Dane County Water Quality Plan

Appendix D Update

Urban Nonpoint Source Analysis

Prepared by the staff of the Capital Area Regional Planning Commission

June 2011

Dane County Water Quality Plan

Appendix D

Urban Nonpoint Source Analysis

June 2011

Capital Area Regional Planning Commission

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CARPC Resolution No. 2011-9

Amending the Dane County Water Quality Plan by Updating Appendix D: Urban Non-Point Source Analysis

WHEREAS, in March 1975, Dane County was designated by the Governor of Wisconsin as an area having substantial and complex water quality control problems, and certified such designation to the federal Environmental Protection Agency; and

WHEREAS, the Capital Area Regional Planning Commission ("CARPC") is contracted with the Wisconsin Department of Natural Resources (WDNR) to conduct areawide water quality management planning in the Dane County region; and

WHEREAS, the *Dane County Water Quality Plan* is the approved areawide water quality management plan for the Dane County region; and

WHEREAS, CARPC has prepared a draft updated Appendix D to the *Dane County Water Quality Plan*, entitled "Urban Non-Point Source Analysis", which has incorporated review comments by the Commission's Technical Advisory Committee including the WDNR; and

WHEREAS, CARPC has made the draft Appendix D update available to all local units of government, as well as other interested parties, in Dane County since March 11, 2011 and no comments have been received; and

WHEREAS, a public hearing was held at the CARPC meeting of May 12, 2011, to take testimony on the draft Appendix D update and any pertinent comments were incorporated into the report.

NOW, THEREFORE, BE IT RESOLVED that the Capital Area Regional Planning Commission, in accordance with Sec. 66.0309, Wis. Stats, and Sec. 208 of P.L. 92-500, hereby adopts the updated Appendix D: Urban Non-Point Source Analysis of the Dane County Water Quality Plan, including all of its recommendations.

June 9, 2011
Date Adopted

Larry Palm, Vice-Chairperson

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Introduction

The hydrologic effects of urban land use have been studied since the late 1960s (Leopold, 1968). The last *Urban Nonpoint Source Analysis* (Technical Appendix D to the *Dane County Water Quality Plan*) was prepared by the Dane County Regional Planning Commission in 1979. There has been a significant amount of research since that time which has contributed to an increased understanding and regulation of urban nonpoint source pollution. Summary Plan updates to the *Dane County Water Quality Plan* in 1995 and 2004, have provided brief overviews of the evolving management of urban nonpoint source pollution. The purpose of this update to the Urban Nonpoint Source Analysis is to bring the Dane County Water Quality Plan up to date with an in depth assessment and analysis of the current state of urban nonpoint source pollution issues and management practices in our region. This report is not intended to serve as a design manual for best management practices (BMPs), but it does provide useful references to some of the many guidance documents that are available for the design of BMPs.

The Wisconsin Department of Natural Resources 2010 Impaired Waters List includes twenty-seven impaired waters in our region. Four of these waters (Badfish Creek, Lake Mendota, Lake Monona, and the Wisconsin River) are polluted with PCBs. This is historical contamination and not a result of current practices. Seven of the listed resources are urban beaches (Bernies, Brittingham, Esther Park, James Madison, Olbrich Park, and Vilas Park) polluted by E. Coli. Urban stormwater runoff is a likely contributor to this impairment. Sediment and suspended solids polluted fifteen of the impaired water resources. In about half of these cases phosphorous, E. Coli, metals, or biological oxygen demand (BOD) also polluted the resource. Of the fifteen resources polluted by sediment and suspended solids, the Dane County Waterbody Classification Project classified nine (Dorn Creek, German Valley Branch, Halfway Prairie Creek, Maunesha River, Mud Creek, Pleasant Valley Branch, Stony Brook, Vermont Creek, and Wendt Creek) as rural waters. Agricultural runoff is the most likely source of impairment in these cases. Two (Nine Springs Creek and Starkweather Creek) were classified as urban waters. Urban runoff is the most likely source of impairment in these cases. Four (Lake Koshkonong, Pheasant Branch, Token Creek, and the Lower Yahara River) were classified as developing waters. Agricultural runoff and urban runoff are both likely sources of the impairment in these cases. Wingra Creek is impaired by chronic aquatic toxicity from an unknown pollutant. It is classified as an urban water body, and urban runoff is the most likely source of impairment.

This report provides an overview of urban nonpoint source pollution, including the hydrology and the effects of urban nonpoint source pollution. It summarizes relevant existing federal, state, and local regulations, available models, and current monitoring of urban nonpoint source pollution in the region. Management considerations and recommendations are also discussed.

Summary of Recommendations

This summary of recommendations includes any new recommendations made in this report as well as all of the urban nonpoint source recommendations from the 1995 and 2004 Summary Plan updates to the Dane County Water Quality Plan that have been reaffirmed. Some of the recommendations have been revised or strengthened from earlier recommendations, based on the current state of knowledge of urban nonpoint source pollution. The history refers to any related recommendations as numbered in previously approved summary plans. Most of the previous recommendations have been implemented to some extent.

1. CARPC should collaborate with management agencies to develop watershed level plans that assess the resources in the watershed, identify the range of potential opportunities for protecting and enhancing the resources, and set goals for improvement. Priority should be given to sensitive (i.e., Badger Mill Creek, Black Earth Creek, Token Creek and Sugar River) watersheds and/or currently impaired watersheds (History: Revised, 2004-U-5, 1995-U-8).

2. Management agencies should encourage stormwater management systems that emphasize low impact development and green infrastructure (History: Revised, 2004-U-8, 1995-U-6).

3. Management agencies should continue to cooperate in sponsoring field tests of the feasibility and effectiveness of innovative stormwater management ideas and technologies (History: 2004-U-11, 1995-U-10).

4. Management agencies should continue to evaluate and promote potential approaches for improving sediment and phosphorus removal in the design, operation, and maintenance of stormwater management systems (History: 2004-U-10, 1995-U-11).

5. Management agencies should continue to encourage stormwater management systems that minimize the potential for nutrients or toxic materials being washed or discharged into surface waters, with an emphasis on source control (History: 2004-U-12, 1995-U-12).

6. Municipalities should continue to conduct street sweeping with regenerative-air or vacuum-assist sweepers for the control of litter and floatables, particularly in early spring and late autumn (History: Revised, 2004-U-17, 1995-U-5).

7. Management agencies should continue to conduct public education and information programs regarding pollution prevention and source control on an annual basis (History: 2004-U-16, 1995-U-3).

8. Management agencies should collaboratively prepare a chloride management plan for the region which continues to expand efforts to reduce ground and surface water impacts associated with salt use, including identifying alternative materials and approaches (History: Strengthened, 2004-U-18, 1995-U-13).

9. Dane County and all municipalities should adopt the climate change adaption recommendations of the WICCI Stormwater Working Group, particularly they should update their stormwater ordinances to incorporate more current official rainfall data as it becomes available. CARPC should collaborate with other management agencies to prepare a technical paper to examine the issue of climate change as it relates to our region (New Recommendation).

10. Dane County and all municipalities should update their stormwater ordinances to include at a minimum, a performance standard of maintaining pre-development peak runoff rates for the 1-, 2-, 10-, and 100-year 24-hours design storms (History: Strengthened, 2004-U-1).

11. Dane County and all municipalities should update their stormwater ordinances to include at a minimum, a performance standard of maintaining 90% of the pre-development stay-on volume on an average annual basis for all land uses (History: Strengthened, 2004-U-1 and 2004-U-9).
12. Dane County and all municipalities should update their stormwater ordinances to include a performance standard of maintaining pre-development groundwater recharge rates based on the rates in the Wisconsin Geological and Natural History Survey's 2009 report, Groundwater Recharge in Dane County, Wisconsin, Estimated by a GIS Based Water-Balance Model or future updates, or by a site specific analysis (History: Strengthened, 2004-U-2).
13. Management agencies should put into practice adaptive management strategies that include monitoring of the resources, monitoring of the maintenance and performance of the BMPs, and implementation of corrective actions as needed (New Recommendation).
14. CARPC should collaborate with the Dane County Lakes and Watershed Commission to undertake a legal and institutional analysis of workable approaches to BMP monitoring and enforcement (New Recommendation).
15. CARPC should collaborate with other management agencies to ensure that these research needs identified by the Commission's Technical Advisory Committee, for the future evaluation of the volume control issue, are carried out in a timely manner (New Recommendation).
16. Management agencies should continue to promote inter-agency review to streamline permitting while ensuring protection of the natural resources (History: 2004-U-13).
17. Urban management agencies should enact and enforce leaf, yard, and garden debris storage and disposal ordinances in urban areas, including leaf pick-up in the fall, with emphasis on keeping leaves and yard waste off of streets and paved surfaces (History: 2004-U-14, 1995-U-1, U-4).
18. Urban management agencies should include provisions in building codes and ordinances to require that, wherever feasible, drainage from roofs, driveways, and parking lots be directed toward grassed or vegetated areas, rather than paved areas or storm sewers (History: 2004-U-15, 1995-U-2).
19. Designated municipalities should implement the state NR 216, NR 151, and federal Phase II stormwater regulations along with the existing Erosion Control and Stormwater Management Ordinance (Chap. 14). Other municipalities should consider developing consistent programs, ordinances, and requirements (History: 2004-U-3, 1995-U-7).
20. A coordinated stormwater management plan should be developed for all communities in the municipal NR 216 stormwater permit area (History: 2004-U-6, 1995-U-9).
21. Management agencies should apply for grant funding to develop stormwater management plans and install best management practices that control urban stormwater impacts (History: Revised, 2004-U-7).

Overview of Urban Nonpoint Source Pollution

Hydrology

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

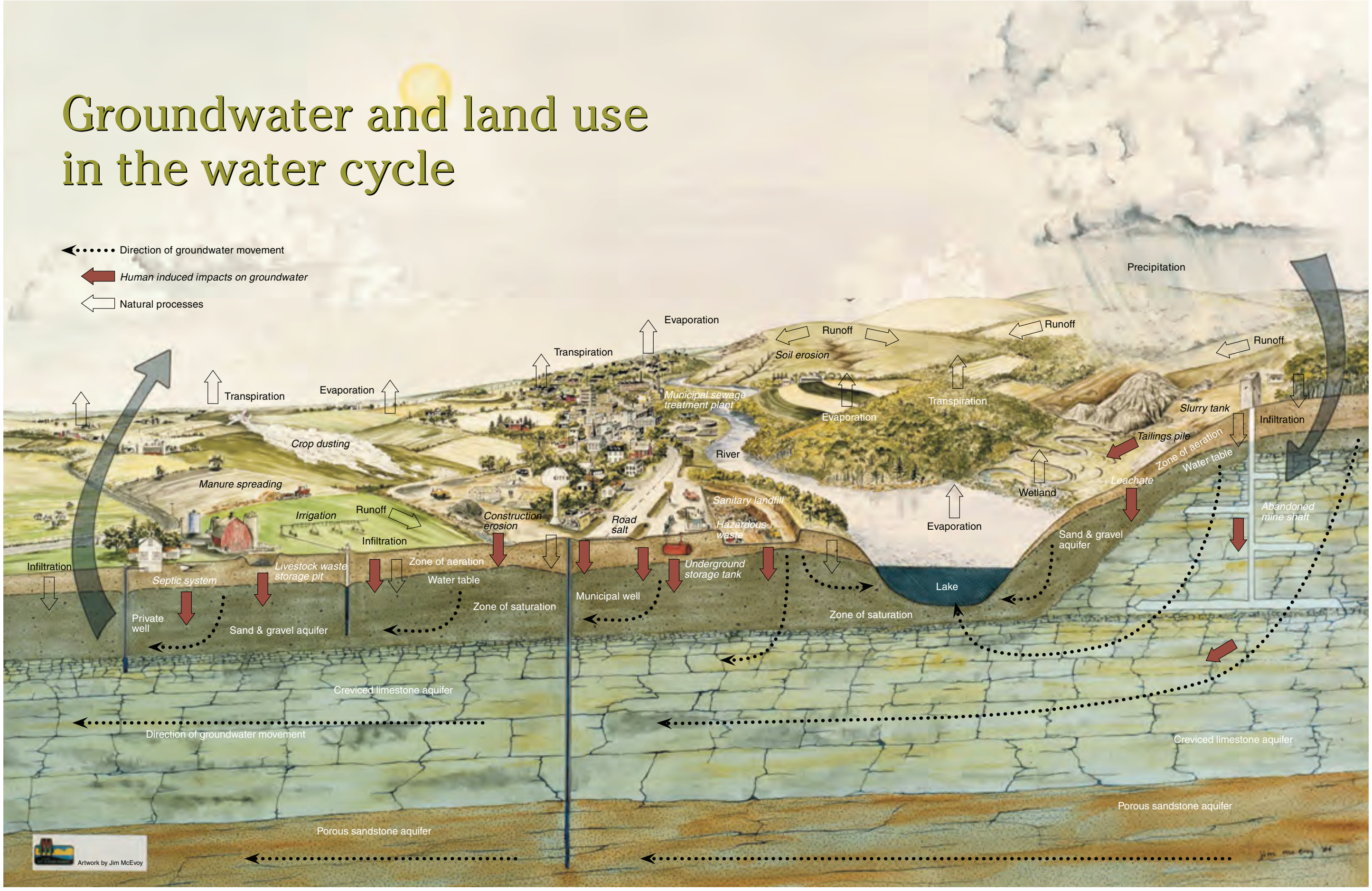
According to the Wisconsin State Climatology Office, the average annual precipitation in the Madison area from 1971 to 2000 has been 32.95 inches. Official data for the period 1981 to 2010 will be available by the end of 2011. The average monthly precipitation in our area varies seasonally as shown in **Figure 2**. Historically, 37% of the annual rainfall occurs between June and August and 67% occurs between April and September.

Figure 3 shows the rainfall records for over 50 years at the Dane County Airport from August 1948 to December 2010. Over 98% of these events have been less than 2 inches of rainfall. These more frequent storms are responsible for the majority of the annual runoff volume and pollutant loads. The largest, infrequent events are responsible for nuisance and catastrophic flooding.

The rainfall depth-frequency-duration data most commonly used for modeling runoff rates in Dane County and the State of Wisconsin is from Technical Paper No. 40: Rainfall Frequency Atlas of the United States (Hershfield, 1961). The report includes rainfall durations from 30 minutes to 24 hours and return periods from 1 to 100 years. It is derived from weather station data collected through 1958. The National Oceanic and Atmospheric Administration's National Weather Service is in the process of updating the rainfall frequency data for Midwestern states, including Wisconsin. The result of this work is scheduled for publication in May 2012. Another source for rainfall data in Dane County is Illinois State Water Survey Bulletin 71 (Huff and Angel, 1992). This report presents the results of an analysis of 275 gauge records in nine midwestern states including Wisconsin. For the Dane County region, the rainfall depths for the 24-hour duration storm events in Bulletin 71 are less than those in Technical Paper 40 for storms with a recurrence interval of less than 10-years and more than those in Technical Paper 40 for storms with a recurrence interval of more than the 10-years.

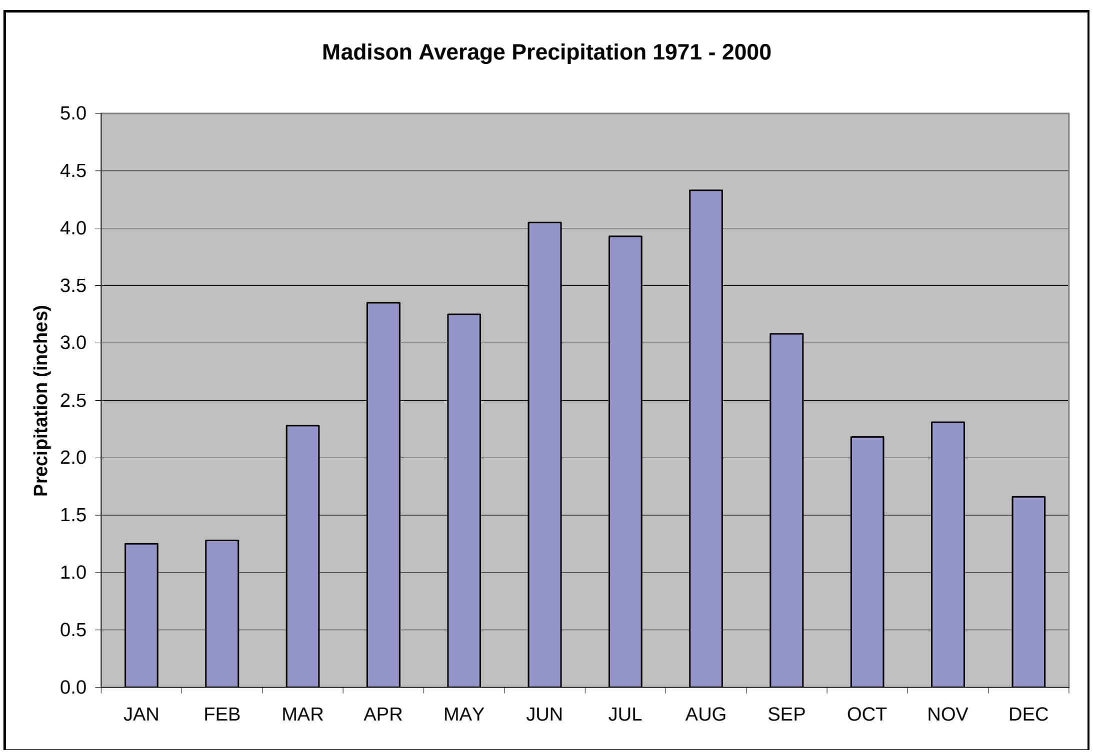
Table 1 compares the rainfall depths in Technical Paper 40 to those of Bulletin 71. Most municipal stormwater ordinances in Dane County use the rainfall depths from Technical Paper 40 as their design storms. The City of Middleton stormwater ordinance is an exception. It requires the use of the higher rainfall depth data from these two sources.

