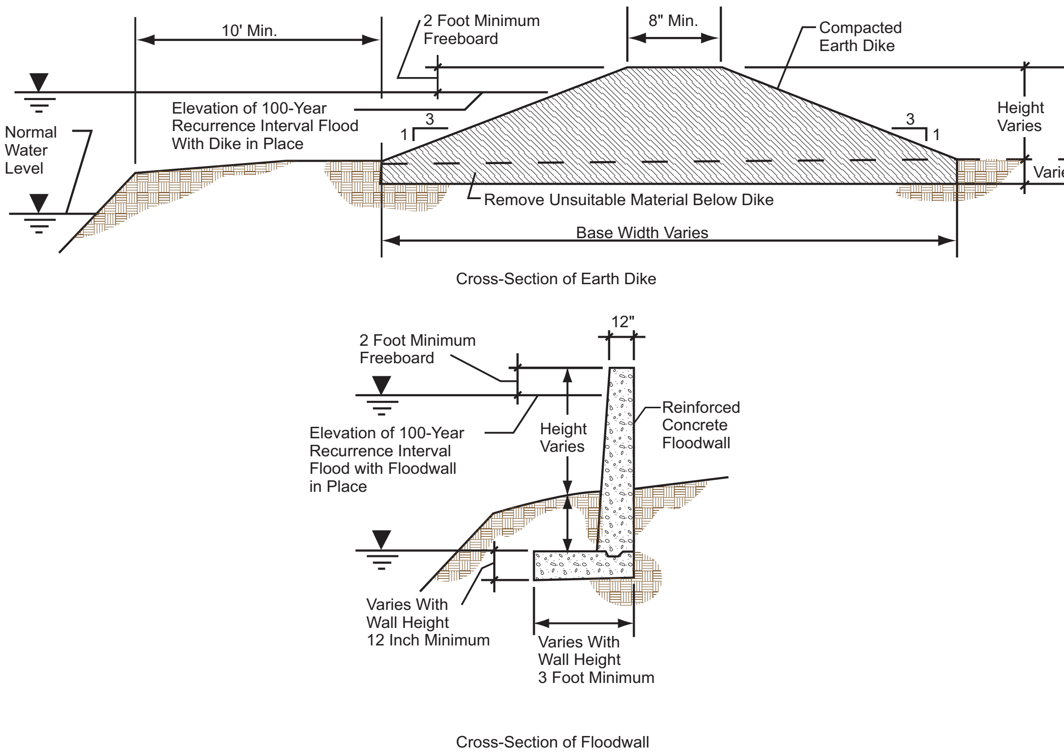


Figure 1-19
Typical earthen levee and concrete floodwall (Adapted from SEWRPC, 1978).

Levees and floodwalls have been constructed within the District's planning area. For example in 2001, the District implemented a levee/floodwall solution to flooding problems in Valley Park. Levees or floodwalls are just one minor component of comprehensive flood management plans and are only chosen as solutions when other more natural options are determined to be infeasible.

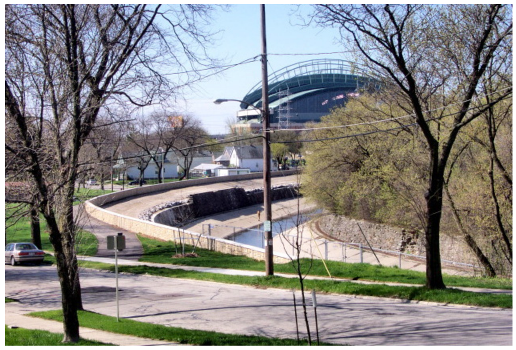


Figure 1-20
Floodwall solution to flooding issues within Valley Park.

When space is at a premium, floodwalls are usually used because they require a much narrower strip of land than levees. The protected area on the landward side of levees typically requires supplemental drainage works, including pumps, to collect and convey local stormwater runoff over the levees into the stream. A levee or floodwall should be configured to preserve as much of the floodplain, and its conveyance and storage capability, as possible (**Figure 1-20**). Levees and floodwalls may be objectionable because they obstruct the view of and access to the waterway. They also require extensive hydraulic modeling and acquisition of permits.

Upstream storage or diversion can reduce flooding in two or more communities and provide other benefits.

