2A-1 General Information

A. Concept

This section sets forth concepts for stormwater management objectives. Urbanization significantly alters the hydrology of a watershed as residential and commercial development leads to an increase in impervious surfaces in the drainage area. As a result, the response of an urbanized watershed to precipitation is significantly different from the response of a natural watershed. Post-developed peak runoff is expected to exceed pre-developed runoff from a similar storm event. The most common effects are reduced infiltration and decreased travel time, which significantly increase peak discharge rates and runoff volumes. Factors influencing the amount (volume) of runoff include precipitation depth, the infiltrative capacity of soils, soil moisture, antecedent rainfall, cover type, the amount of impervious surfaces, and surface retention. Travel time is determined primarily by slope, length of flow path, depth of flow, and roughness of flow surfaces. A variety of inorganic, organic, and bacteriological pollutants are added to the surface runoff as it moves across the urban landscape. The greater portion of the annual pollutant loading is added to local streams from the smaller, high frequency (< 1-year) storms. To accommodate the higher rates and volumes of stormwater runoff in suburban and higher-density urban development, storm sewer conveyance systems are installed to provide efficient drainage of the landscape. Additional protection is provided through detention and storage structures to control release rates to downstream systems. Traditional design considerations have been the prevention of damage to the development site, streams, drainageways, streets, public and private property from flooding, and to the reduction of soil erosion. With the implementation of the stormwater NPDES Phase I and II regulations, stormwater runoff quality is now an additional management goal for some communities.

The purpose of this manual is to present planning and design guidelines for the management of stormwater quality *and* quantity in the urban environment. Jurisdictions with Phase I and Phase 2 NPDES stormwater permits may use alternative methods and design strategies for meeting post-construction requirements for stormwater quality improvement, including the information in this manual. While this manual includes most of the commonly-used stormwater management BMPs, it is not a comprehensive list. The material in this manual includes the hydrologic design and implementation of stormwater quality best management practices (BMPs) and traditional analysis and design of stormwater runoff conveyance for larger storm events to prevent flooding. Additional guidance is provided on improved site planning to reduce runoff volume through reduction of impervious area and increased emphasis on infiltration practices.

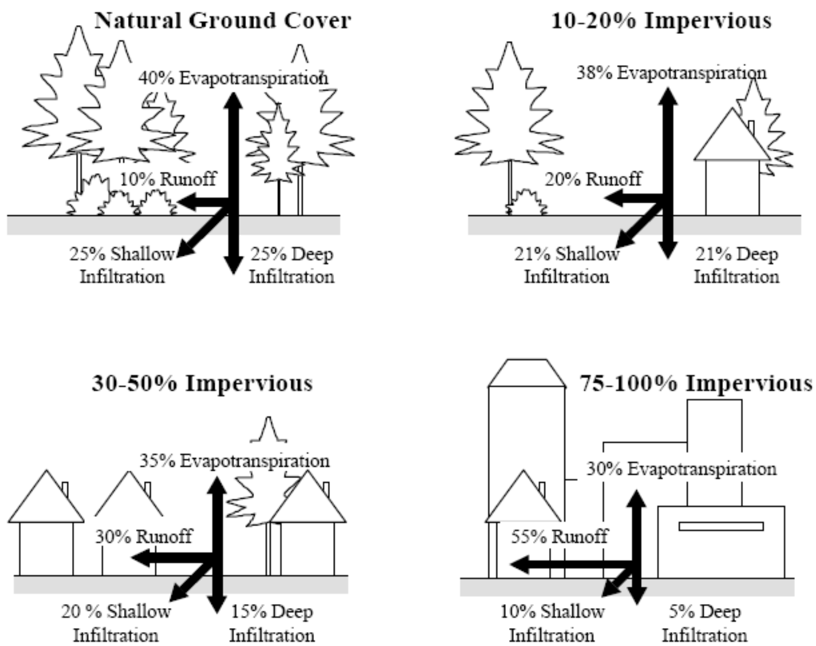
The traditional management goal for detention and storage has been to manage runoff from larger rainfall events, typically greater than the 5-year recurrence interval (RI). While traditional detention practices can reduce the peak runoff flows from urban development, the increase in runoff volume and frequency of peak flows is not reduced and very little improvement in stormwater quality is accomplished.