Figure 1: The Hydrologic Cycle



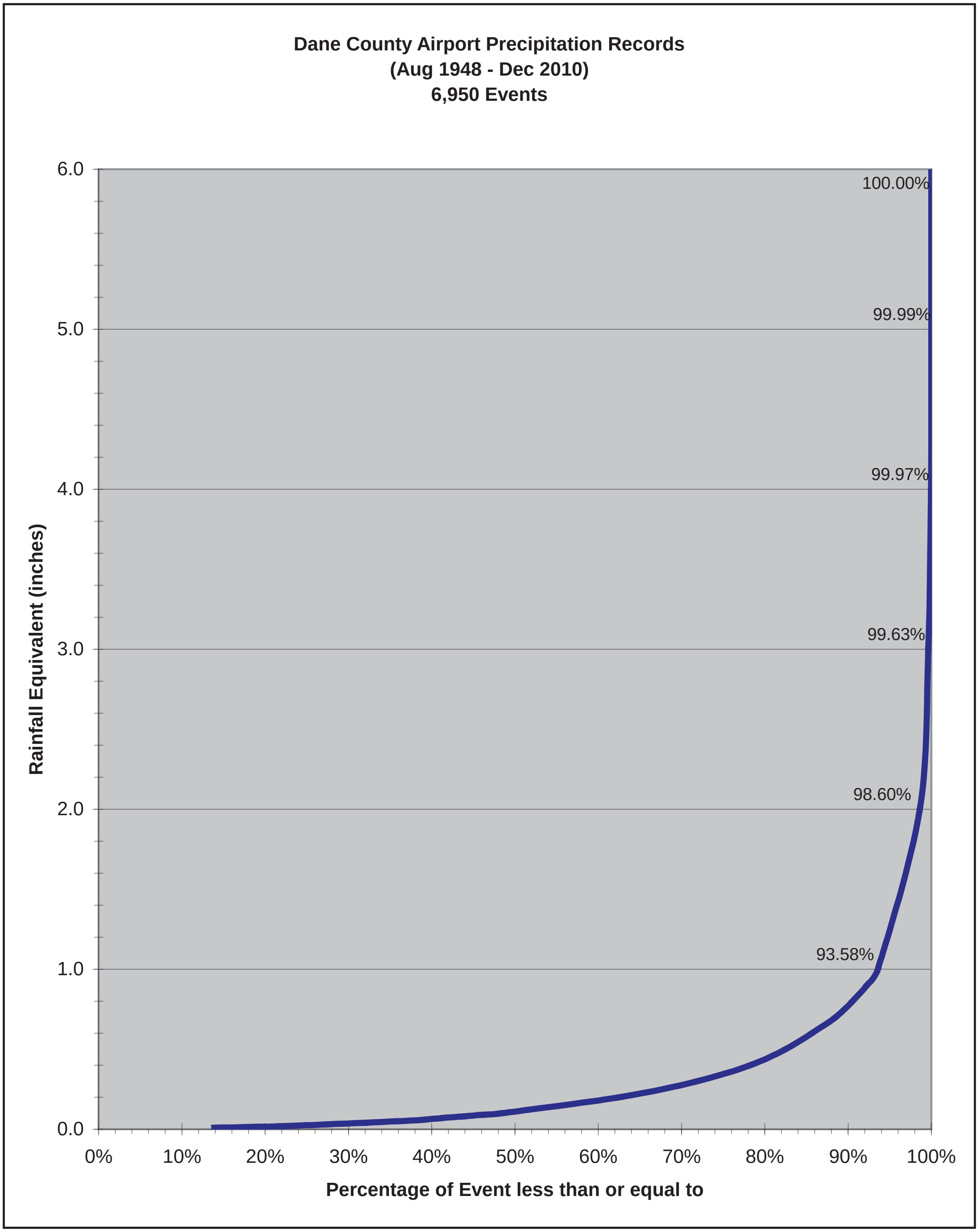
Source: Wisconsin Department of Natural Resources

Figure 2: Average Monthly Precipitation in Madison



Data source: Wisconsin State Climatology Office

Figure 3: Dane County Airport Precipitation Records



Data source: WinSLAMM & Wisconsin State Climatology Office

Table 1:
Rainfall Depths for Dane County
(24-hour duration)

Frequency	Rainfall Depth	
	Technical Paper 40	Bulletin 71
1 year	2.5 inches	2.25 inches
2 years	2.9 inches	2.78 inches
5 years	3.6 inches	3.53 inches
10 years	4.2 inches	4.20 inches
25 years	4.8 inches	5.18 inches
50 years	5.3 inches	6.06 inches
100 years	6.0 inches	7.06 inches

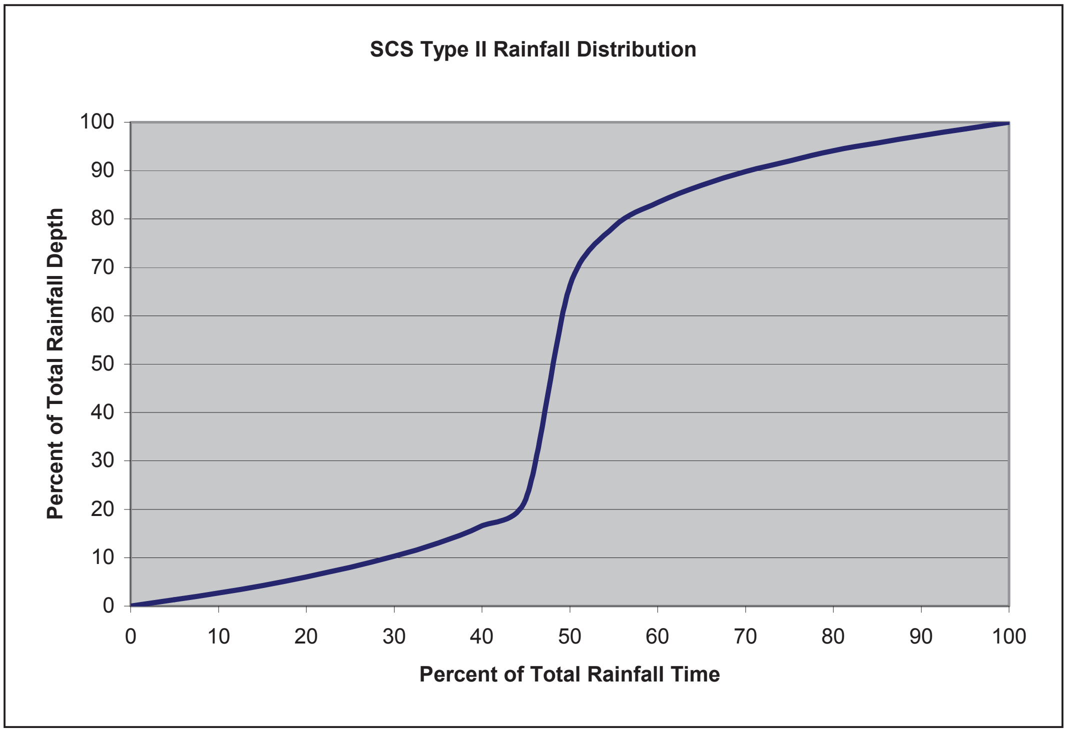
The time distribution of rainfall is necessary to develop The time distribution of rainfall is necessary to develop design storms that can be used in hydrologic models that will provide flows and volumes for sizing stormwater management facilities. In 1964, the United States Department of Agriculture Soil Conservation Service (SCS, now the Natural Resources Conservation Service or NRCS) published several nested, non-uniform, distributions for use in various parts of the United States. The Type II distribution was proposed for most of the United States, including all of Wisconsin. The objective of this distribution was to incorporate a range of storm durations into a single 24-hour event to permit obtaining a critical duration analysis in a single model run. The SCS Type II rainfall distribution is shown in Figure 4. The pattern is nearly symmetrical with the highest intensity during the twelfth hour.

Over the years, the SCS distributions have become widely used as standards for design storms throughout the United States. Experience with this distribution has shown that peak flows based on SCS Type II are higher than flows developed by other methods in many instances (SWRPC, 2000). This is because the distribution assumes a very intense storm. Overestimating post development peak flow rates is conservative from an infrastructure design standpoint. However it is likely that this also overestimates pre-development peak flow rates. This is not conservative because pre-development peak flow rates are used to determine the allowable release rates of detention basin outlet structures.

Camp, Dresser, and McKee conducted an analysis of the time distributions of 24-hour storms recorded at five sites in southeastern and south central Wisconsin for the Southeast Regional Planning Commission (SWRPC, 2000). The cumulative rainfall distributions of 93 storms selected for this analysis are shown in Figure 5. Each storm contained at least 0.8 inches of rain and was normalized by dividing by the total rainfall. The distributions indicate a random variation of the cumulative distribution of real rainfall. The rainfall pattern varies across a wide range with a strong central tendency. Real distributions of rainfall within a storm vary over a wide range of possible patterns. Rainfall distributions appear to have a strong central tendency that is also nearly symmetrical. The central or median distribution of all real storms is a uniform distribution.

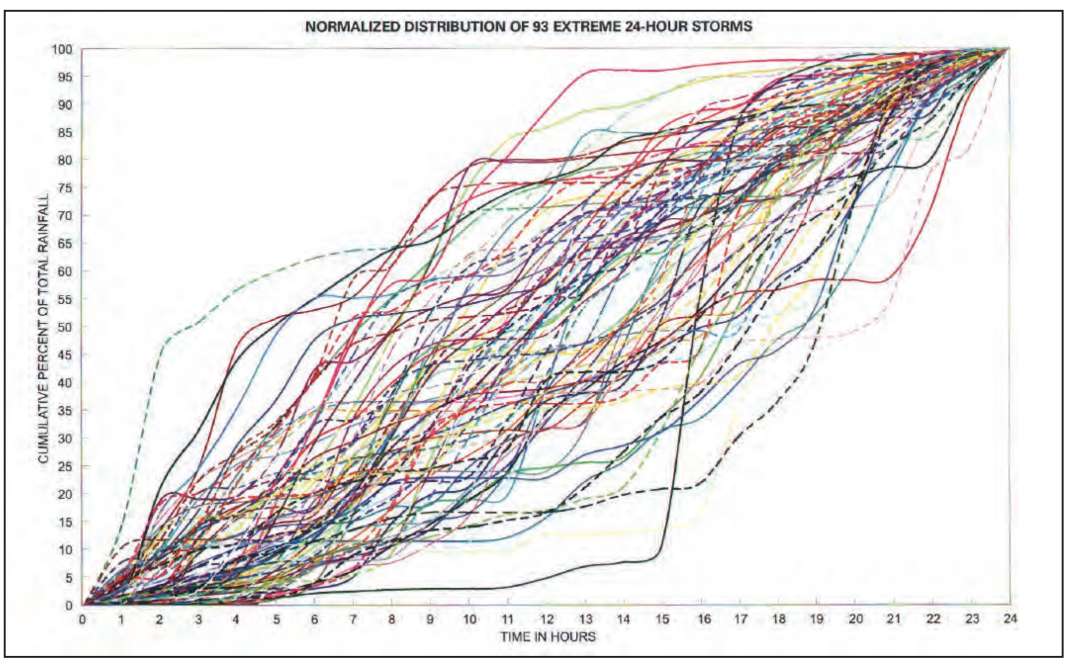
The rainfall data required by the Wisconsin Administrative Code to be used for modeling runoff volumes in Dane County is the 1981 annual rainfall series for Madison, shown in Figure 6. In 1981 there were 109 rain events, totaling 32.10 inches for the year. The state and county regulations require that runoff volumes be modeled without winter conditions. Average annual rainfall means measured precipitation in Madison, Wisconsin, between March 12 and December 2, 1981. The total rainfall for this time period is 28.81 inches and the largest storm was 2.59 inches. The durations of the 1981 rainfall events are summarized in Figure 7. A majority of the rainfall events had a duration of 6 hours or less.

Figure 4: SCS Type II Rainfall Distribution



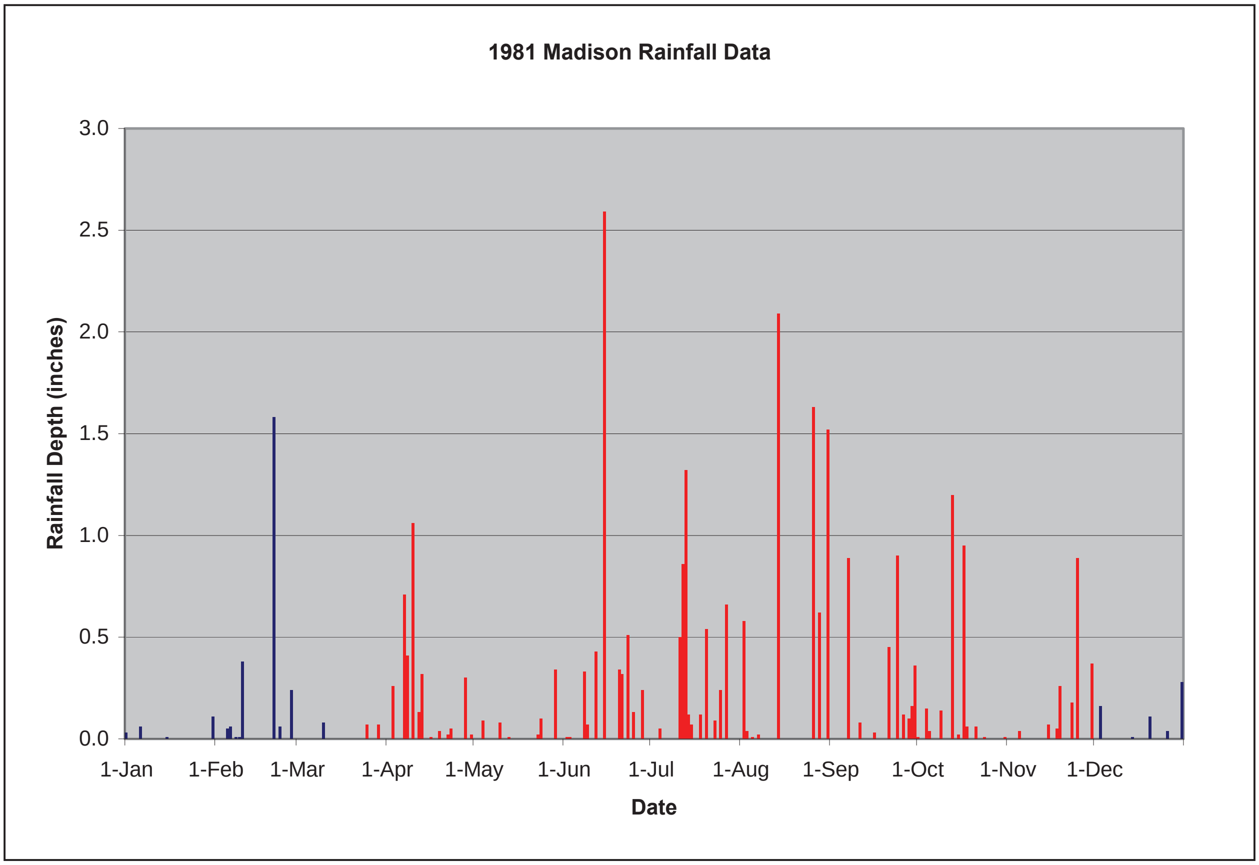
Data source: HydroCAD

Figure 5: Distribution of Recorded Rainfalls in Southern WI



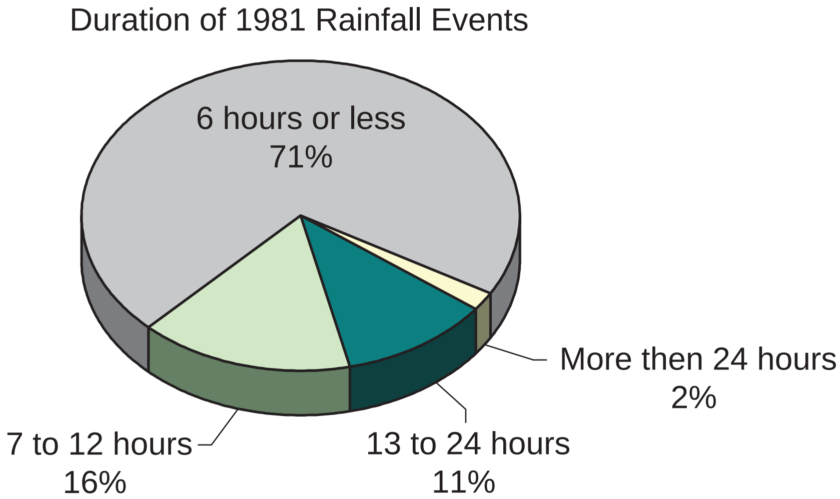
Source: Southeastern Wisconsin Regional Planning Commission (2000)

Figure 6: Average Annual Rainfall Series



Data source: WinSLAMM

Figure 7: Rainfall Durations



Data source: WinSLAMM

Hydrologic Soil Groups

Hydrologic groups are defined as groups of soils having similar runoff potential under similar storm and cover conditions. Soil properties that influence runoff potential are those that influence the minimum rate of infiltration for a bare soil after prolonged wetting and when not frozen. These properties are depth to a seasonally high water table, intake rate and permeability after prolonged wetting, and depth to a very slowly permeable layer. The influence of ground cover is treated independently. There are four hydrologic soil groups; A, B, C, and D.