On-line and Off-Line Storage

Upstream storage or diversion to off-line storage can be effective flood mitigation measures. Although on-line and off-line storage function differently, as shown in **Figure 1-21**, they have similar effects on downstream flood-prone communities. Both reduce peak flow rates; that is, "shave" off the top of the hydrographs and, therefore, diminish peak flood stages and floodplain widths.

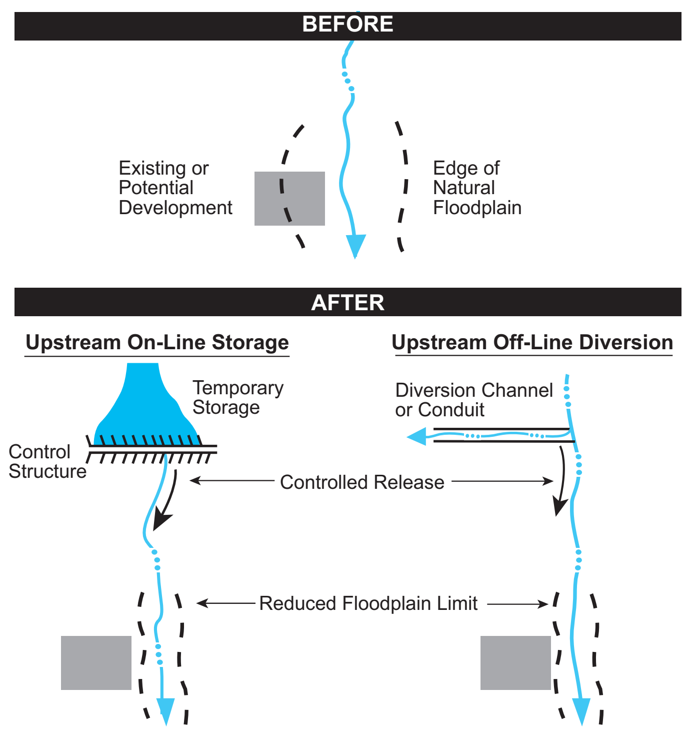
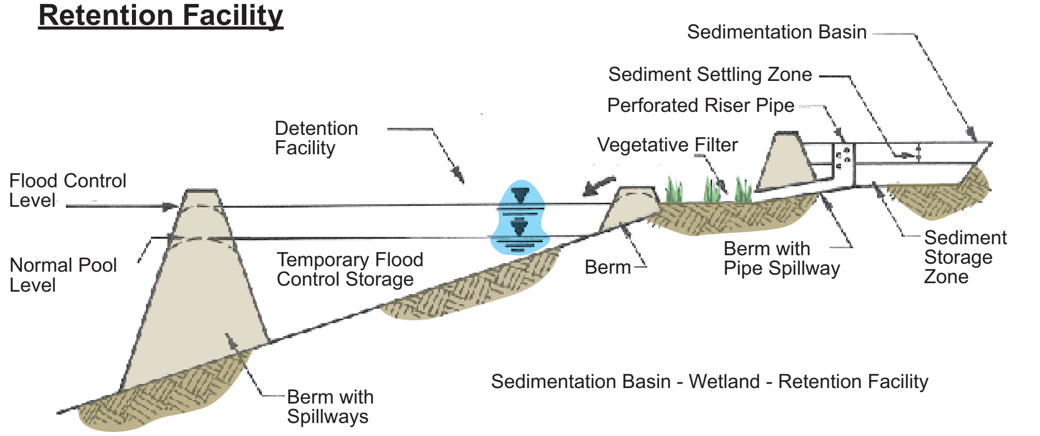