The Engineer is encouraged to use cost-effective designs that are hydrologically and hydraulically appropriate through the use of good engineering judgment.

B. Overview of stormwater discharges

Stormwater runoff from urbanized areas is generated from a number of sources including residential areas, commercial and industrial areas, roads, highways, and bridges. Essentially, any surface that does not have the capability to pond and infiltrate water will produce runoff during storm events. When a land area is altered from a natural, undeveloped ecosystem to an urbanized land use consisting of rooftops, streets, and parking lots, the hydrology of the system is significantly altered. Water which previously ponded on the forest floor or in depressional features in grasslands, infiltrated into the soil and converted to groundwater, utilized by plants and evaporated or transpired into the atmosphere is now converted directly into surface runoff. An important measure of the degree of urbanization in a watershed is the level of impervious surfaces. As the level of imperviousness increases in a watershed, more rainfall is converted to runoff. Figure 1 illustrates this transformation.

Figure 1: Effects of imperviousness on runoff and infiltration



Source: Adapted from Arnold and Gibbons, 1996

The traditional means of managing stormwater runoff in urban areas has been to construct a curb-and-gutter, catch basin, and storm drain network to transport the runoff volume quickly and efficiently away from the urbanized area and discharge the water to downstream surface waters. While some older and larger metropolitan areas may still have some areas served by combined sewers (storm and sanitary flow conveyance), most all communities maintain separate stormwater conveyance systems and wastewater collection systems. Several of the larger jurisdictions in Iowa still operate sections of combined sewers and these are now regulated under USEPA's Combined Sewer Overflow (CSO) regulations.

Historically, as urbanization occurred and storm drainage infrastructure systems developed in this country, the primary concern was to limit nuisance and potentially damaging flooding due to the large volumes of stormwater runoff that are generated. The environmental impacts of such practices were not considered. High flow rates of stormwater discharges can cause a number of impacts to receiving streams and may also increase the pollutant concentrations in stormwater runoff. As a result, streams that receive stormwater runoff frequently cannot convey the large volumes of water and increased flow velocity generated during runoff events, without significant degradation of the receiving stream. High velocity runoff can detach and transport significant amounts of suspended solids and associated pollutants such as nutrients and metals from the urban landscape. In addition, high flow rates in drainage channels and receiving waters can erode stream banks and channels, further increasing suspended solids concentrations in waters that receive stormwater discharges. To reduce the pollutant concentrations in runoff and receiving water impacts associated with high stormwater flow rates, best management practices (BMPs) that provide flow attenuation are frequently implemented. In areas undergoing new development or redevelopment, the most effective method of controlling impacts from stormwater discharges is to limit the amount of rainfall that is converted to runoff.

In addition to point sources such as municipal separate storm sewers and combined sewer overflows, stormwater runoff can enter receiving streams as a non-point source. Stormwater runoff from a variety of sources such as parking lots, highways, open land, agricultural land, residential areas, and commercial areas can enter waterways directly as sheet flow or as a series of diffuse, discrete flows. Due to the diffuse nature of many stormwater discharges, it is difficult to quantify the range of pollutant loadings to receiving streams that are attributable to stormwater discharges. It is much easier, however, to measure the increased stream flows during rainfall events that occur in urbanized areas and to document impacts to streams that receive stormwater runoff.

Awareness of the damaging effects stormwater runoff is causing to the water quality and aquatic life of receiving streams is a relatively recent development. Stormwater management traditionally was, and still is in many cases, a flood control, rather than a quality control, program. Local governments intending to improve the quality of their runoff-impacted streams are incorporating best management practices (BMPs) into their stormwater programs. The implementation of the stormwater NPDES Phase I and Phase 2 regulations requires regulated jurisdictions with Municipal Separate Stormwater Systems (MS4s) to manage for water quality for construction activities and for post-construction conditions. BMPs which reduce the volume of runoff discharged to receiving streams, such as minimizing directly connected impervious surfaces, providing on-site storage and infiltration, implementing stream buffers, and restoring riparian cover along urban streams can help prevent further degradation and result in improvements of streams which receive stormwater discharges. However, in many existing urbanized areas, the cost of infrastructure changes necessary to retrofit existing stormwater drainage systems with structural BMPs – to provide for stormwater quality as well as quantity control – can be expensive. In these cases, non-structural BMPs can be implemented to reduce pollutant sources and to reduce the transfer of urban pollutants to runoff before more expensive structural controls are instituted.