Hydrologic group A soils have low runoff potential. These soils have a high infiltration rate even when thoroughly wetted. They chiefly consist of deep, well drained to excessively drained sands or gravels. They also have a high rate of water transmission (greater than 0.3 in / hr).

Hydrologic group B soils have a moderate infiltration rate when thoroughly wetted. They chiefly are moderately deep to deep, moderately well drained to well drained soils that have moderately fine to moderately coarse textures. They also have a moderate rate of water transmission (0.15 to 0.3 in / hr).

Hydrologic group C soils have a slow infiltration rate when thoroughly wetted. They chiefly have a layer that impedes downward movement of water or have moderately fine to fine texture. They also have a slow rate of water transmission (0.05 to 0.15 in / hr).

Hydrologic group D soils have a high runoff potential. These soils have a very slow infiltration rate when thoroughly wetted. They chiefly consist of clay soils that have a

high swelling potential, soils that have a permanent high water table, soils that have a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. They have a very slow rate of water transmission (0 to 0.05 in / hr).

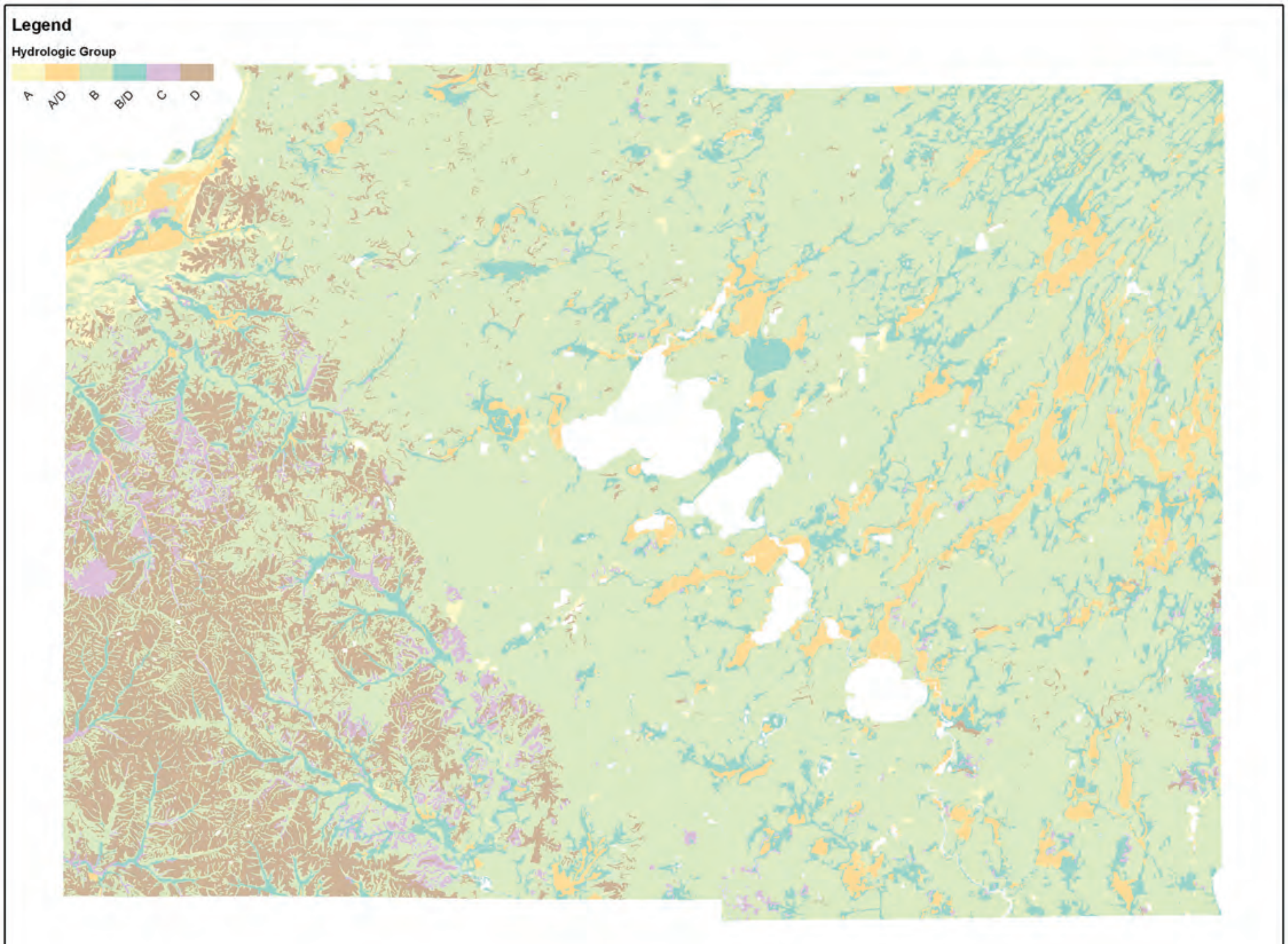
The majority of the land in Dane County is hydrologic group B soils, as shown in Table 2 and illustrated in Figure 8. Soils with a dual classification (i.e. A/D or B/D) belong to the first hydrologic group when drained and the latter hydrologic group when undrained.

Table 2 Dane County Soils

Hydrologic Soil Group	Percent of Land Area[1]
A	1.25
A/D	5.35
B	66.47
B/D	9.43
C	2.31
D	11.66

1 An additional 3.53% of the land area is water bodies, which do not have a hydrologic soil group.

Figure 8: Hydrologic Soil Groups in Dane County

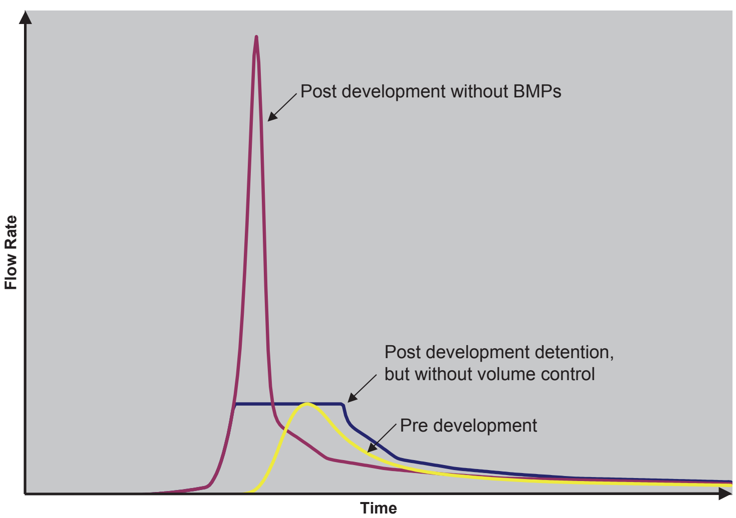


Data source: Dane County Land Information Office

The Effects of Urban Nonpoint Source Pollution

It is widely understood that land development without effective Best Management Practices (BMPs) results in changes to the rainfall-runoff process. Replacing vegetation with impervious surfaces (i.e., asphalt or concrete pavement and rooftops) and altering the natural drainage system (i.e., replacing natural swales with storm sewer) results in increased runoff rates, longer runoff durations, increased runoff volumes, and decreased infiltration (Shaver et. al., 2007). Figure 9 illustrates many of these changes. Increased runoff rates are shown by a higher discharge in the post development runoff curve. Longer runoff duration is shown by more time with a discharge in the post development runoff curve. A larger area under the post development runoff curve shows increased runoff volume.

Figure 9: Effect of Development on Runoff Flow Rates and Volumes



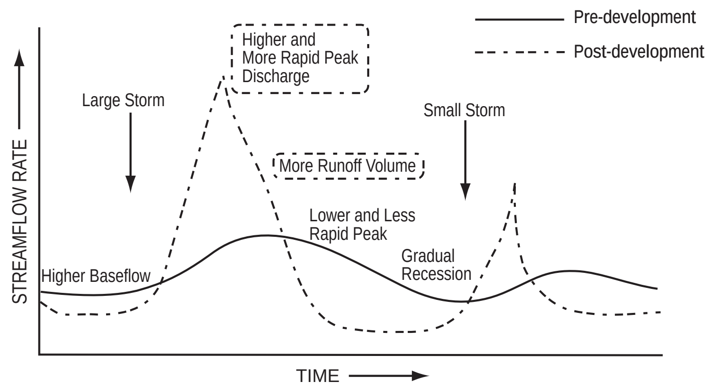
Source: Capital Area RPC, generated with HydroCAD

Development can also cause substantial soil erosion and off-site siltation during construction activities (Owens *et al.*, 2000). Research (Bledsoe and Watson, 2001; Booth and Jackson, 1997; Lathrop et al., 2005; MacRae, 1996; Shaver et. al., 2007) has well documented that without effective mitigation measures, the potential impacts of development on receiving water bodies can include:

- Flashier stream flows (sudden higher peaks)
- Increased frequency and duration of bankful flows
- Reduced groundwater recharge and stream base flow
- Greater fluctuations in wetland water levels
- Increased frequency, level, and duration of flooding
- Additional nutrients and contaminants entering the receiving water bodies
- Geomorphic changes in receiving streams and wetlands

Figure 10 illustrates many of these changes.

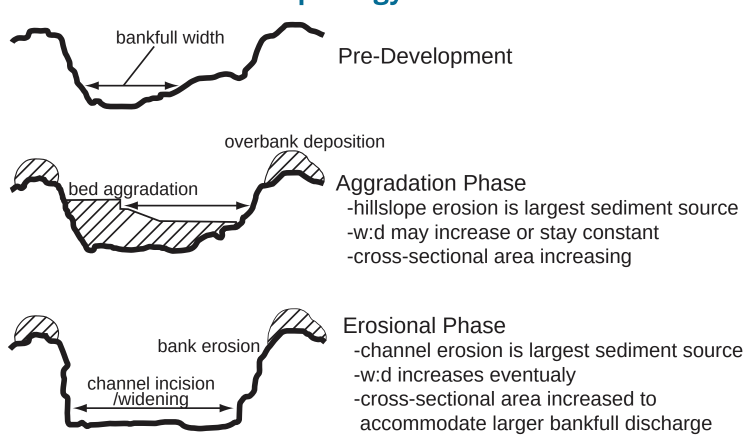
Figure 10: Stream Hydrographs Pre- and Post- Development without BMPs



Source: Fundamentals of Urban Runoff Management (Shaver et. al., 2007)

Natural drainage systems adapt to the dominant flow conditions. The frequency of bank-full events often increase with urbanization and the stream attempts to enlarge its cross section to reach a new equilibrium with the increased channel forming flows. Higher flow velocities and volumes increase the erosive force in a channel, which alters streambed and bank stability. This can result in channel incision, bank undercutting, increased bank erosion, and increased sediment transport. The results are often wider, straighter, sediment laden streams, greater water level fluctuations, as well as loss of riparian cover, shoreland, and aquatic habitat. This is illustrated in Figure 11.

Figure 11: Changes in Stream Channel Geomorphology without BMPs



Source: Fundamentals of Urban Runoff Management (Shaver et. al., 2007)

These changes in hydrology, combined with increased pollutant loading, can have adverse effects on the aquatic ecosystem of streams. It is important to realize that flow is a major determinant of the physical habitat in a stream, which in turn determines the biotic composition of stream communities. A growing body of literature documents that channel geomorphology, habitat structure, and complexity are determined by prevailing flow conditions, which in turn determine the biota that can inhabit the area. This is true for both the fish as well as the aquatic insects upon which they feed. Studies of streams affected by uncontrolled urbanization have shown that fish populations either disappear or become dominated by rough fish that can tolerate the associated lower water quality levels.

Increased Peak Runoff

Peak runoff rates are a function of land slope, land cover, soil type, and type of stormwater conveyance. The time of concentration is the travel time for runoff from the hydrologically farthest point. An increase in impervious area (i.e. roofs, driveways, streets, parking lots) or a reduction in the time of concentration (i.e. storm sewer) results in an increase in peak discharge. Without management practices this leads to flashier stream flows, increased flooding, and geomorphic changes in receiving waters.

As Figure 9 illustrates, detention basins can be effective in controlling the increased peak runoff rates, but they do not mitigate the longer runoff durations, increased runoff volumes, or decreased infiltration. Detention basins are designed for peak flow rate control of relatively large, infrequent storms, generally the 2-year and 10-year, 24-hour storms. As a result, flow rates from smaller, frequently-occurring storms typically exceed those that existed onsite before development occurred and these increases in runoff rates, volumes, and durations typically result in flows erosive to stream channel stability (Shaver et. al., 2007).

Increased Runoff Volume

Runoff volumes are a function of land cover and soil type. An increase in impervious area results in increased runoff volumes. This leads to more frequent and more severe flooding in receiving lakes and rivers during wet periods (Lathrop et al., 2005). Changes in the volume or duration of stormwater runoff entering a wetland can also change its ecological integrity. This often results in changes in the functional capacity, fish and wildlife habitat, replacement of native vegetation with invasive and disturbance-tolerant plant species, and/or other impacts to the wetland's functions and values. (MBWSR 2010).

Figure 9 illustrates the increase in peak flow rate and runoff volume due to development. With detention, the magnitude of the peak flow rate does not change, but the duration of erosive flow increases. This may increase channel erosion since banks are exposed to a longer duration of erosive flows and the total energy available to transport bed materials is increased (Brown et al., 2001).

Biotic Impacts

In an effort to develop quantitative relationships between various flow alterations (magnitude, frequency, duration, timing and rate of change) and ecological responses (abundance, diversity, and demographics) Poff and Zimmerman (2010) reviewed 165 published papers. Ninety-two percent of the reviewed papers reported decreased values for recorded ecological metrics in response to a variety of flow alterations, whereas 13% reported increased values (a few reported both effects). The majority of the papers evaluated the metric flow magnitude. Their quantitative analysis of this metric found that fish abundance, diversity, and demographic rates consistently declined in response to both elevated and reduced flow magnitude. They also found that macroinvertebrates showed mixed responses to changes in flow magnitude; with abundance and diversity both increasing and decreasing in response to both elevated flows and reduced flows. While their analysis did not support the use of the existing literature to develop a general, transferable, quantitative relationship between flow alteration and ecological response it, did support the conclusion that ecological change is associated with flow alteration and that the risk of ecological change increases with increasing degrees of flow alteration.

Reduced Infiltration

The slow infiltration of rainfall through the soil layer is essential for replenishing groundwater. Groundwater is a critical water resource throughout Dane County. Not only does groundwater supply our drinking water, the health of many aquatic systems is also dependent on its steady discharge. During periods of dry weather, groundwater sustains flows in streams and helps to maintain the hydrology of wetlands.