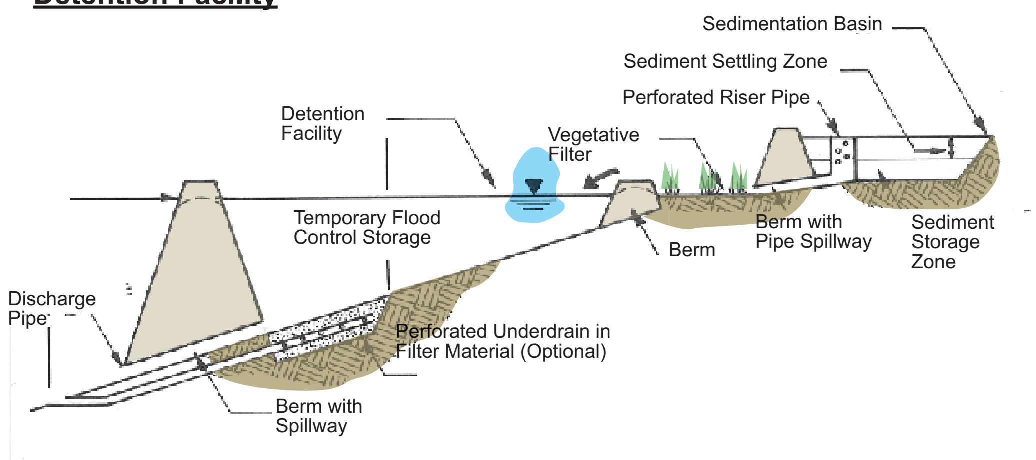
Figure 1-21
Upstream on-line and off-line storage facilities mitigate flooding by reducing downstream flood stages and floodplain widths (Walesh, 1989).

The District has constructed several floodwater detention basins. For instance, the Lincoln Creek Project utilizes a combined storage of about 250 acre-feet or 80 million gallons in the Green Tree and Havenwoods floodwater detention facilities to control peak flows and reduce the required size of the channel in downstream reaches.

Retention Facility



Detention Facility



Adding flood storage to a sedimentation basin-wetland system creates a multi-purpose facility.

Figure 1-22
Sedimentation Basins, wetlands and retention or detention facilities can be combined in various ways to mitigate flooding, control pollution and possibly offer recreation, wildlife habitat, education and aesthetic benefits (Walesh, 1989).

A positive feature of upstream storage or diversion is that one facility can mitigate flooding problems in several downstream communities. It could also provide opportunities for a multipurpose facility. Besides flood management, the storage facility and immediate surroundings might provide water quality, wildlife habitat, recreation and aesthetic benefits.

Stormwater storage facilities take one of two forms. Some are normally dry and designed to temporarily hold (detain) stormwater runoff during and immediately after a rainfall or snowmelt event. These are dry detention facilities and sometimes referred to as "dry basins." A detention facility is shown in the lower portion of **Figure 1-22**.

Other stormwater storage facilities always contain (retain) some water for recreational, aesthetic, or other purposes. However, they are designed to temporarily store, above the normal water level, stormwater runoff during and immediately after a rainfall or snowmelt event. These are wet detention facilities or "wet ponds." Refer to the upper portion of **Figure 1-22**, for an illustration of a wet detention facility.

Both detention and wet detention facilities perform well as flood management devices. While both will also tend to remove potential pollutants from the temporarily stored stormwater, wet detention ponds are likely to be more effective (WDNR, 1994).

Bridge and Culvert Alteration, Replacement or Removal

The purpose of altering, replacing or removing bridges and culverts is to reduce or eliminate backwater effects. Backwater is the increase in stage, or elevation of the water surface, on the upstream side of a bridge or culvert above that which would occur if the bridge or culvert did not exist. Eliminating some or all of the backwater may reduce upstream flood stages and mitigate flooding.

Removing a bridge or culvert, or maybe only modifying it, is sometimes a cost-effective way to reduce upstream flooding.

Possible bridge or culvert alterations include: installing a more effective inlet configuration; enlarging the waterway opening; replacing with a new, more hydraulically effective structure; or completely eliminating the structure.

An example of the last approach is the removal of 14 bridges across the lower Kinnickinnic River in the 1980s. An example of a bridge or culvert alteration within the District's planning area is the construction of the N. 35th Street bypass culvert to reduce flooding as one component of the Lincoln Creek project.

Sedimentation Basin

A sedimentation basin is a facility that traps suspended solids and buoyant debris transported by stormwater runoff. By trapping some suspended solids, the sedimentation basin also removes potential pollutants adsorbed onto or absorbed into the solids. **Figure 1-23** illustrates the essential components of a sedimentation basin.

Sedimentation basins vary from temporary to permanent facilities. Temporary facilities may be constructed at development sites to mitigate potential adverse construction effects. Permanent sedimentation basins are integrated into new developments for long-range management of stormwater quality.

Sedimentation Basin — Wetland System

In some situations, a sedimentation basin followed by a natural, restored or artificial wetland can be an effective means of removing some suspended solids, nutrients, and other potential pollutants from stormwater runoff. The primary function of the sedimentation basin is, as already noted, to remove buoyant debris and suspended solids and the related potential pollutants.