The climate of a region can have a significant impact on the quantity and quality of stormwater runoff. Factors such as the length of the antecedent dry periods between storms, the average rainfall intensity, the storm duration, and the amount of snowmelt present can have significant impacts on the characteristics of runoff from an area. In areas where there is a significant amount of atmospheric deposition of particulates, stormwater runoff can contain high concentrations of suspended solids, metals, and nutrients. High-intensity, short-duration rainfall events can generate significant loadings of suspended solids in stormwater runoff. Many site factors can influence the nature and constituents contained in stormwater runoff. Factors such as the soil types, slopes, land use patterns, and the amount of imperviousness of a watershed can greatly affect the quality and quantity of runoff that is produced from an area.

C. Pollutants in urban stormwater

Urbanized areas contribute significant quantities of pollutants that accumulate on streets, rooftops and other surfaces. During rainfall or snowmelt, these pollutants are mobilized and transported from the streets and rooftops into the storm drain system, where they are conveyed and ultimately discharged to waterways. Contaminants enter stormwater from a variety of sources in the urban landscape. Urban stormwater runoff has been the subject of intensive research since the inception of the Water Quality Act in 1965. There have been numerous studies conducted to characterize the nature of urban stormwater runoff and the performance of stormwater BMPs. Data sources include the "208 Studies," the area-wide waste treatment management plans conducted by states under section 208 of the 1972 Clean Water Act (CWA); EPA's Nationwide Urban Runoff Program (NURP); the U.S. Geological Survey (USGS) Urban Stormwater Database; and the Federal Highway Administration (FHWA) study of stormwater runoff loadings from highways. In addition to these federal sources, there is a great deal of information in the technical literature, as well as data collected by states, counties and municipalities. A more recent data source is stormwater monitoring data collected by municipalities regulated by the Phase I NPDES storm water regulations. As part of the Phase I permit application, regulated municipalities were required to collect data from five representative sites during a minimum of three storm events.

The most comprehensive study of urban runoff was NURP, conducted by the EPA between 1978 and 1983. NURP was conducted in order to examine the characteristics of urban runoff and similarities or differences between urban land uses, the extent to which urban runoff is a significant contributor to water quality problems nationwide, and the performance characteristics and effectiveness of management practices to control pollution loads from urban runoff (US EPA, 1983). Sampling was conducted for 28 NURP projects including 81 specific sites and more than 2,300 separate storm events. NURP focused on the following ten constituents:

- Total Suspended Solids (TSS)
- Biochemical Oxygen Demand (BOD)
- Chemical Oxygen Demand (COD)
- Total Phosphorus (TP)
- Soluble Phosphorus (SP)
- Total Kjeldahl Nitrogen (TKN)
- Nitrate + Nitrite (N)
- Total Copper (Cu)
- Total Lead (Pb)
- Total Zinc (Zn)

NURP examined both the soluble and the particulate fraction of pollutants, since the water quality impacts can depend greatly on the form that the contaminant is present. NURP also examined coliform bacteria and priority pollutants at a subset of sites. Median event mean concentrations (EMCs) for the ten general NURP pollutants for various urban land use categories are presented in Table 1.

Table 1: Median event mean concentrations for urban land uses

Pollutant	Units	Residential		Mixed		Commercial		Open/Non-urban	
		Median	COV*	Median	COV	Median	COV	Median	COV
BOD	mg/L	10	0.41	7.8	0.52	9.3	0.31	----	----
COD	mg/L	73	0.55	65	0.58	57	0.39	40	0.78
TSS	mg/L	101	0.96	67	1.14	69	0.85	70	2.92
Total Lead	μg/L	144	0.75	114	1.35	104	0.68	30	1.52
Total Copper	μg/L	33	0.99	27	1.32	29	0.81	----	----
Total Zinc	μg/L	135	0.84	154	0.78	226	1.07	195	0.66
Total Kjeldahl Nitrogen	μg/L	1900	0.73	1288	0.50	1179	0.43	965	1.00
Nitrate + Nitrite	μg/L	736	0.83	558	0.67	572	0.48	543	0.91
Total Phosphorous	μg/L	383	0.69	262	0.75	201	0.67	121	1.66
Soluble Phosphorous	μg/L	143	0.46	56	0.75	80	0.71	26	2.11
* COV: Coefficient of variation									