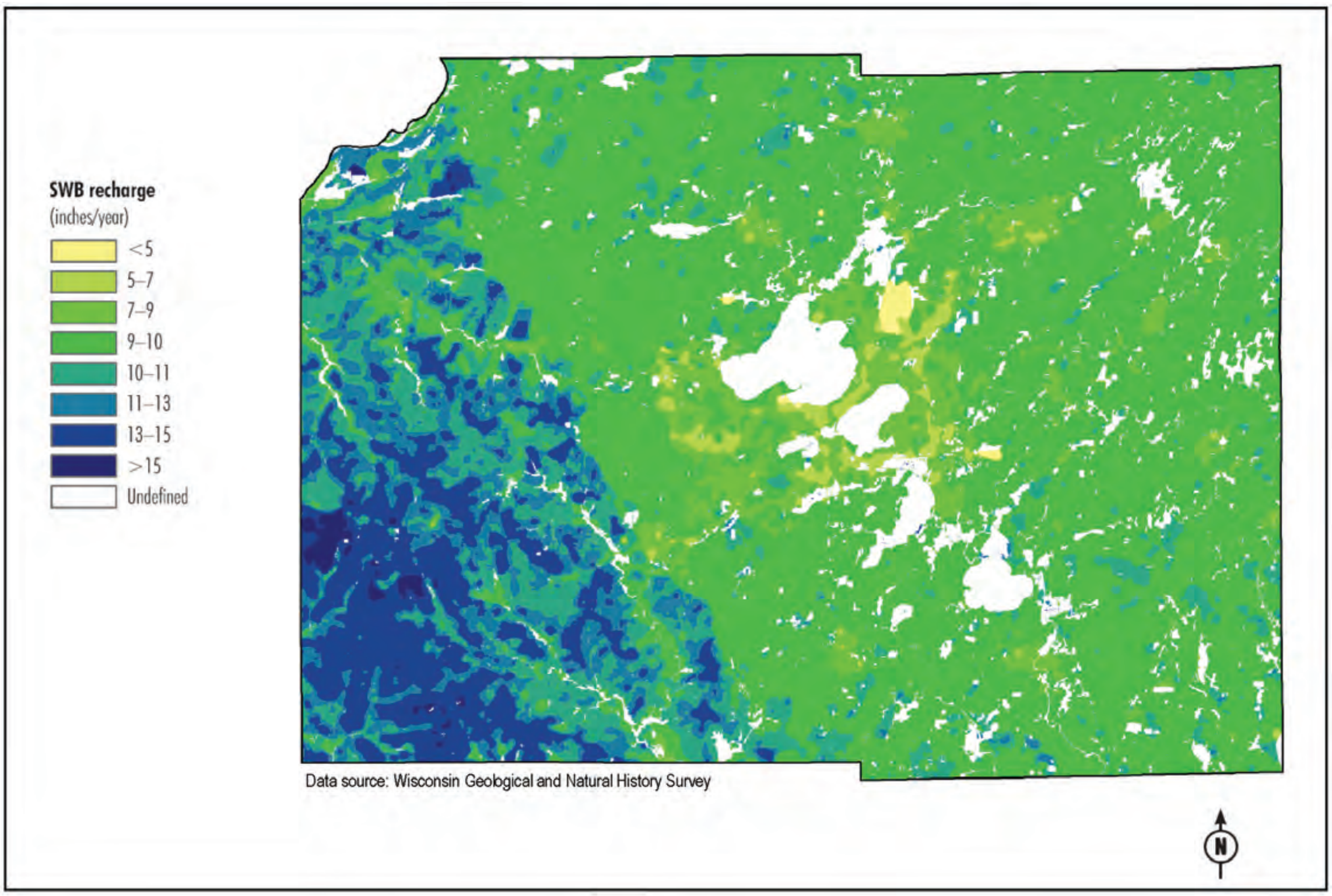
Because development creates impervious surfaces that prevent natural recharge, a net decrease in groundwater recharge rates has been documented in urban watersheds (Spinello and Simmons, 1992). Thus, during prolonged periods of dry weather, streamflow sharply diminishes. In smaller headwater streams, the decline in stream flow can cause a perennial stream to become seasonally dry. An increase in impervious area results in less infiltration of rainfall and snowmelt. This contributes to lowered groundwater levels leading to a decline in the flow of springs and in the dry weather baseflow in streams (Lathrop *et al.*, 2005).

Other research has indicated that urban areas can provide substantial recharge from leaking pipe networks (Lerner, 2002). Leaking water mains were identified as the main source, although leaking sanitary sewers and storm sewers also contribute to urban recharge. In our region leaking water supplies appear to make a relatively small contribution to recharge. The Madison Water Utility estimated water system losses to be 1,029,456,000 gallons in their 2009 annual report to the Public Service Commission. This equates to the equivalent of 0.81 inches of recharge over the 46,708.86 acres of urban service area in the city.

In 2006, the Dane County Community Analysis and Planning Division developed relative infiltration maps for Dane County. The maps are available on the CARPC web site. They are meant to be used as a screening tool to identify relatively high infiltration areas, as well as areas that might be enhanced through engineering techniques such as engineered soils.

In 2009, the Wisconsin Geological and Natural History Survey (Hart *et al,* 2009) published a report estimating the existing groundwater recharge rates in Dane County based on the soil water balance method. The study found that the groundwater recharge rates generally ranged from 5 to 15 inches per year in Dane County, with the majority of the county being from 9 to 10 inches per year as shown in Figure 12.

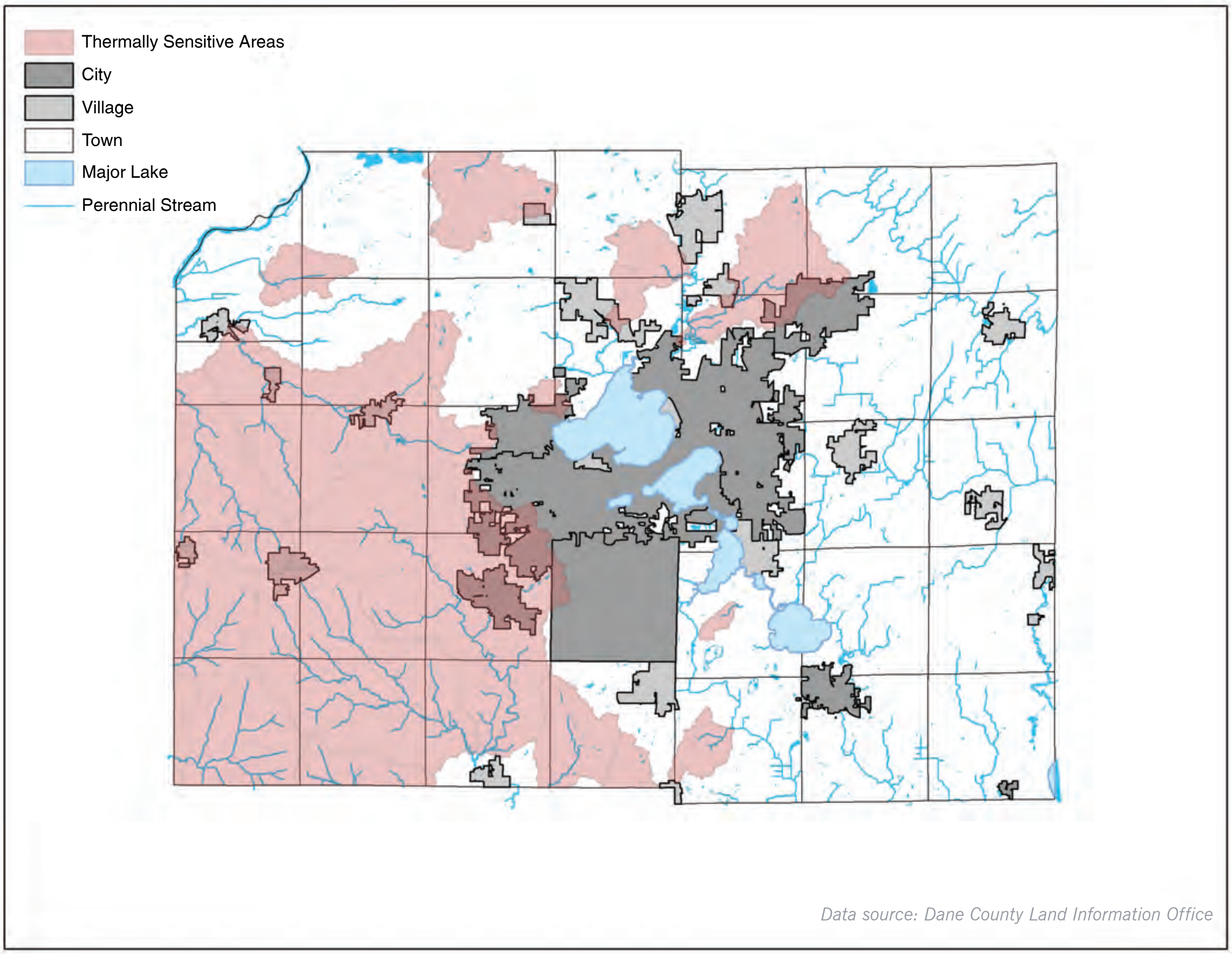
Figure 12: Groundwater Recharge in Dane County



Increased Water Temperature

An increase in impervious surface area can increase stream temperature. Impervious surfaces, particularly dark surfaces like asphalt pavement, absorb solar radiation that raises their temperature. When a rain event occurs, some of this heat is transferred to the water that falls on these surfaces. This heated water becomes runoff and eventually flows into streams, raising their temperature. Impervious surfaces also reduce infiltration, which decreases baseflow. Baseflow tends to have a cooling effect on stream temperature because groundwater is usually maintained at a relatively constant temperature, despite fluctuations in surface temperatures. As baseflow decreases, this cooling effect decreases as well. Therefore, as more impervious surfaces are created, stream temperatures increase due to the combined effect of increasing warmer runoff and decreasing cooler baseflow. Direct exposure of sunlight to shallow ponds and impoundments as well as unshaded streams may further elevate water temperatures. Elevated water temperatures can exceed fish and invertebrate tolerance limits, reducing survival and lowering resistance to disease. Coldwater fish such as trout may be eliminated, or the habitat may become marginally supportive of coldwater species. The watersheds of streams supporting coldwater fish are thermally sensitive areas and are shown in Figure 13. Elevated water temperatures also contribute to decreased oxygen levels in water bodies and dissolution of solutes.

Figure 13: Thermally Sensitive Areas in Dane County



Reduced Water Quality

In 1996, the WDNR and USGS conducted a study of the quality of stormwater at storm-sewer-monitoring sites in Wisconsin (*Bannerman et al., 1996*). The study found that the concentrations of pollutants in stormwater runoff vary considerably between sites and storm events. Summary statistics for typical pollutant concentrations in urban stormwater runoff in Wisconsin are summarized in Tables 3 through 6.

The US EPA has established national recommended water quality criteria for many pollutants (Attachment A). However, it should be noted that the total concentration of a potential pollutant is not always a reliable indicator of the pollutant's water quality impact, or the impairment of the aquatic life related beneficial uses of the water resources. This is because many chemical constituents of water quality concern exist in a variety of chemical forms, only some of which are toxic or otherwise available to adversely affect the water resources. In order to reliably assess the potential water quality impacts of a chemical in runoff, it is necessary to incorporate information on the aquatic chemistry and toxicology of the potential pollutants in the runoff and the receiving waters as well as information on thermodynamics, mixing and transport processes that occur (Jones-Lee et al, 2009).

Table 3: Conventional Constituents

Constituent	Number of Samples	Concentration (mg/l)			
		Maximum	Minimum	Median	Mean
pH (standard units)	131	8.11	5.63	7.3	7.24
Chemical oxygen demand, COD	97	310	<5	48	69
BOD, 5-day at 20°C	112	210	<1	9.4	18
Coliform, fecal (colonies/100 mL)	54	370,000	<10	6,500	30,000
Hardness, dissolved	173	220	<6	26	33
Hardness, total	209	900	3	51	87
Alkalinity, total as CaCo 3	82	149	2	34.5	40.7
Sulfate, dissolved	26	23	<1	9	9.1
Chloride, dissolved	94	1,000	<0.01	10	64
Suspended solids	247	1,850	<2	120	237
Total solids	167	2,810	<10	256	386
Nitrite plus nitrate, dissolved	147	73.6	<0.01	0.493	1.1
Nitrogen, ammonia, dissolved	102	1.3	<0.01	0.24	0.3
Nitrogen, ammonia, organic, total	34	34	<0.2	1	1.8
Phosphorus, total	204	3.8	<0.02	0.29	0.45
Phosphate, ortho, dissolved	137	3.31	<0.002	0.09	0.178
Carbon, organic total	100	66	<0.5	11	16

Source: Quality of Wisconsin Stormwater, 1989-1994

Nutrients

Excessive nutrients (nitrogen and phosphorus) coming from eroded soils, leaf litter, field and lawn fertilization, poorly managed manure, and streets cause explosions of plant and algae growth in the water. As plants decay, bacteria feeding on them use up oxygen, taking away essential oxygen from fish and other aquatic animals. Oxygen depletion sometimes causes fish kills.

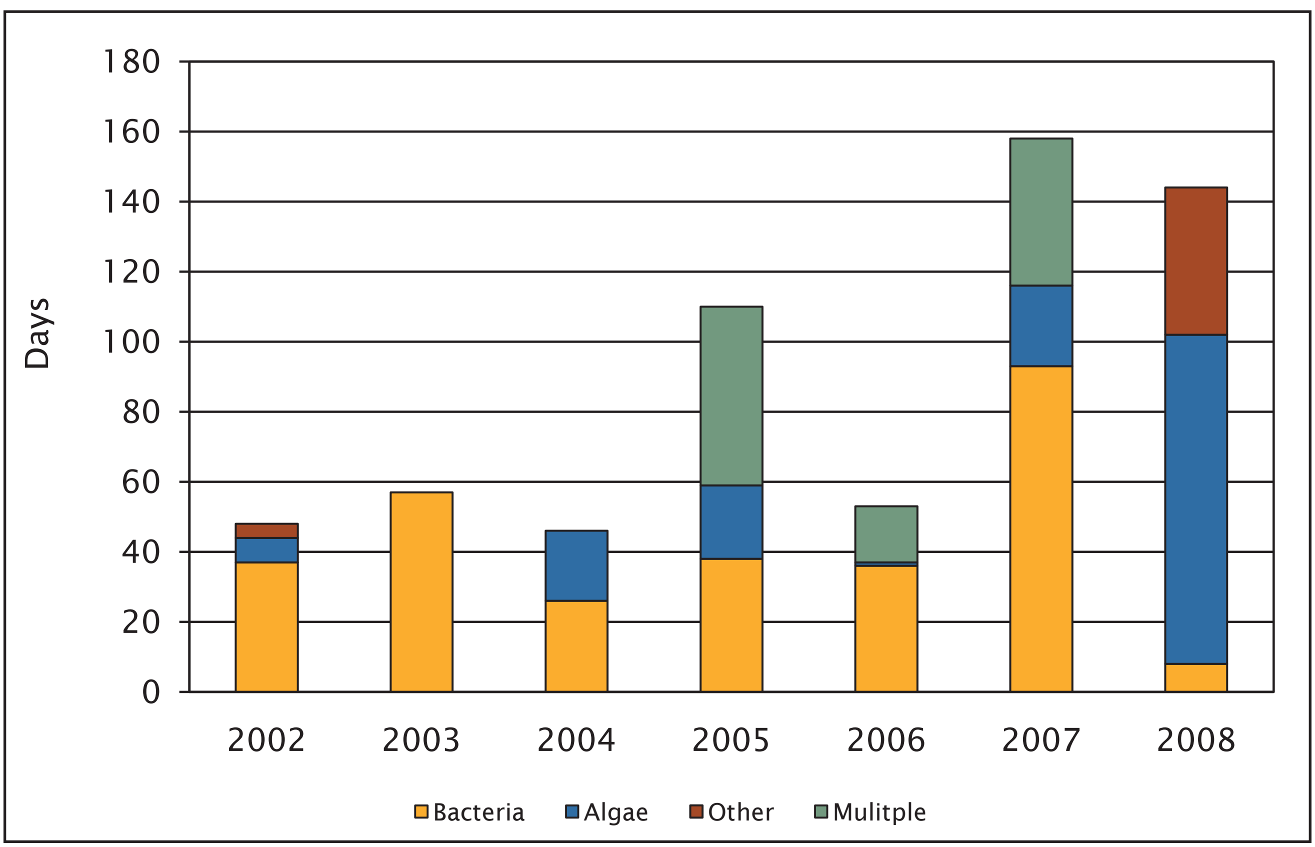
Both algae and blue-green algae (cyanobacteria) occur naturally in surface waters. Although they are usually microscopic, when nutrient levels are too high and conditions are ideal, both can reproduce rapidly and undergo a phenomenon known as a “bloom.” Common algae are not toxic to humans or animals. In contrast, some forms of cyanobacteria can be extremely toxic and capable of causing serious illness or even death. These blooms may occur at phosphorus levels above 30 ppm and are common at levels higher than 50 ppm; levels that are typical in Dane County lakes. As these algae decay they create nasty odors and cause oxygen depletion in the water.

Pathogens

Pathogens are bacteria, protozoa, and viruses that can cause disease in humans. The presence of bacteria such as fecal coliform or enterococci is used as an indicator of pathogens and of potential risk to human health. Pathogen concentrations in urban runoff can exceed public health standards for water contact recreation. Potential sources of pathogens in stormwater runoff include sanitary sewer overflows; animal waste from pets, wildlife, and waterfowl; failing septic systems; and illegal sanitary sewer cross connections.

As a precaution Dane County beaches are closed to the public when elevated levels of algae and/or bacteria are detected to protect the health of beach users. The Public Health Department collects data on the number of beach closing due to water quality problems as shown in Figure 14. There are approximately 1,500 beach days in Dane County annually (15 beaches x 100 days between Memorial Day and Labor Day). High levels of indicator bacteria and / or algae in stormwater have led to a number of beach closures as shown in.