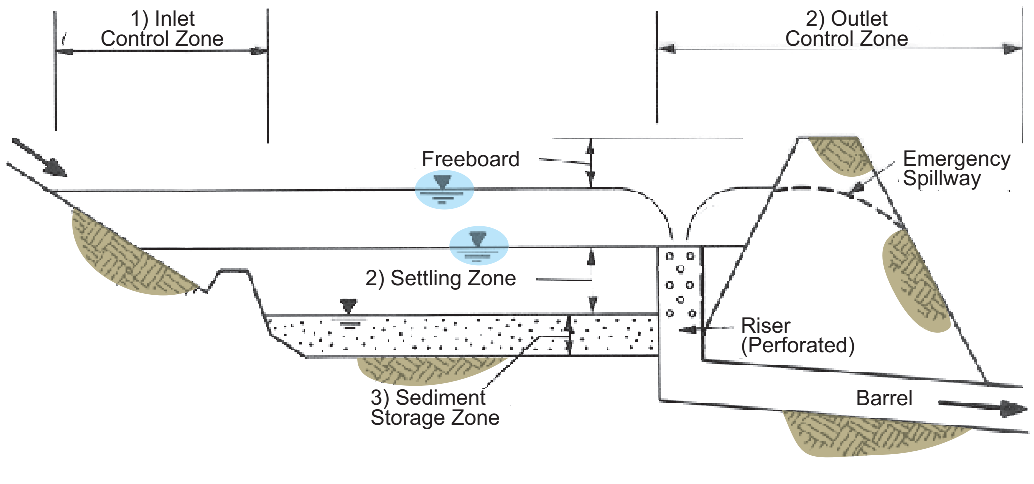


Figure 1-23
A properly designed sedimentation basin has four principal components that enable it to remove pollutants from stormwater (Adapted from Malcom and New, 1975).

Sedimentation basins remove potential pollutants from stormwater.

Stormwater then passes into the wetland where physical (e.g., settling) and biological (e.g., nutrient uptake by vegetation) processes remove additional potential pollutants. The wetland offers opportunities to develop wildlife habitat, education (e.g., self-guided tours), and aesthetic benefits.

A sedimentation basin followed by a wetland can be an effective way to remove pollutants from stormwater runoff.

Figure 1-22 illustrates how a sedimentation basin and wetland (vegetative filter) can operate in series. Typically, when viewed from above, the wetland is much larger than the sedimentation pond.

Sedimentation Basin - Wetland - Dry Detention/Wet Retention System

The previously discussed sedimentation basin — wetland system can be augmented by adding, at the downstream end, a detention or wet detention facility as illustrated in Figure 1-22. The principal purpose of adding the storage element is to provide flood management. The dry detention or wet detention facility also offers potential for additional recreation, wildlife habitat, education, and aesthetic benefits creating a truly multipurpose facility.

A variation on the sedimentation basin—wetland—detention/wet detention system is to omit the wetland component.

Low Impact Development Measures

Stormwater management measures that capture and control rainfall close to where it first strikes the earth and prevent significant adverse quantity and quality problems often associated with urban development are referred to as "low impact." Low impact development (LID) measures are typically small; often requiring only a small portion of individual lots or parcels. Examples of LID measures are rooftop storage, rain barrels and cisterns, porous pavement, vegetative filter strips along waterways, roadside and other swales and infiltration trenches (Prince George's County, 1997). To illustrate the concept, one LID measure, the infiltration trench, is discussed here.

Infiltration Trench

An infiltration trench is a stormwater storage facility intended to serve a small area, such as a parking lot, in contrast with much larger areas typically served by detention/wet detention facilities. An infiltration trench is typically a long, narrow and shallow excavation filled with course aggregate, wrapped with filter fabric and covered with pervious soil. **Figure 1-24** illustrates an infiltration trench designed to intercept stormwater runoff from a parking lot.

Stormwater diverted into an infiltration trench is temporarily stored as it slowly infiltrates into the surrounding soil and/or into a perforated underdrain that carries flow to the stormwater system. An infiltration trench that includes a perforated drainpipe is also called a "french" drain. Some water quality enhancement may occur. However, the principal purpose of an infiltration trench is to control stormwater quantity; that is, to intercept and reduce peak flows from small drainage areas. Some of the water infiltrates into the soil and the remainder is slowly released into the stormwater system.