Source: Nationwide Urban Runoff Program (US EPA 1983)

Results from NURP indicate that there is not a significant difference in pollutant concentrations in runoff from different urban land use categories. There is a significant difference, however, in pollutant concentrations in runoff from urban sources than that produced from non-urban areas.

The pollutants that are found in urban stormwater runoff originate from a variety of sources. The major sources include contaminants from residential and commercial areas, industrial activities, construction, streets and parking lots, and atmospheric deposition. Contaminants commonly found in stormwater runoff and their likely sources are summarized in Table 2.

The concentrations of pollutants found in urban runoff are directly related to degree of development within the watershed. This trend, shown in Table 3, is a summary of typical pollutant loadings from different urban land uses. A comparison of the concentration of water quality parameters in urban runoff with the concentrations in domestic wastewater is shown in Table 4.

Table 2: Sources of contaminants in urban stormwater runoff

Contaminant	Contaminant Sources
Sediment and Floatables	Streets, lawns, driveways, roads, construction activities, atmospheric deposition, drainage channel erosion
Pesticides and Herbicides	Residential lawns and gardens, roadsides, utility right-of-ways, commercial and industrial landscaped areas, soil wash-off
Organic Materials	Residential lawns and gardens, commercial landscaping, animal wastes
Metals	Automobiles, bridges, atmospheric deposition, industrial areas, soil erosion, corroding metal surfaces, combustion processes
Oil and Grease/ Hydrocarbons	Roads, driveways, parking lots, vehicle maintenance areas, gas stations, illicit dumping to storm drains
Bacteria and Viruses	Lawns, roads, leaky sanitary sewer lines, sanitary sewer cross-connections, animal waste, septic systems
Nitrogen and Phosphorus	Lawn fertilizers, atmospheric deposition, automobile exhaust, soil erosion, animal waste, detergents

Table 3: Typical pollutant loadings from runoff by urban land use (lbs/acre-yr)

Land Use	TSS	TP	TKN	NH_3-N	NO_2+NO_3-N	BOD	COD	Pb	Zn	Cu
Commercial	1000	1.5	6.7	1.9	3.1	62	420	2.7	2.1	0.4
Parking Lot	400	0.7	5.1	2	2.9	47	270	0.8	0.8	0.04
HDR*	420	1	4.2	0.8	2	27	170	0.8	0.7	0.03
MDR**	190	0.5	2.5	0.5	1.4	13	72	0.2	0.2	0.14
LDR***	10	0.04	0.03	0.02	0.1	NA+	NA	0.04	0.04	0.01
Freeway	880	0.9	7.9	1.5	4.2	NA	NA	2.1	2.1	0.37
Industrial	860	1.3	3.8	0.2	1.3	NA	NA	7.3	7.3	0.5
Park	3	0.03	1.5	NA	0.3	NA	2	NA	NA	NA
Construction	6000	80	NA	NA	NA	NA	NA	NA	NA	NA

*HDR: High Density Residential
**MDR: Medium Density Residential
***LDR: Low Density Residential
+NA: Not available; insufficient data to characterize loadings

Source: Horner et al, 1994

Table 4: Comparison of water quality parameters in urban runoff with domestic wastewater

Parameter	Urban Runoff		Domestic Wastewater		
	Separate Sewers		Before treatment		After Secondary Treatment
	Range, mg/L	Typical, mg/L	Range, mg/L	Typical, mg/L	Typical, mg/L
COD	200-275	75	250-1,000	500	80
TSS	20-2,890	150	100-350	200	20
Total P	0.02-4.30	0.36	4-15	8	2
Total N	0.4-20.0	2	20-85	40	30
Lead	0.01-1.20	0.18	0.02-0.94	0.10	0.05
Copper	0.01-0.40	0.05	0.03-1.19	0.22	0.03
Zinc	0.01-2.90	0.02	0.02-7.68	0.28	0.08
Fecal Coliform per 100 mL	400-50,000		10^6 - 10^8		200