Figure 14: Dane County Beach Closings



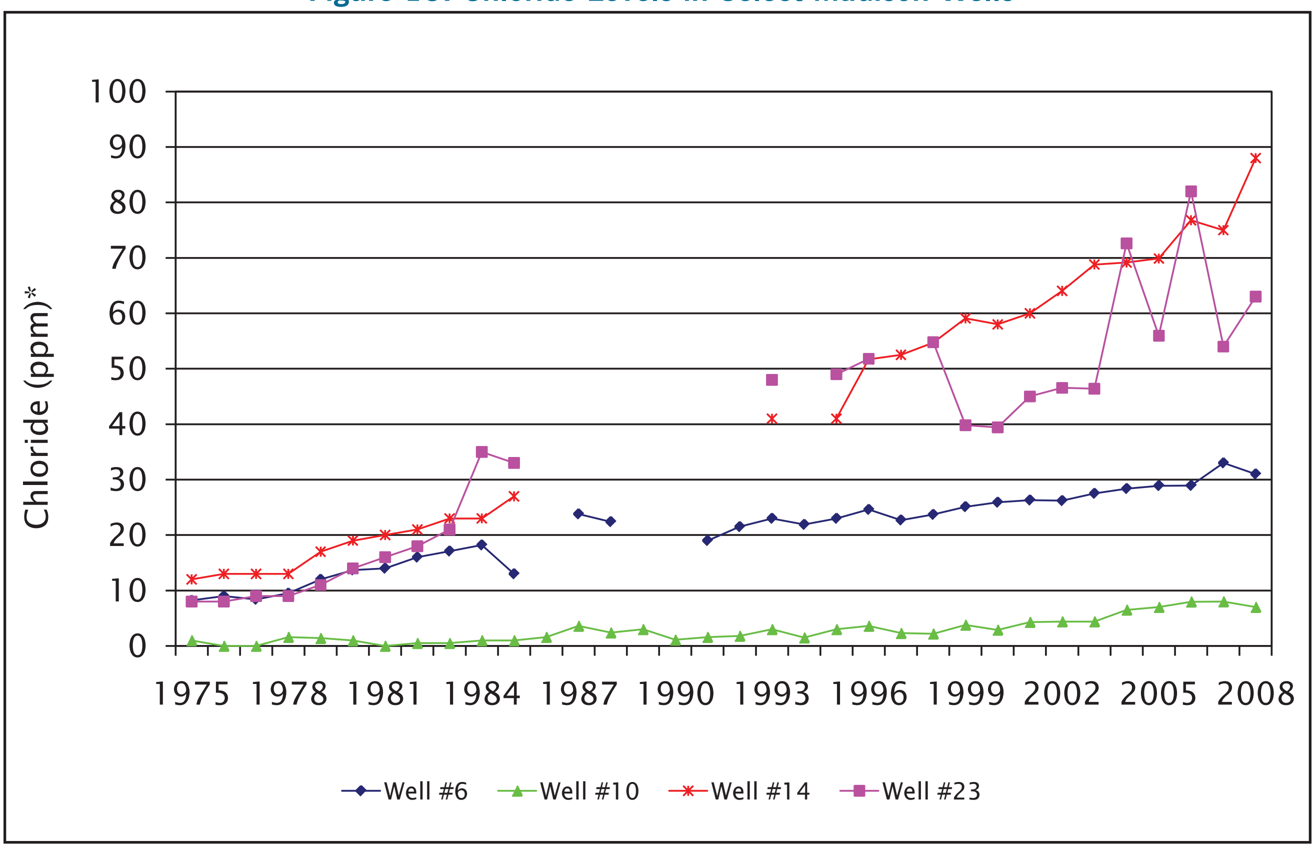
Data provided by Public Health - Madison and Dane County

Chlorides

Elevated chloride can inhibit plant growth, impair reproduction, and reduce the diversity of organisms in streams (Mullaney et. al., 2009). Use of salt for deicing roads and parking lots in the winter is a major source of chloride. Other sources include wastewater treatment plant discharge (from water softeners), septic systems, and farming operations. Road salt (sodium chloride) is the most common deicing material used in Dane County. The literature has well documented the significant adverse effects of road salt on roadside vegetation, soil, groundwater, and surface waters (Transportation Research Board, 1991). It also clearly indicates that the effects depend on a wide range of factor unique to each site. A recently published study by the USGS (Corsi et. al., 2010) demonstrated a substantial effect from road salt on stream water quality and aquatic life based on long- and short-term runoff sampling programs in Wisconsin.

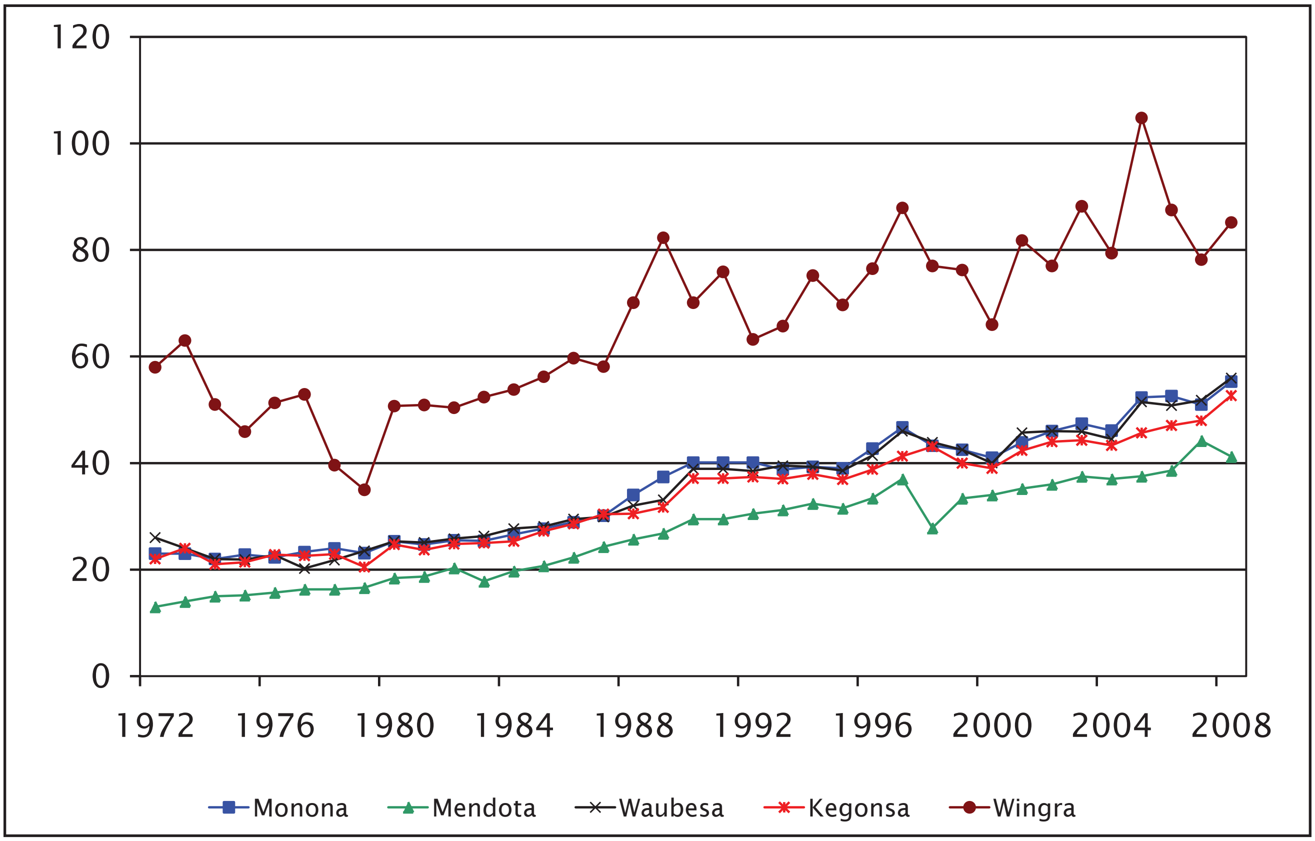
Chloride does not have enforceable federal or state drinking water quality standard. However, a secondary standard of 250 ppm and has been established by the US EPA for chloride and the state of Wisconsin has established a Preventative Action Limit (PAL) of 125 ppm. Currently, the EPA requires that all public water systems monitor sodium levels and report levels greater than 20 mg/l to local health authorities so that physicians treating people on sodium-restricted diets can advise patients accordingly. According to a report on road salt use by the Public Health Department (PHMDC, 2010), the monitoring of surface and groundwater continues to show increasing trends in chloride and sodium levels. The data collected shows that several City of Madison drinking wells have sodium levels in excess of 20 mg/l as shown in Figure 15.

Figure 15: Chloride Levels in Select Madison Wells



*Source: Public Health Madison - Dane County (2009) * Breaks in the trend lines indicates missing data*

Figure 16: Dane County Lake Chloride Levels



Source: Public Health Madison - Dane County (2009).

The national recommended freshwater quality criteria for non-priority pollutants (US EPA, 2009) define the chronic exposure level for chloride as 230 mg/l. The WDNR has established a chronic toxicity criterion of 395 mg/L for chloride. The acute exposure level for chloride is 860 mg/l. Research by the USGS in Milwaukee has found that chloride concentrations in urban streams can exceed the standards for acute toxicity to fish and other aquatic life. Stormwater monitoring during snowmelt has identified surges of high levels of chloride. Data collected by the Public Health Department shown in Figure 16 illustrates that while chloride concentrations in Madison lakes are generally well below toxicity standards for surface waters, they have doubled since the 1970s. Levels that exceed WDNR toxicity standards for surface water have been observed in storm water runoff, ponds, creeks, and in Lake Mendota itself near the Spring Harbor storm sewer outfall. These surges have the potential of harming aquatic life and/ or causing species shifts, eliminating less tolerant species from our lakes and streams.

Sediment (Suspended Solids)

Both suspended and deposited sediments can have adverse effects on aquatic life in streams and lakes. Sediment is the largest load of urban nonpoint pollution. Turbidity resulting from sediment can reduce light penetration for submerged aquatic vegetation critical to lake littoral zones. In addition, the energy from light reflecting off of suspended sediment can increase water temperatures. Sediment can physically alter habitat by destroying the riffle-pool structure in stream systems and smothering benthic organisms, reducing the number, diversity, and productivity of plants and animals living in aquatic environments. Finally, sediment also transports many other pollutants to the receiving waters.

Urban sources of sediment include washoff of particles that are deposited on impervious surfaces, stream bank and bed erosion, and construction sites. A USGS study found that sediment loads from construction sites were 10 times larger than typical loads from rural and urban land uses in Wisconsin (Owens et. al., 2000). The data indicated that active construction sites produced total and suspended solids concentrations that were orders of magnitude higher than pre- and post- construction periods.

Litter

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

Metals

Metals such as cadmium , chromium, copper, lead, mercury, nickel, and zinc are commonly found in urban stormwater runoff. The primary sources of these metals in stormwater runoff are vehicular exhaust residue, fossil fuel combustion, corrosion of galvanized and chrome-plated products, atmospheric deposition, roof runoff, stormwater runoff from industrial sites, and the application of deicing agents. Architectural copper associated with building roofs, flashing, gutters, and downspouts has been shown to be a source of copper in stormwater runoff.

Table 4: Metals and Inorganics

Constituent	Number of Samples	Concentrations (μg/l)			
		Maximum	Minimum	Median	Mean
Antimony, total recoverable	74	4	<1	<1	1.2
Arsenic, total recoverable	71	5	<1	1	1.1
Cadmium, total recoverable	197	7	<0.2	0.5	0.89
Cadmium, dissolved	89	3.8	<0.2	0.08	0.3
Chromium, total recoverable	164	90	<3	7	11
Copper, total recoverable	223	210	<3	18	26
Copper, dissolved	120	33	<3	5	6.5
Cyanide, total	59	0.09	<0.01	<0.01	0.005
Lead, total recoverable	230	570	<1	24	48
Lead, dissolved	120	13	<1	<3	0.87
Nickel, total recoverable	81	52	<1	5	8.3
Silver, total recoverable	129	52	<0.5	<0.5	1.9
Zinc, total recoverable	249	1,500	<10	150	200
Zinc, dissolved	135	840	< 10	70	89

Source: Quality of Wisconsin Stormwater, 1989-1994

Pesticides and Other Toxics

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

Table 5: Pesticides

Constituent	Number of Samples	Concentration (µg/l)			
		Maximum	Minimum	Median	Mean
Alachlor	79	2.9	<0.1	<0.25	0.36
Atrazine	79	6.5	<0.1	0.1	0.26
Chlordane	98	1	<.05	<0.1	0.086
Cyanazine	79	1.9	<0.1	<0.1	0.13
DDD	52	0.1	<0.01	<0.01	0.01
DDE	52	0.1	<0.01	<0.01	0.01
DDT	52	0.1	<0.01	<0.01	0.013
Diazinon	87	2.2	<0.01	<1	0.11
Dicamba	83	0.5	<0.01	<0.22	0.06
Endosulfan	52	0.1	<0.01	<0.01	0.013
Heptachlor	52	0.1	<0.01	<0.01	0.013
Heptachlor epoxide	52	0.1	<0.01	<0.01	0.013
Lindane	80	0.1	<0.01	<0.01	0.0084
Malathion	86	1.1	<0.01	<0.2	0.023
Methoxychlor	80	0.5	<0.01	<0.04	0.023
Metolachlor	48	0.7	<0.1	<0.1	0.12
Picloram	54	0.2	<0.01	<0.1	0.036
Prometon	42	0.5	<0.1	<0.1	0.045
2,4-D	83	10	<0.01	0.1	0.99
2,4-DP	54	1.2	<0.01	<0.1	0.07

Source: Quality of Wisconsin Stormwater, 1989-1994

Traffic Related Debris, Oil, and Grease

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

Vegetation

Vegetation such as grass clippings and leaves are commonly found in stormwater runoff. The decomposition of this organic matter in water bodies can deplete oxygen from the water, thereby causing similar effects to those caused by nutrient loading. Organic matter is of primary concern in water bodies where oxygen is not easily replenished, such as lakes and slow moving streams.

Table 6: Polycyclic Aromatic Hydrocarbons

Constituent	Number of Samples	Concentration (μg/l)			
		Maximum	Minimum	Median	Mean
Acenaphthene	26	6	<0.05	<3.4	0.31
Acenaphthylene	22	0.27	<0.05	0.075	0.1
Anthracene	26	19	<0.12	0.23	1.2
Benzo[a]anthracene	25	23	<0.003	0.9	2.1
Benzo[a]pyrene	30	16	<0.002	1.3	2.3
Benzo[b]flouranthene	30	23	<0.0045	1.4	2.7
Benzo[ghi]perylene	26	15	<0.0047	1	2
Benzo[k]flouranthene	29	14	<0.0034	0.88	1.7
Chrysene	30	24	<0.023	1.4	2.8
Fluoranthene	30	88	<0.009	3.2	8.6
Fluorene	25	7	<0.05	<0.6	0.41
Indeno Pyrene	28	17	<0.02	1.4	2.4
Phenanthrene	24	52	<0.17	1.6	4.6
Pyrene	27	66	<0.007	1.8	5.8

Source: Quality of Wisconsin Stormwater, 1989-1994

Regulation of Urban Nonpoint Source Pollution

Federal Clean Water Act

The 1972 amendments to the Federal Water Pollution Control Act (known as the Clean Water Act or CWA) provide the statutory basis for the National Pollutant Discharge Elimination System (NPDES) permit program and the basic structure for regulating the discharge of pollutants from point sources to waters of the United States. Section 402 of the CWA specifically required EPA to develop and implement the NPDES program.

The CWA gives EPA the authority to set effluent limits on an industry-wide (technology-based) basis and on a water-quality basis that ensure protection of the receiving water. The CWA requires anyone who wants to discharge pollutants to first obtain an NPDES permit, or else that discharge will be considered illegal.

The CWA allowed EPA to authorize the NPDES Permit Program implementation to state governments, enabling states to perform many of the permitting, administrative, and enforcement aspects of the NPDES Program. In states, like Wisconsin, that have been authorized to implement CWA programs, EPA still retains oversight responsibilities.

Polluted stormwater runoff is commonly transported through Municipal Separate Storm Sewer Systems (MS4s), which historically was often discharged untreated into local waterbodies. To prevent harmful pollutants from being washed or dumped into an MS4, operators must obtain a NPDES permit and develop a stormwater management program.

Phase I, issued in 1990, requires *medium* and *large* cities or certain counties with populations of 100,000 or more to obtain NPDES permit coverage for their stormwater discharges. Phase II, issued in 1999, requires regulated small MS4s in urbanized areas, as well as small MS4s outside the urbanized areas that are designated by the permitting authority, to obtain NPDES permit coverage for their stormwater discharges. Generally, individual permits cover Phase I MS4s and a general permit covers Phase II MS4s. Each regulated MS4 is required to develop and implement a stormwater management program to reduce the contamination of stormwater runoff and prohibit illicit discharges.

Wisconsin Administrative Code

Chapters NR 216 and NR 151 of the Wisconsin Administrative Code establishes the minimum standards for stormwater management in the State of Wisconsin.

NR 216

To meet the requirements of EPA's Storm Water Phase II Final Rule, the Wisconsin DNR drafted revisions to ch. NR 216, Wis. Adm. Code. NR 216 revisions amended an existing rule that outlines requirements for storm water discharge permits for municipal separate storm sewer systems, industrial facilities and construction sites. This rule became effective in August 2004.

The following urbanized areas in Dane County are currently required to have a stormwater discharge permit under NR 216:

- The cities of Fitchburg, Madison, Middleton, Monona, Stoughton, Sun Prairie, and Verona.
- The villages of Cottage Grove, Deforest, Maple Bluff, McFarland, Shorewood Hills, and Waunakee
- The towns of Blooming Grove, Bristol, Burke, Cottage Grove, Dunn, Dunkirk, Madison, Middleton, Pleasant Springs, Westport, and Windsor
- Dane County facilities
- The University of Wisconsin - Madison

NR 216 requires storm water permit coverage of all MS4s serving a population over 10,000 that are located outside of an urbanized area. The following communities are expected to reach this population threshold in the near future:

- Village of Oregon ~ 2015
- Village of Mount Horeb ~ 2030

The rules require permitted MS4s to have a stormwater management program that includes public education, public participation, elimination of illicit discharges, the creation and enforcement of local ordinances to regulate erosion control and long-term storm water management, and pollution prevention at municipally owned facilities. The education component includes informing residential landowners on proper methods for yard waste collection and disposal, litter control, and pet waste collection and disposal.