An infiltration trench can reduce peak runoff water and possibly enhance water quality.

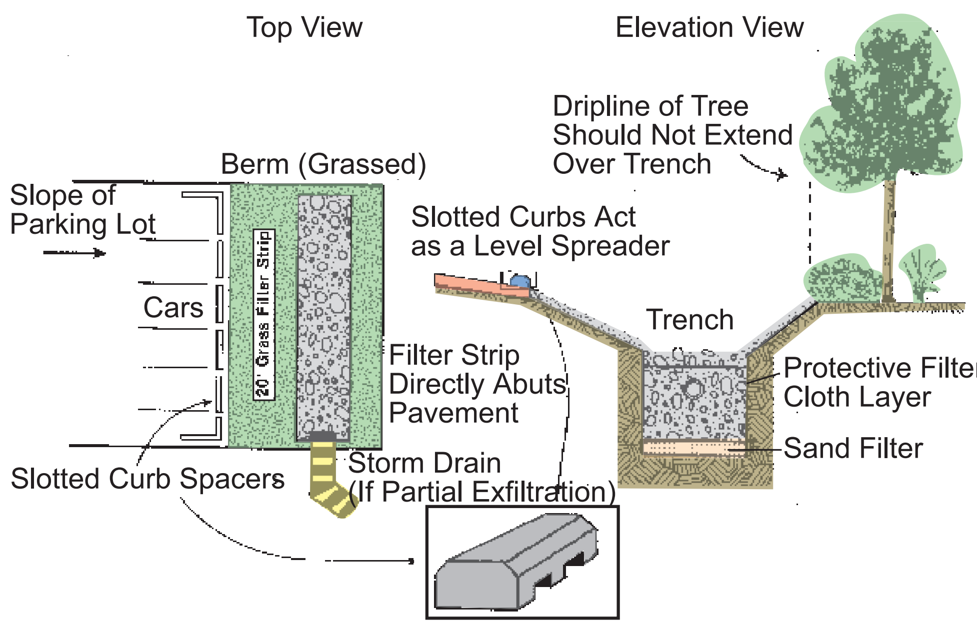


Figure 1-24
Intercepting stormwater runoff from a parking lot is one use of an infiltration trench (Schueler, 1987).

Infiltration trenches should be used with caution within the District's planning area. Many soils in the area are not suitable for infiltration, limiting the effectiveness of this structural measure. Freezing may hamper operation during the winter and early spring. Frequent maintenance may be required to remove solid material carried by stormwater into the trench (WDNR, 1994). More information on LID measures can be found in Appendix L.

SUMMARY

The purpose of Volume 1 of the District's Guidance Manual is to introduce the District's interested, non-technical stakeholders to SWM. The key ideas and information presented in this volume are:

- Reducing stormwater flooding and pollution are important parts of the District's broad mission.

- Stormwater runoff can be a pollution source because it carries potential pollutants from the land into creeks, rivers, ponds and lakes.

- The District's SWM Program has many stakeholders ranging from federal and state agencies and local communities to individual citizens. Interested citizens can, by individual and group actions, partner with the District or municipalities in advancing the SWM Program.

- The hydrological cycle is a given; we can choose to work with or against it.

- Heavy rainfalls are inevitable; pollution and flood damage are not inevitable. Application of available knowledge is the deciding factor.

- Watersheds are the framework used in planning and designing urban development that will minimize flooding and pollution problems.

- All urban stormwater system components must be designed and maintained to function in an integrated manner.

- Policies adopted by the District guide SWM decision-making in accordance with the District's mission. These policies stress partnering with stakeholders, a watershed approach, prevention over remediation, non-structural rather than structural management measures, multiple purpose over single purpose facilities, and protection of primary environmental corridors.

- SWM measures, non-structural and structural, are the "tools" used to prevent or remedy flooding and pollution problems. Structural SWM measures are typically costly and complex projects. In contrast, non-structural measures usually cost less and can be implemented faster. Non-structural measures are most effective when applied in a preventive mode to areas as they are being developed.

- The challenge to the District and its stakeholders is finding and implementing the optimal mix of non-structural and structural measures.

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