Source: Bastian, 1997

D. Management of stormwater quality and quantity

By utilizing site design techniques that incorporate on-site storage and infiltration and reduce the amounts of directly connected impervious surfaces, the amount of runoff generated from a site can be significantly reduced. This can reduce the necessity for traditional structural BMPs to manage runoff from newly developed areas. There are a number of practices that can be used to promote on-site storage and infiltration and to limit the amount of impervious surfaces that are generated. However, the use of on-site infiltration can be limited in certain areas due to factors such as slope, depth to the water table, and geologic conditions.

1. **Site design features** such as providing rain barrels, dry wells or infiltration trenches to capture rooftop and driveway runoff, maintaining open space, preserving stream buffers and riparian corridors, using porous pavement systems for parking lots and driveways, and using grassed filter strips and vegetated swales in place of traditional curb-and-gutter type drainage systems can greatly reduce the amount of stormwater generated from a site and the associated impacts.

2. **Street construction features** such as placing sidewalks on only one side of the street, limiting street widths, reducing frontage requirements and eliminating or reducing the radius of cul-de-sacs also have the potential to significantly reduce the amount of impervious surfaces and therefore the amount of rainfall that is converted to runoff.

3. **Construction practices** such as minimizing disturbance of soils and avoiding compaction of lawns and greenways with construction equipment can help to maintain the infiltrative capacity of soils.

There are several guides that contain useful information regarding development practices that can limit the impacts associated with stormwater runoff (Delaware DNREC, 1997; US EPA, 1996b; Center for Watershed Protection, 1998). A general list of additional sources of BMP design information can be found at www.iowasudas.org/stormwater/index.cfm.

In areas that are already developed, flow control can be more complicated. Since a drainage infrastructure already exists, retrofitting these systems to provide flow control can be prohibitively expensive. Regional stormwater management systems can be used to manage runoff in these areas, but space considerations and high capital costs can limit their application.

Depending on site-specific constraints, however, there are a number of practices that can be incorporated on-site to reduce runoff volumes from these areas. Down spouts can be disconnected from the storm drain system and this rainfall can instead be collected and stored on a property in rain barrels to be used for watering lawns and landscaping during periods between events.

Infiltration and retention practices such as bioretention areas and infiltration trenches can be constructed to capture runoff from rooftops, lawns, and driveways and reduce the volume of runoff discharged to storm sewers. Alternatives such as using vegetated swales in place of traditional curb-and-gutter piped conveyance systems can be considered to provide treatment and infiltration of small storm runoff. Stormwater from commercial areas and golf courses can be collected and stored in ponds and subsequently used for irrigation.

Stormwater reuse can help to maintain a more natural, pre-development hydrologic balance in the watershed (Livingston et al, 1998). Parking lots can also be used as short-term storage areas for ponded stormwater, and bioretention facilities placed around the perimeter of parking lots can be used to infiltrate this water volume.

In order to reduce the impacts to receiving waters from the high concentrations of pollutants contained in the runoff, BMPs can be implemented to remove these pollutants. Where the generation of runoff cannot be avoided, end-of-pipe structural BMPs may be implemented to decrease the impacts of stormwater discharges to receiving streams. However, BMPs are limited in their ability to control impacts, and frequently cause secondary impacts such as increased temperatures of discharges to receiving streams. BMPs that can be designed to provide significant flow attenuation include grassed swales, vegetated filter strips, detention and retention basins, wetland basins, and wetland channels and swales. These BMPs can also provide the added benefit of removing pollutants such as suspended solids and associated nutrients and metals from stormwater runoff.