NR 151

NR 151 originally became effective Oct. 1, 2002 as part of a package of Department Natural Resources and Department of Agriculture, Trade and Consumer Protection rules that address nonpoint source pollution, the major cause of polluted waters in Wisconsin and the United States. Several revisions to the standards in NR 151 went into effect on January 1, 2011.

The standard for construction sites requires implementation of an erosion and sediment control plan using Best Management Practices (BMPs) that, by design, reduce to the Maximum Extent Practicable (MEP) 80 percent of the sediment load on an average annual basis.

The post-construction site performance standards set a minimum level of control of runoff pollution from construction sites after construction is completed and final stabilization has occurred.

Total Suspended Solids Control

This standard requires BMPs to capture to the MEP 80 percent of the total suspended solids that would normally run off the site, based on an average annual rainfall. For redevelopment and for in-fill development under 5 acres, the reduction goal is 40 percent.

Peak Discharge Rate

This standard requires that BMPs be used to maintain or reduce the peak runoff discharge rate of the 1-year and 2-year, 24 hour design storms, to the MEP. The pre-development land use is assumed to be in good hydrologic condition. Redevelopment sites and in-fill development of less than 5 acres are exempt.

Infiltration

This performance standard requires that, to the MEP, a portion of the runoff volume be infiltrated. The amount required to be infiltrated is based on the percentage of connected impervious area on the site as shown in Table 7. The standard allows a cap on the land area required for infiltration. There is a concern that the structure of this standard creates an incentive to connect impervious area, which is contrary to the fundamental principle of low impact development, which is to disconnect impervious area.

Table 7: NR 151 Infiltration Requirements Effective January 1, 2011

Site Connected Impervious Area	Pre-Development Infiltration Volume Requirement	Infiltration Area Cap
< 40%	90%	1%
40 to 80%	75%	2%
> 80%	60%	2%

To protect groundwater the standard also identifies areas where infiltration is prohibited. This includes industrial storage and loading areas, fueling and maintenance areas; areas near karst features; areas in close proximity to wells; areas with inadequate separation distance to groundwater or bedrock; and areas where the soils are contaminated and areas where the soils are too coarse. The standard further identifies areas where infiltration is not required, such as areas where the infiltration rate is less than 0.6 inches per hour; areas with less than 5,000 square feet of parking lot or roads in commercial and industrial development; redevelopment areas; in-fill areas less than 5 acres; and certain roads.

Protective Areas

The standard also identifies where, to the MEP, a permanent vegetative buffer area must be maintained around lakes, streams, and wetlands to filter pollutants and protect against erosion. Buffer sizes vary according to the type and classification of the waterbody: 75 feet for outstanding and exceptional resource waters and wetlands of special natural resource interest; 50 feet for streams, lakes, and most wetlands; and 10-30 feet for less susceptible wetlands; 10 feet for concentrated flow channels draining more than 130 acres.

Fueling and Maintenance Areas

The standard also requires, to the MEP, that runoff from fueling and vehicle maintenance areas containing petroleum products must be controlled to remove all visible sheen in the runoff.

Local Ordinances

Dane County Chapter 14

Chapter 14 of the Dane County Code of Ordinances establishes the minimum standards for stormwater management in Dane County.

Sediment control

The ordinance requires that new developments include practices to retain soil particles greater than 5 microns on the site (80% reduction) resulting from a one-year 24-hour storm event (2.5 inches over 24-hour duration), according to approved procedures.

Oil and grease control

The ordinance requires that all non-residential sites with the potential for oil or grease pollution treat the first 0.5 inches of runoff using the best oil and grease removal technology available.

Runoff rate control

The ordinance requires runoff calculations to use the methodology described in the Natural Resources Conservation Service's Technical Release 55, "Urban Hydrology for Small Watersheds" (commonly known as TR-55), or other methodology approved by the Dane County Conservationist. For agricultural land uses, the maximum runoff curve number (RCN) that can be used in the calculations are 51 for HSG A, 68 for hydrologic soil group B, 78 for HSG C, and 83 for HSG D. The TR-55-specified curve numbers for other land uses shall be used. Heavily disturbed sites will be lowered one permeability class for hydrologic calculations. Lightly disturbed areas require no modification. Where practices have been implemented to restore soil structure to predeveloped conditions, no permeability class modification is required.

The ordinance requires that predevelopment peak runoff rates be maintained for the 2-year, 24-hour storm event (2.9 inches over 24-hour duration) and the 10-year, 24-hour storm event (4.2 inches over 24-hour duration). Safely pass the 100-year, 24-hour storm event (6.0 inches over 24-hour duration).

The ordinance also requires that discharges from new construction sites have a stable outlet capable of carrying the designed flow at a non-erosive velocity.

Infiltration

Like the previous NR 151 rules, the Dane County performance standard previously required that 90 percent of pre-development infiltration volume for residential land uses and 60 percent of predevelopment infiltration volume for non-residential (commercial, industrial, institutional) land uses based upon average annual rainfall. Instead of caps on the land area required for infiltration BMPs, the ordinance allows an alternate groundwater recharge standard of the estimated county-wide average annual recharge rate (7.6 inches per year) when the cap levels (1% for residential sites and 2% for nonresidential sites) are reached. In March 2011, Dane County adopted Ordinance Amendment 33, which requires both residential and nonresidential developments to design practices to infiltrate sufficient runoff volume so that post-development infiltration volume shall be at least 90% of the pre-development infiltration volume, based upon average annual rainfall. It also changed the annual pre-development recharge rate to be based on the Wisconsin Geological and Natural History Survey's 2009 report, Groundwater Recharge in Dane County, Estimated by a GIS-Based Water-Balance Model.

The ordinance requires pre-treatment before infiltrating parking lot runoff or runoff from new road construction in commercial, industrial and institutional areas that will enter an infiltration system. The purpose of the pretreatment is to protect the infiltration system from premature clogging and to protect groundwater quality.

Infiltration systems are prohibited in areas that might result in groundwater contamination. This includes Tier 1 industrial facilities, the storage and loading areas of Tier 2 industrial facilities, fueling and vehicle maintenance areas, and areas within 1,000 feet up gradient or within 100 feet down gradient of karst features. In areas with less than three feet from the bottom of the infiltration system to the elevation of seasonal high groundwater or the top of bedrock, infiltration is limited to roof runoff only. In areas with more than three feet but less than five feet from the bottom of the infiltration system to the elevation of seasonal high groundwater or the top of bedrock, residential street runoff can also be infiltrated.

Alternate uses of runoff, such as for toilet flushing, laundry or irrigation, are given equal credit toward the infiltration volume requirements.

Thermal control

The ordinance requires practices to reduce the temperature of runoff for sites located within the watershed of a river or stream identified by the Wisconsin Department of Natural Resources as a Cold Water Community or a trout stream. Alternatively, modeling must demonstrate that the post-development temperature increase of runoff from the site will be zero.

Dane County Chapter 80

Dane County has had an ordinance regulating the application and sale of lawn fertilizer since 2005. The ordinance prohibits the use of phosphorus-containing lawn fertilizers, unless a soil test shows that phosphorus is necessary. It exempts newly-established turf and lawns during their first growing season, fertilizers intended primarily for garden and indoor plant application, and fertilizers applied to trees and shrubs and for agricultural uses.

Municipal Ordinances

Every municipality in Dane County also has its own local stormwater management ordinance. Many of these ordinances require performance standards that are more stringent than those in Dane County Chapter 14. At least ten municipalities in Dane County require peak flow rate control for the 100-year, 24-hour design storm. The Cities of Verona and Middleton and the Villages of McFarland and Oregon require the use of pre-settlement (instead of pre-development) curve numbers for calculating allowable peak flow rates. The City of Middleton has a specific groundwater recharge requirement. The Town of Westport requires infiltration of the increase in runoff volume for the 100-year 24-hour design storm. The Village of DeForest has recently adopted a 100% pre-development volume control standard and a specific groundwater recharge requirement. Attachment B summarizes municipal stormwater ordinances in the region.

Modeling of Urban Nonpoint Source Pollution

HEC-HMS

The U.S. Army Corps of Engineers Hydrologic Engineering Center (HEC) developed the Hydrologic Modeling System (HEC-HMS). The model is designed to simulate the precipitation-runoff processes of watershed systems. It is designed to be applicable in a wide range of geographic areas for solving the widest possible range of problems. This includes large river basin water supply and flood hydrology, and small urban or natural watershed runoff. Hydrographs produced by the program are used directly or in conjunction with other software for studies of water availability, urban drainage, flow forecasting, future urbanization impact, reservoir spillway design, flood damage reduction, floodplain regulation, and systems operation.

HSPF

The Hydrological Simulation Program-FORTRAN (HSPF) model was developed by Aqua Terra Consultants for US EPA. The model simulates hydrologic and water quality processes in natural and man-made water systems. It can be used in the planning, design, and operation of water resources systems. The model uses information on rainfall, temperature, evaporation, land use patterns, soil characteristics, and agricultural practices to simulate the processes that occur in a watershed. The result of the simulation is a time history of the quantity and quality of water transported over the land surface and through various soil zones down to the groundwater aquifers. Runoff flow rate, sediment loads, nutrients, pesticides, toxic chemicals, and other quality constituent concentrations can be predicted. The model uses these results and stream channel information to simulate instream processes that are sued to produce a time history of water quantity and quality at any point in the watershed.

P8

P8 is an urban catchment model developed by William W. Walker Jr. for US EPA, MPCA, and WDNR. The name stands for Program for Predicting Polluting Particle Passage thru Pits, Puddles, & Ponds. The model is used to predict the generation and transport of stormwater runoff pollutants in urban watersheds. Continuous water-balance and mass-balance calculations are performed on a user-defined system consisting of multiple watersheds, best management practices, particle classes, and water quality components. Simulations are driven by continuous hourly rainfall and daily air temperature time series.

RECARGA

The University of Wisconsin – Madison Civil & Environmental Engineering Department Water Resources Group developed the RECARGA model. The model was developed to provide a design tool for evaluating the performance of bioretention facilities, raingarden facilities, and infiltration basins. The model continuously simulates the movement of water throughout the facility (ponding zone, soil layers and underdrains), records the soil moisture and volume of water in each water budget term (infiltration, recharge, overflow, underdrain flow, evapotranspiration, etc.) at each time step and summarizes the results. The results of this model can be used to size facilities to meet specific performance objectives, such as reducing runoff volume or increasing recharge, and for analyzing the potential impacts of varying the design parameters. The model uses the Green-Ampt infiltration model for initial infiltration into the soil surface and the van Genuchten relationship for drainage between soil layers. Input to the facility is calculated from user specified land cover data (percent impervious area, pervious area curve numbers and the area of the facility and tributary basin) using an initial abstraction equation (for impervious areas) or the TR-55 methodology for pervious areas. Underdrain flow is calculated using the orifice equation. The model also tracks continuous soil moisture and evapotranspiration between storm events. More details on the methodology are available in the user's manual for the model (Atchison and Severson, 2004).

SLAMM

The Source Loading and Management Model (SLAMM) was developed by Professor Robert Pitt and John Voorhees. The model was developed to estimate runoff volumes as well as particulate and pollutant loadings based on land use and to evaluate the effectiveness of stormwater management practices. The model emphasizes small storm hydrology and particulate wash-off. WinSLAMM is one of the models approved by the Wisconsin Department of Natural Resources for demonstrating compliance with the stormwater management requirements in NR 151 and NR 216. More details on the methodology are available in the user's manual for the model (Pitt and Voorhees, 2000).

SWAT

The Soil & Water Assessment Tool (SWAT) is a public domain model actively supported by the USDA Agricultural Research Service at the Grassland, Soil and Water Research Laboratory in Temple, Texas, USA. It is a river basin scale model developed to quantify the impact of land management practices in large, complex watersheds. The model components include weather, surface runoff, return flow, percolation, evapo-transpiration, transmission losses, pond and reservoir storage, crop growth and irrigation, groundwater flow, reach routing, nutrient and pesticide loading, water transfer. The model predicts the effect of management decisions on water, sediment, nutrient and pesticide yields on large, ungauged river basins.

SWMM

The Storm Water Management Model (SWMM) is an urban stormwater model developed and maintained by the U.S. Environmental Protection Agency. SWMM is applied to stormwater simulations including urban runoff, flood routing, and flooding analysis. The model provides continuous simulation, using variable time steps, of rainfall-runoff processes and associated pollutant wash-off and transport. SWMM also includes flow routing capabilities for open channels and piped systems.

TR-20 / TR-55

The U.S. Department of Agriculture, Natural Resources Conservation Service (NRCS), developed the TR-20 / TR-55 model. TR-55 uses the runoff curve number method and unit hydrographs to convert rainfall into runoff. TR-55 and TR-20 are infiltration loss models that use the runoff curve number methods synthetic storm flow hydrograph development to predict peak flow rates and volumes for a given catchment area. The advantage of applying TR-55 and TR-20 is the convenience of tables and input parameters included for a wide range of soil and land use conditions. A number of stormwater runoff modeling programs, such as HydroCAD, use the TR-20 and TR-55 methodology.

The traditional SCS TR-55 methods are valuable for estimating peak discharge rates for large storms (i.e., greater than 2 inches), but can significantly underestimate runoff from small storm events (Claytor and Schueler, 1996). One of the principal short comings of TR-55 is that the methodology assumes a constant CN for a large range of rainfall events. While this assumption does not significantly affect the accuracy of the model for larger storm events (> 2”), smaller rainfall events produce more runoff than are predicted by the SCS procedure (Pitt, 1999).

Monitoring of Urban Nonpoint Source Pollution

USGS

The United States Geological Survey Wisconsin Water Science Center (USGS WI WSC) office in Middleton, Wisconsin conducts quantity and quality monitoring of surface water and ground water systems throughout the state. The program is partly funded by local units of government through regional cooperators. CARPC is a regional USGS cooperator, continuing over three decades of cooperation between its predecessor the DCRPC and the USGS.

In the USGS surface water quantity monitoring program, continuous streamflow data are collected and computed using traditional and state-of-the-art acoustic methods and the data are posted on the USGS website in real time. These data are used for flood forecasting and emergency flood response, understanding and modeling hydrologic systems, defining flood plains for planning developments, designing and operating hydroelectric, flood control, water supply, and wastewater facilities, designing and sizing bridges and culverts, managing lakes and wetlands, abating and preventing pollution, determining trends in floods and low-flows, and determining the occurrence and distribution of water.

In the USGS surface water quality monitoring program, water samples are collected to describe occurrence and distribution, trends, and modeling of certain pollutants and their relationships between natural factors, land use and water quality, and the relationship between ecological responses and water quality. The WI WSC has monitoring capabilities associated with PCB, organics, virus, and pathogens sampling as well as in the areas of flow-composite auto sampling, small plot agricultural sampling, and urban source area sampling.

The USGS nonpoint source evaluation monitoring program provides instrumentation, data collection, and data analyses for urban non-point source research projects. Data is collected at plot, field, and whole watersheds scales. The evaluations have included single best management practices and end-of-the-pipe treatment devices being used by municipalities to improve urban stormwater quality and to meet permit requirements. The program collects actual field data that are used in the calibration, verification, and continued enhancement of the SLAMM model.

WDNR

The Water Division of the Wisconsin Department of Natural Resources (DNR) gathers environmental information to assess aquatic environmental health, evaluate environmental problems and to determine success of management actions that are intended to protect aquatic resources. The *WDNR Water Division Monitoring Strategy* (WDNR, 2006) directs their monitoring efforts. The data collected includes baseline physical, chemical, and biological information. The monitoring determines water quality and fisheries status and trends based on ecologically based indicators, and identifies potential problem areas.

Public Health

The Department of Public Health for Madison and Dane County (PHMDC) provides sampling, laboratory analysis and reporting services for beaches, public drinking water wells, and surface water resources in our region.

All public beaches in Dane County are monitored by the PHMDC during the swimming season (Memorial Day - Labor Day). Public Health conducts water quality testing at 13 Madison beaches, one UW beach and two Dane County beaches for bacteria, and algal toxins such as microcystin and cylindrospermopsin. The purpose of the beach monitoring program is to protect the public health and assure that the beach water is safe for recreational activities and to minimize the likelihood of water-borne disease outbreaks on Madison beaches.

The PHMDC also maintains a routine surveillance and sampling schedule of area lakes, streams, primary and secondary outfalls, and point and non-point source run-off to ground surface, wetlands, and surface waters. Each month the Public Health-Madison and Dane County (PHMDC) Laboratory monitors Lakes Waubesa, Wingra, Monona, Mendota, and Kegonsa for chemicals that might be present in the water. Some of the things lab analyzes in the water include chloride, fluoride, nitrite, nitrate and sodium. Water samples are also tested less frequently for other contaminants, including arsenic, cadmium, calcium, mercury, selenium, lead, and zinc.

Water Quality Conditions

Technical Appendix B (Water Quality Conditions) of the *Dane County Water Quality Plan* (DCRPC 1979), the *Dane County Water Quality Plan Appendix B Update: Surface Water Quality Conditions* (DCRPC 1992), and *Dane County Water Quality: Conditions and Problems* (DCRPC 1999), compiled and analyzed the available data on the water quality of Dane County streams and major lakes. The data sources include fishery surveys, pollution investigations, and research projects conducted by state agencies and the University of Wisconsin among others. This appendix is currently being updated.

Management of Urban Nonpoint Source Pollution

Stormwater management involves the selective use of various best management practices (BMPs) to address the potential adverse water quality and quantity impacts of uncontrolled urban stormwater runoff in a cost-effective and environmentally sound manner. In most cases, well-designed and well-maintained stormwater management practices when coupled with well-designed urban landscapes can preserve or improve upon the pre-development condition of water resources.

Resource Considerations

Stormwater treatment practices should be tailored not only to the conditions that exist at a particular site, but also to the downstream resources that could be impacted by stormwater discharges from the site. The resources include rivers and streams, groundwater aquifers, lakes and ponds, and wetlands.

Rivers and Streams

The rate and volume of stormwater discharges from new developments are especially critical to these systems, as they can impact the flood carrying capacity of the watercourse and increase the potential for channel erosion. In addition, sensitive cold-water fisheries, including stocked streams, can also be adversely impacted by stormwater runoff with elevated temperatures. Streams and rivers that are classified by the WDNR as Outstanding and Exceptional Resource Waters have excellent water quality, high recreational and aesthetic value and high quality fishing. These resources, as well as their tributary watercourses and wetlands, warrant a high degree of protection.

Groundwater Aquifers and Springs

Groundwater is the source of drinking water in Dane County. In addition, groundwater is the source of dry weather flows (baseflow) in waterways, which is critical for maintaining suitable habitat. Groundwater recharge is also critical to maintaining the flow to springs. As a result, it is important to maintain both the quantity and quality of groundwater recharge.

Lakes and Ponds

Lakes and ponds are especially sensitive to sediment and nutrient loadings. Excess sediments and nutrients are the cause of algal blooms in these surface waters, leading to eutrophication and degradation. These conditions often result in costly dredging and rehabilitation projects. In fresh water systems, phosphorus is typically the limiting nutrient, that is, much less phosphorus is needed compared to other nutrients such as nitrogen to create eutrophic conditions. As a result, treatment practices should focus on nutrient removal, particularly phosphorus, for stormwater discharges to lakes and ponds, and watercourses that feed lakes and ponds.

Wetands

Hydrology is typically the primary factor driving the other elements of a wetland ecosystem. Many wetlands are sensitive to changes in the frequency, duration, or depth of water that can occur with urban runoff. The functions and benefits that can be provided by wetlands include, reducing the rate and volume of stormwater runoff, reducing flooding, treating and removing pollutants, and providing important wildlife habitat. The *Dane County Wetlands Resource Management Guide* (CARPC, 2008) and the *Recommended Wetland Management Classification System* (MBWSR, 2010) provide an in depth discussion of the issues and recommended standards related to managing these resources.

Site Design Considerations

Effective site planning and design is the most critical and potentially beneficial element of a successful stormwater management program since it addresses the root causes of both stormwater quality and quantity problems early in the development process. Source controls and pollution prevention, as well as construction erosion and sedimentation controls, are also key elements for preventing or mitigating stormwater quality problems. These preventive measures can reduce the size and scope of stormwater treatment and flood control facilities. It should be noted that many factors are considered in site design in addition to stormwater management. Inevitably, a successful design involves a balance between sometimes competing factors including street connectivity, safety, aesthetics, walkability, and cost effectiveness.

The goal of the low impact design approach, also often referred to as conservation design, is to mimic predevelopment hydrology by minimizing imperviousness and maximizing the use of distributed management practices that store, infiltrate, evapotranspirate, and detain runoff. Design considerations for minimizing imperviousness include site fingerprinting, and building, street, and drainage design. The distributed management practices typically used in a low impact design include green roofs, rainwater collection for beneficial reuse, bioretention, filter strips, swales, and infiltration trenches. The *Low-Impact Development Design Strategies Manual* (Prince George's County DER, 1999) and *Better Site Design: A Handbook for Changing Development Rules in Your Community* (CWP, 1998) provide useful guidelines and additional references for planning and designing developments using these approaches.

The report *Reducing Stormwater Costs through Low Impact Development (LID) Strategies and Practices* (US EPA, 2007) summarizes seventeen case studies of developments that include Low Impact Development (LID) practices. In most cases, LID practices were shown to be both fiscally and environmentally beneficial to communities. In a few cases, LID project costs were higher than those for conventional stormwater management practices. In the vast majority of cases, significant savings were realized due to reduced costs for site grading and preparation, stormwater infrastructure, site paving, and landscaping. Total capital cost savings ranged from 15 to 80 percent when LID methods were used, with a few exceptions in which LID project costs were higher than conventional stormwater management costs. There were also benefits that the study did not monetize and did not factor into the project's bottom line. These benefits include improved aesthetics, expanded recreational opportunities, increased property values due to the desirability of the lots and their proximity to open space, increased total number of units developed, increased marketing potential, and faster sales. More research is needed to quantify the environmental benefits that can be achieved through the use of LID techniques and the costs that can be avoided. Examples of environmental benefits include reduced runoff volumes and reduced pollutant loadings to downstream waters. Finally, more research is needed to monetize the cost reductions that can be achieved through improved environmental performance, reductions in long-term operation and maintenance costs, and/or reductions in the life cycle costs of replacing or rehabilitating infrastructure.

Site Design

Site fingerprinting is the practice of minimizing the amount of site area that is disturbed during development. This has the benefits of maintaining pre-development curve numbers and times of concentration, preserving native soil infiltration rates, in the undisturbed areas. It can also reduce the costs of site clearing and grubbing and reduce the potential for site erosion during construction.

Building Design

Rooftops contribute a significant portion of imperviousness. Building design affects rooftop imperviousness. For example, more roof area is generally required for ranch-type homes that spread out square footage over one level compared to two-story homes. With this in mind, vertical construction is favored over horizontal layouts to reduce the square footage of rooftops.

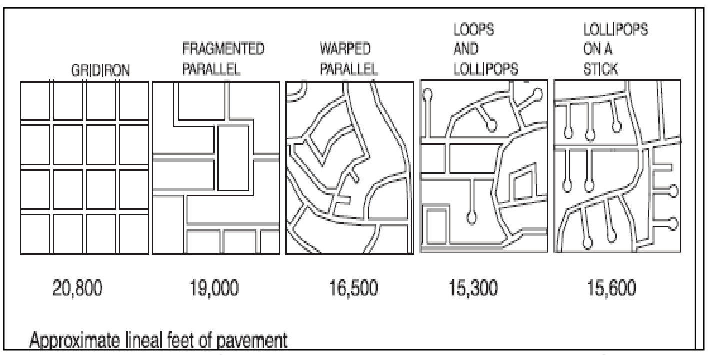
Driveway Design

Driveways are another element of the site design that can be planned to reduce the amount of total imperviousness and reduce runoff. Some techniques that can be used include; using shared driveways, limiting driveway widths, reducing driveway lengths (by minimizing building setbacks), and directing flows from driveways to stabilized vegetated areas.

Street Design

Street layout can have a very significant influence on the total imperviousness and hydrology of a site. Figure 17 illustrates that the total length of pavement or imperviousness for various road layout options can vary from 20,800 linear ft. for a typical gridiron layout to 15,300 linear ft. for a loops and lollipops layout. Selection of an alternative road layout can result in a total site reduction in imperviousness of up to 26 percent (Prince George's County DER 1999).

Figure 17: Street Design Alternatives



Source: Low-Impact Development Design Strategies

Walkability is also an important planning consideration in street design. There may be tradeoffs between street layouts that reduce impervious surfaces and those that promote walkability. The best street designs seek to provide both walkability and reduce the amount of imperviousness compared to conventional development. One approach to this dilemma is to provide additional connectivity with bike and pedestrian paths, rather than with streets.

Constructing roads across steep sloped areas unnecessarily increases soil disturbance on a site. Good road layouts avoid placing roads on steep slopes, by designing roads to follow grades and run along ridgelines.

Street widths typically range from 48 feet to 26 feet. SLAMM modeling shows that every 1–foot decrease in street width decreases the annual runoff volume from the streets by about 1%.

Drainage Design

Site drainage design decisions have a significant effect on the rates and volumes of runoff from a site. Maintaining the pre-development flow path length and time of concentration will help in controlling peak flow rates. Site and infrastructure components that affect the time of concentration include travel distance (flow path), slope of the ground surface, surface roughness, and channel shape, pattern, and material components. Techniques to control the time of concentration can be incorporated into the drainage design by managing flow and conveyance systems within the development site. These techniques include maximizing overland sheet flow, increasing and lengthening flow paths, lengthening and flattening site and lot slopes, maximizing the use of open swale systems, and increasing and augmenting site and lot vegetation.

Green Infrastructure

Green Infrastructure is a term used to describe the stormwater management approach and practices that can be used to infiltrate, evapotranspirate, capture and reuse stormwater to maintain or restore the natural hydrology. The preservation and restoration of natural landscape features, including woodlands, floodplains and wetlands, are critical components of green infrastructure. The protection of these ecologically sensitive areas contribute to the improvement of water quality while providing wildlife habitat and opportunities for outdoor recreation. On a site scale, green infrastructure best management practices include rain gardens, porous pavements, green roofs, infiltration planters, trees and tree boxes, and rainwater harvesting for non-potable uses such as toilet flushing and landscape irrigation.

Best Management Practices

Best Management Practices (BMPs) include a variety of activities, procedures, and engineered devices implemented to prevent, control, treat, or reduce water pollution from stormwater runoff and meet the water quality performance standards in federal, state, and local regulations. The DNR, in collaboration with the Wisconsin Standards Oversight Council, have developed technical standards for a number of BMPs. The technical standards specify the minimum requirements for planning, designing, installing and maintaining the practices so that they adequately and effectively protect water resources. They are based on current research, field experience, and the best available technology determined to meet the performance standards of state stormwater regulations.

The first attempt to mitigate the impacts of runoff due to development was peak flow rate control with detention basins. A few communities in the region have used detention basins since the 1970s and the RPC has required them since the 1980s. They were not required throughout the region until the passage of NR 151 and the amended Dane County Chapter 14 in 2002. The volume control standard in NR 151 has been in effect since October 2004.

The variety of best management practices being used to mitigate the effects of urban nonpoint source pollution has grown significantly since the first *Dane County Water Quality Plan*. Detention basins and infiltration basins are by far the most common. However, distributed practices including rain gardens, green roofs, porous pavement, and cisterns are growing in use.

A number of extensive design manuals and guidance documents for BMPs have been developed across the country. Good examples that should be used as references for designers and constructors of BMPs include; The *Dane County Erosion Control and Stormwater Management Manual* (Dane County, 2007), the *Wisconsin Storm Water Manual* (WDNR, 2000), The *Minnesota Stormwater Manual* (MPCA, 2008), the *2004 Connecticut Stormwater Quality Manual* (CDEP, 2004), the *Low-Impact Development Design Strategies Manual* (Prince George's County DER, 1999), and the *Vermont Stormwater Management Manual* (VANR, 2002).

Most of these practices are not new ideas. Cisterns were common prior to the widespread availability of public water supply systems. Porous pavement was recommended as a best management practice in the first *Dane County Water Quality Plan* in 1979. Green roofs have been widely used in places like Germany for several decades. Attachment C contains fact sheets on many of the best management practices for urban nonpoint source pollution. The fact sheets contain a description of the practice, information on the typical water quality benefits and costs of the practices, design references and considerations, as well as a listing of local examples where available.

Treatment Trains

A treatment train is a group of stormwater management practices that operate in series, each providing its own unique pollution control capability. A treatment train may not result in additional sediment removal, but rather a modified sediment removal rate based on the particle size distribution received by each practice. An infiltration practice will reduce pollutant loads by 100% if the runoff does not reach surface water, but the loads to the bmp will be reduced by and practice located upstream. The advantage of treatment trains comes from each management practice's ability to remove certain pollutants more effectively than others, thus providing better removal of a variety of pollutants.

Other Considerations

Climate Change

The Wisconsin Initiative on Climate Change Impacts (WICCI) was formed to assess and anticipate climate change impacts on specific Wisconsin natural resources, ecosystems and regions. As part of this effort, the Center for Climatic Research and the Center for Sustainability and the Global Environment, Nelson Institute, University of Wisconsin-Madison have developed a series of maps depicting recent and projected climate change in Wisconsin (WICCI, 2010). These maps show that the observed increase in total annual average precipitation from 1950 to 2006 has been between 3.5 to 7.0 inches for our region. They also show that the estimated increase in total annual average precipitation from 1980 to 2055 will be 1.5 inches in our region. Although the historical data indicate that increases in total average annual precipitation have already occurred, the models do not predict much of an additional increase in total annual average precipitation in the near future. More significant than the projected changes in total average annual precipitation is the projected shift in precipitation from summer months to more winter and spring precipitation (WICCI, 2011). This could have significant impacts on erosion, resulting in higher sediment and phosphorous loads from agricultural areas due to the limited amount of agricultural vegetation at this time of year.

The climate models also indicate that the number of large rainfalls will increase in the future. Typically, heavy precipitation events of at least two inches occur roughly

12 times per decade (once every 10 months) in southern Wisconsin. Southern Wisconsin is projected to receive 2 to 2.5 more of these large events per decade, or roughly a 20% increase in their frequency. This will have the most significant impact on older urban areas that were developed with limited or no stormwater management practices.

The stormwater working group of WICCI concluded that the physical principles and climate models indicate that the magnitude of large rainfalls will increase. The historical data indicate that increases have already occurred. But the current models and historical data do not yet provide a statistical basis for hydrologic design. The working group recommends that adapting hydrologic design to climate change should include (Potter, 2010):

- Use the latest rainfall statistics (e.g. not TP-40; see the Hydrology section of this report)
- Use climate scenarios to evaluate vulnerabilities of existing infrastructure
- Make greater use of continuous hydrologic simulation and coupled models (e.g., surface and groundwater)
- Re-evaluate design criteria (e.g. for detention basins)
- Design based on risk-based design, incorporating uncertainty

The CARPC Annual Unified Planning Work Program and Overall Program Design includes a future initiative for evaluating the inter-relationship between regional plans and climate change. This climate change analysis is proposed as a technical appendix of the Dane County Water Quality Plan that would be completed during 2011-2012.

Stream Channel Protection

Bankfull discharge for most streams has a recurrence interval of between 1 and 2 years (Leopold, et al., 1964; Leopold, 1994). This is based on the recurrence interval of an annual flood corresponding to once a year flooding by all floods. But it should be noted that a stream with a bankfull annual flood recurrence interval of 1.01 overflows its banks about five times per year.

A number of design criteria have been developed for the purpose of stream channel protection. The most common method relies on control of post-development peak flows associated with the 2-year, 24-hour storm event to pre-development levels. This standard offers little to no control of runoff from the smaller, more frequent storms that produce most of the runoff reaching streams. It is runoff from these small storms that largely determines how a stream will function and transform in response to more erosive velocities, larger flow volumes, and flashier stream flows. More recent research indicates that this method does not adequately protect stream channels from erosion and may actually contribute to erosion since banks are exposed to a longer duration of erosive bankfull and sub-bankfull events (Brown et. al., 2001). Several alternative approaches to a channel protection standard have been developed to address this concern.

The Distributed Runoff Control (DRC) method was developed by MacRae (1996) and is proposed for adoption in Ontario, Canada. It involves detailed field assessments and hydraulic/hydrologic modeling to determine hydraulic stress and erosion potential of stream banks. This level of detailed, site-specific analysis is generally not warranted for stream channel protection criterion, since other protective standards are available.

The "Two-Year Over-Control" method requires controlling the 2-yr, 24-hour post-development peak flow rate to 50 percent of the pre-development rate or to the 1-yr, 24-hr pre-development rate. This standard was developed as a modification of the original two-year control approach to provide additional protection by reducing the duration of bankfull flows. The state of Connecticut uses this standard.

Extended detention is another approach to channel protection. In this method the runoff is captured and gradually released over a long period of time to control erosive velocities in downstream channels. In Vermont for example, they require 12-hour extended detention of the post-development 1-year, 24-hour rainfall event in coldwater fish habitats and 24-hr. detention in warmwater fish habitats.

Inclusion of the 1-yr 24-hr storm in the range of design storms used for peak flow rate control is another method for increasing channel protection. The WDNR has also acknowledged that research is showing that the current standard is not protective of the bank-full condition and has recently adopted a change to NR 151 that added peak flow rate control for the 1-yr 24-hr design storm.

Cold Weather Performance

A U.S. Army Cold Regions Research and Engineering Laboratory (CRREL) publication noted that essentially everywhere north of 40˚N latitude can be classified as "cold regions" based upon air temperature, snow depth, ice cover and frozen ground. Thus cold weather performance is an important consideration for our region (43˚N latitude). This may change to some degree with climate change.

The *Minnesota Stormwater Manual* (MPCA, 2008) contains a chapter of guidance on how to adapt BMP design for cold climates. The WDNR Conservation Practice Standards for BMPs also contain considerations for cold weather performance. These guidance documents indicate that with the appropriate considerations and adaptations, many stormwater BMPs are suitable for effective use in cold climate areas. A study by the University of New Hampshire Stormwater Center (Roseen 2009) supports this conclusion. The study found that filtration and infiltration systems exhibited similar peak flow reduction performance between summer and winter. The study also found that except for nitrate, seasonal contaminant removal performance varied little for filtration and infiltrations systems and retention ponds. In contrast, swales and hydrodynamic separators did have a noticeable seasonal performance decline in the winter.