The environmental aspects of stormwater quantity control must be carefully balanced against the hazard and nuisance effects of flooding. Large or intense storm events or rapid snowmelt can produce significant quantities of runoff from urban areas with high levels of imperviousness. This runoff must be rapidly transported from urbanized areas in order to prevent loss of life and property due to flooding of streets, residences, and businesses. This is frequently accomplished by replacing natural drainage paths in the watershed with paved gutters, storm sewers, or other artificial means of drainage. These drainage systems can convey runoff at a faster rate than natural drainage paths, allowing rapid transport of runoff away from areas where flooding is likely to occur. However, as large quantities of runoff are conveyed rapidly from the urban landscape and discharged to receiving streams, downstream areas can flood. Following urbanization, large volumes of runoff can be produced from even small storm events due to the high amounts of impervious surfaces. The increased volume and rate of runoff to local urban streams often occurs much more frequently following urbanization. Therefore, design of stormwater drainage systems must always balance flood protection with ecological concerns.

In highly urbanized and densely populated cities, little opportunity exists for retrofitting storm drainage systems with BMPs to provide water quantity control due to flooding considerations. The large area of impervious surfaces in heavily urbanized areas produce large quantities of runoff. Rapid conveyance by the storm drain system is frequently the only option that exists in order to prevent flooding of yards, streets, and basements. In these areas, the most appropriate BMPs are those that limit the generation of pollutants or remove pollutants from the urban landscape. With this principle in mind, a unique opportunity exists in newly developing areas or in more sparsely populated suburban areas to use BMPs that control runoff at the point of generation, instead of trying to manage it at the point of discharge to the receiving stream.

When rainfall is managed as a *resource* instead of as a waste requiring treatment, future problems with quantity control may be avoidable. When rainfall is managed at the site level by promoting the concepts of conservation design and by providing on-site storage, infiltration, and usage of rainfall for irrigation of the urban landscape, the need for traditional curb-and-gutter storm drainage system can be reduced. The need for constructing and maintaining capital-, land-, and maintenance-intensive regional BMPs to manage large flows from developed watersheds may be reduced to some measurable extent by distributed, site-level BMPs that provide a water quality benefit as well as reducing the overall volume of downstream runoff.

It is important to note that there will always be a need in the urban environment to provide systems to convey the runoff from the larger, low frequency storm events to protect homes, businesses, and local infrastructure from damage due to flooding. Nuisance flooding of downstream areas can also be limited by reducing the overall volume of water draining from a watershed. Limiting the discharge of large volumes of stormwater to urban streams can help to prevent the degradation of these streams to the point of being non-supporting of a designated use. Comprehensive urban stormwater planning and design should include management of runoff from the entire range of storm events to improve water quality and prevent damage from flooding.

E. Permit requirement overview

Figure 2: NPDES stormwater permit requirements

NPDES Stormwater Permit Requirements

Phase I areas (large urban areas and major industries)

- Under permit since early 1990s
- Individual municipal permits all include a program element for new development or "post-construction" BMPs

Phase II areas (small urban areas and additional industries)

- Under Iowa Individual MS4 Permit since early 2003
- Permit includes new development requirements

New development BMPs are required under NPDES permits shown in Figure 2. The intent of incorporating BMPs in new private development and public capital projects is to prevent any net detrimental change in runoff quantity or quality resulting from new development and redevelopment. Typical permit requirements that are now being included in all Phase I MS4 permits and are incorporated in the Phase II Iowa General Permits include:

- Specific thresholds for "priority projects" that must include both source and treatment control BMPs in the completed projects (typical project thresholds are discussed in Section 2A-3)
- A list of source control (both non-structural and structural) BMPs and treatment control BMPs to be included or considered
- Specific water quality design volume and/or water quality design flow rate for treatment control BMPs
- A requirement for flow control BMPs when there is potential for downstream erosion
- Adopt a standard model or template for identifying and documenting selected BMPs, including a plan for long-term operations and maintenance of BMPs

Permittees might also include the use of regional or watershed-based programs as alternatives to incorporating all of the BMPs to be on-site or project-based. Under this approach, programs would be developed and adopted that address specific water quality and pollutant concerns, achieve at least equivalent pollutant reduction as would have been required for all new development and redevelopment projects in the watershed through project-based BMPs, and can provide additional benefits by reducing impacts from existing developed areas. Where regional or watershed programs are developed, there will typically need to be a partnership between the planning agencies or permittees and the development community to clearly define the approach for satisfying the permit requirements and evaluating choices between project-based and regional BMPs. State and federal permit requirements are discussed in more detail in Section 2A-3.