Downstream Peak Flow Analysis

In some watersheds the timing of peak runoff may increase downstream flooding if on-site peak runoff attenuation criteria are applied uniformly throughout the watershed. In this case a regional stormwater management approach may be more effective at reducing downstream flooding than stormwater management practices on many individual sites.

Peak runoff control criteria are typically applied at the immediate downstream boundary of a project area. However, since stormwater management facilities may change the timing of the post-development hydrograph, multiple stormwater treatment practices or detention facilities in a watershed may result in unexpected increases in peak flows (coincident peaks) at critical downstream locations such as road culverts and areas prone to flooding. This effect is most pronounced for detention structures in the middle to lower third of a watershed. A downstream analysis should be conducted to identify potential detrimental effects of proposed stormwater treatment practices and detention facilities on downstream areas. The *Connecticut Stormwater Quality Manual* (CDEP, 2004) recommends that a downstream analysis include the following elements:

- Routing calculations downstream to a confluence point where the site drainage area represents 10 percent of the total drainage area (i.e., the "10 percent rule")
- Calculation of peak flows, velocities, and hydraulic effects at critical downstream locations (stream confluences, culverts, other channel constrictions, and flood-prone areas) to the confluence point where the 10 percent rule applies
- An appropriate hydrograph routing method, such as TR-20, to route the pre- and post-development runoff hydrographs from the project site to the downstream critical locations.

The ultimate objective of this analysis is to ensure that proposed projects do not increase post-development peak flows and velocities at critical downstream locations in the watershed. Increases in flow rates and velocities at these locations should be limited to less than 5 percent of the pre-developed condition and should not exceed freeboard clearances or allowable velocities.

Seasonal High Groundwater

About 39% of the soils in Dane County have the potential for seasonal (typically from April to June) high groundwater within five feet of the surface. These areas may have a zone of soil saturation that can cause problems with groundwater induced flooding. Historically, buildings with basements, foundations drains, and sump pumps have been built in many of these areas without consideration for the affects that this may have on stormwater management. Where buildings with basements and sump pumps exist, it is appropriate that the stormwater management plans account for this additional water volume in the design of the stormwater management facilities.

Unintended Consequences of Infiltration

Improperly located infiltration systems have the potential to mound the groundwater in some areas to the extent that it could result in water leaking into basements and/or the sanitary sewerage system. In either case, this excessive volume of clear water could reduce the capacity of the wastewater conveyance and treatment systems, resulting in increased costs or lower levels of service.

In 2005, the Milwaukee Metropolitan Sewerage District awarded funding for four BMP construction criteria projects. The primary objective of these projects was to determine whether increased infiltration of stormwater by BMPs such as porous pavement, rain gardens, downspout disconnection, green roof discharges, and wet detention basins may increase soil saturation levels and increase infiltration and inflow into sanitary sewers and laterals.

The rain garden study found that at 10 feet away, the rain gardens had no significant effect on soil moisture (MMSD, 2007). Water that falls on a rain garden percolates straight down and there is little horizontal movement in the unsaturated zone. The project concluded that a rain garden built at a horizontal distance of 2 feet or greater from a sewer lateral would probably not lead to a significant increase in infiltration into the sewer lateral. Downspout extension experiments performed with 5-foot extenders resulted in no discharge into the foundation drains. Discharge from a rain barrel through a weeping hose placed 2.5 feet from the foundation showed no discharge into the foundation drains. The discharge was completely absorbed by the soil.

These studies indicate that the goals of infiltrating stormwater runoff and reducing clear water infiltration and inflow into sanitary sewer systems can be compatible when proper consideration is given to the design and location of these practices.

Conclusions and Recommendations

The 1979 Dane County Water Quality Plan and subsequent Summary Plan updates in 1995 and 2004 included several recommendations for urban nonpoint source control. The recommendations from the 1995 and 2004 plans are summarized in Table 8. Many of these previous recommendations have been implemented to some degree either voluntarily or to fulfill the requirements of state and local regulations that have subsequently been passed. Others need to be revisited, reaffirmed, and strengthened.Previous Plans and Plan Updates

Previous Plans and Plan Updates

Table 8: 1995 and 2004 Summary Plan Recommendations

1995 Summary Plan	2004 Summary Plan	2011 Status
U-1: Urban nonpoint source management agencies should enact and enforce leaf and yard and garden debris storage and disposal ordinances in urban areas, particularly those urban areas draining to lakes or impoundments, with emphasis on keeping leaves and yard waste off streets and paved surfaces.	This recommendation was combined with 1995 recommendation U-4 and reaffirmed in 2004 as recommendation U-14.	This recommendation has been implemented to some extent and is reaffirmed as recommendation #17.
U-2: Urban nonpoint source management agencies should include provisions in building codes and ordinances providing that, wherever feasible, drainage from roofs, driveways, and parking lots should be directed toward grassed or vegetated areas, rather than being directly connected to paved areas or storm sewers.	This recommendation was reaffirmed in 2004 as recommendation U-15.	This recommendation has been implemented to some extent and is reaffirmed as recommendation #18.
U-3: Urban nonpoint source management agencies should conduct aggressive public education and information programs regarding source control, on an annual basis	This recommendation was reaffirmed in 2004 as recommendation U-16.	This recommendation has been implemented to some extent and is reaffirmed as recommendation #8.
U-4: Urban nonpoint source management agencies should improve leaf pick-up in the fall for areas which are tributary to lakes or impoundments. Special attention should be given to keeping leaves out of streets and storm sewers.	This recommendation was combined with 1995 recommendation U-1 and reaffirmed in 2004 as recommendation U-14.	This recommendation has been implemented to some extent and is reaffirmed as recommendation #17.
U-5: Urban nonpoint source management agencies in Dane County, particularly those tributary to lakes and impoundments should improve the water quality protection and effectiveness of street sweeping of streets in commercial and industrial areas, and regularly (bi-weekly to monthly) sweeping of residential streets thoughout the sweeping season, with extra efforts at thoroughly cleaning all streets in early spring and late autumn. Vacuum sweepers should be used where feasible because of greater removal effectiveness.	This recommendation was reaffirmed in 2004 as recommendation U-17	This recommendation has been implemented to some extent and is reaffirmed as recommendation #6, with revision since the effectiveness has been shown to be limited to debris and large particles.

1995 Summary Plan	2004 Summary Plan	2011 Status
U-6: Urban nonpoint source management agencies should revise their drainage design practices to emphasize the use of open drainage systems incorporating detention and infiltration areas and natural greenways in developing areas.	This recommendation was reaffirmed in 2004 as recommendation U-8.	This recommendation has been implemented to some extent. It is reaffirmed with the revision of emphasizing green infrastructure as recommendation #2.
U-7: Urban nonpoint source management agencies should adopt and vigorously enforce comprehensive erosion and stormwater runoff control ordinances to limit erosion and increases in runoff from new development, consistent with the basic provisions of Dane County Ordinance 14	This recommendation was reaffirmed in 2004 as recommendation U-3, with the revision of adding new state and federal regulations.	This recommendation has been implemented to some extent and is reaffirmed as recommendation #19.
U-8: Specific watershed plans for stormwater management, incorporating flow and water quality management practices, should be prepared for all existing and developing urban drainage basins. Where possible, such plans should be prepared in the context of comprehensive watershed water quality plans	This recommendation was reaffirmed in 2004 as recommendation U-5	This recommendation has been implemented to some extent. It is reaffirmed with the revision of prioritizing studies in sensitive and/or impaired watersheds as recommendation #1.
U-9: A coordinated stormwater management plan and stormwater permitting process should be developed for all communities in the Central Urban Service Area tributary to the Yahara Lakes.	This recommendation was reworded and reaffirmed in 2004 as recommendation U-6.	This recommendation has been implemented in effect by the NR 216 permitting requirements and is reaffirmed as recommendation #20.
U-10: Urban nonpoint source management agencies in the central urban service area should cooperate in sponsoring field tests of the feasibility and effectiveness of porous asphalt pavement and infiltration trenches for possible use in parking lots and residential streets.	This recommendation was reworded and reaffirmed in 2004 as recommendation U-11.	This recommendation has been implemented in effect by the NR 216 permitting requirements and is reaffirmed as recommendation #3.
U-11: Potential approaches to enhancing or improving sediment and phosphorus removal from urban runoff in the design, operation, and maintenance of urban drainage systems tributary to lakes and impoundments should receive priority attention and evaluation.	This recommendation was reworded and reaffirmed in 2004 as recommendation U-10.	This recommendation has been implemented to some extent and is reaffirmed as recommendation #4.

1995 Summary Plan	2004 Summary Plan	2011 Status
U-12: Urban drainage systems and associated land use practices should be designed to minimize the potential for toxic or hazardous materials being discharged or washed off the land surface waters, with emphasis on source control rather than treatment or infiltration.	This recommendation was reworded and reaffirmed in 2004 as recommendation U-12.	This recommendation has been implemented to some extent and is reaffirmed as recommendation #5.
U-13: The use of deicing compounds which could adversely affect surface or groundwater quality should be reduced to the minimum levels possible consistent with safety considerations, and alternative materials and approaches should be explored. Storage sites for road salt and lowed snow should avoid surface or groundwater pollution from runoff or infiltration.	This recommendation was reworded and reaffirmed in 2004 as recommendation U-18.	This recommendation has been implemented to some extent. It is reaffirmed and strengthened with the revision of recommending the preparation of a regional chloride management plan as recommendation #8.
	U-1: All urbanizing units of government should develop comprehensive stormwater management plans that account for water quality and quantity, that encourage infiltration of stormwater, and that are integrated into the long-term land use and open space plans of the area. Stormwater management plans should attempt to mitigate the adverse impacts of development on water resources to the maximum extent practicable.	This recommendation has been implemented to some extent. It is reaffirmed and strengthened with the revision of recommending the standards of maintaining pre-development peak rate control for the 1-, 2-, 10-, and 100-year 24-hours design storms and at least 90% pre-development stay-on volume as recommendations #10 and #11.
	U-2: Management agencies should promote land use patterns and practices which preserve the integrity of the natural hydrologic system, including the balance between groundwater and surface water. Require future development to implement infiltration measures, wherever practicable, as a means of controlling stormwater impacts and ensuring groundwater recharge.	This recommendation has been implemented to some extent. It is reaffirmed and strengthened with the revision of recommending the standard of maintaining pre-development groundwater recharge rates as recommendation #12.

1995 Summary Plan	2004 Summary Plan	2011 Status
	U-4: Dane County should apply to be certified by the DNR as a Local Qualified Program for the issuance of stormwater permits under NR 216.	This recommendation is not reaffirmed due to the difficulty and expense of meeting the DNR's Authorized Local Program requirements.
	U-7: Eligible units of government should apply for funding through the DNR Targeted Runoff Management or Urban Nonpoint Pollution grant programs to develop stormwater management plans and install practices that control urban stormwater impacts.	This recommendation has been implemented to some extent. It is reaffirmed and reworded as recommendation #21.
	U-9: Urban management agencies should work cooperatively with state and local agencies to incorporate stormwater infiltration practices into local erosion control/stormwater management ordinances. Infiltration practices should be designed to protect the groundwater.	This recommendation has been implemented to some extent. It is reaffirmed and strengthened with the revision of recommending the standard of maintaining at least 90% pre-development stay-on volume as recommendation #11.
	U-13: Promote inter-agency review among the appropriate state and local designated management agencies to work with developers to streamline permitting while ensuring protection of the natural resources.	This recommendation has been implemented to some extent and is reaffirmed as recommendation #16.

Recommended Standards

Chapter NR 151 of the Wisconsin Administrative Code and Chapter 14 of the Dane County Code of Ordinances establish the minimum standards for stormwater management in the State of Wisconsin and Dane County, respectively. There are many examples where communities have adopted more protective standards for stormwater management in their local ordinances than the state or county standards. The following standards are recommended for new urban service area amendments, based on the current knowledge of the impacts of stormwater runoff and the available stormwater best management practices described in this report. It is also recommended that Dane County and local municipalities update their stormwater ordinances to include these performance standards.

1. Water Quality

The current sediment control standard in Wisconsin is to remove 80 percent of the average annual post development total suspended solids load (TSS). The standard is based on the expectation that there is an associated reduction in pollutants such as phosphorus and heavy metals, which are bound to the soil particles. The 80% standard was based on what was determined to be the maximum extent practicable reduction achievable using wet detention basins. This is based on the particle size distribution of typical soils and their associated settling velocity, which is calculated using Stokes Law. In Dane County this is the equivalent to sediment control practices that are designed to retain all soil particles greater than 5 microns, for the 1-year 24-hour storm event, based on a Plano silt loam soil.

The DNR has developed or is in the process of developing the Total Maximum Daily Loads (TMDL) that are allowable to meet water quality standards where water resources are currently impaired by sediment or some other pollutant (i.e. on the 303d list). In some cases this may require controlling TSS more than the 80% removal standard. Meeting this higher standard would likely require the use of bio-retention practices or the addition of polymer to wet detention basins.

2. Channel Protection

The purpose of channel protection criteria is to prevent habitat degradation and erosion in urban streams caused by an increased frequency of bankful and sub-bankful stormwater flows. Channel protection criteria seek to minimize downstream channel enlargement and incision that is a common consequence of urbanization. This stream channel erosion and expansion, combined with direct impacts to the stream system, act to decrease the habitat quality of the stream. As a result, streams experience the following impacts to habitat:

- Decline in stream substrate quality (through sediment deposition and embedding of the substrate)
- Loss of pool/riffle structure in the stream channel
- Degradation of stream habitat structure

Historically, Wisconsin and Dane County have used 2-year control (i.e., reduction of the peak flow from the 2-year storm to predeveloped levels) to prevent channel erosion. Research suggests that this measure does not adequately protect stream channels effectively (McCuen and Moglen, 1988, MacRae, 1996). Although the peak flow is lower, it is also extended over a longer period of time, thus increasing the duration of erosive flows. In addition, the bankfull flow event actually becomes more frequent after development occurs. Consequently, capturing the two-year event may not address the channel-forming event.

The current peak flow rate control standard offers little to no control of runoff from the smaller, more frequent storms that produce most of the runoff reaching streams. It is runoff from these small storms that largely determines how a stream will function and transform in response to more erosive velocities and flashier stream flows. Therefore, it is recommended that the 1-yr 24-hr storm also be included in the range of design storms used for peak flow rate control. The WDNR has also acknowledged that research is showing that the current standard is not protective of the bank-full condition and has adopted a change to NR 151 that will add peak flow rate control for the 1-yr 24-hr design storm effective January 1, 2011.

3. Overbank (10-yr) Flood Protection

Flow events that exceed the capacity of the stream channel spill out into the adjacent floodplain. These are termed "overbank" floods, and can damage property and downstream drainage structures. While some overbank flooding is inevitable and even desirable, the historical goal of drainage design in Dane County has been to maintain pre-development peak discharge rates for the ten-year frequency storms, thus keeping the level of overbank flooding the same after development. This prevents costly damage or maintenance for culverts, drainage structures, and swales.

Overbank floods are ranked in terms of their statistical return frequency. For example, a flood that has a 10% chance of occurring in any given year is termed a "ten-year flood." A ten-year flood occurs when a storm event produces 4.2 inches of rain in a 24-hour period. Under traditional engineering practice, most channels and storm drains in Dane County are designed with enough capacity to safely pass the peak discharge from the ten-year design storm.

The current standard of post-development peak discharge rate not exceeding the pre-development peak discharge rate for the 10-year frequency storm event provides protection from increases in the extent of overbank flooding. However without pre-development volume control the duration of overbank flooding will still increase.

4. Extreme (100-yr) Flood Protection

The level areas bordering streams and rivers are known as floodplains. Operationally, the floodplain is usually defined as the land area within the limits of the 100-year storm water elevation. The 100-year storm has a 1% chance of occurring in any given year. In Dane County, a 100-year flood occurs after 6 inches of rainfall in a 24-hour period. These floods can be very destructive, and can pose a threat to property and human life. The goal of extreme flood criteria is to maintain the boundaries of the pre-development 100-year floodplain, reduce risk to life and property from infrequent but very large floods and protect the physical integrity of stormwater BMPs and downstream infrastructure.

The current Dane County standard of safely passing the 100-year storm provides some protection in extreme floods. However, as with overbank floods, development increases the peak discharge rate associated with the 100-year design storm. As a consequence, the elevation of a stream's 100-year floodplain becomes higher and the boundaries of its floodplain expand. In some instances, property and structures that had not previously been subject to flooding are now at risk. Additionally, such a shift in a floodplain's hydrology can degrade wetland and forest habitats. As a result, several communities (see Attachment B) have adopted the standard of the post-development peak discharge rate not exceeding the pre-development peak discharge rate for the 100-year storm event. It is recommended that the 100-year, 24-hr storm be included in the range of design storms used for peak flow rate control.

5. Volume Control

The importance of volume reduction in addition to peak flow rate control has become apparent as more urban areas have been developed. Volume control is needed to mitigate the impacts of longer runoff durations and increased runoff volumes. The term volume control should be distinguished from infiltration. There are many techniques and BMPs, other than infiltration, which can used to provide volume control. Any technique that soaks water into the ground, makes water available for evaporation and/or transpiration, stores water for re-use, or in any way diverts stormwater away from the drainage system can be considered a volume reduction practice. Infiltration is certainly one of these practices, but it is only one of many. In circumstances where soils are too tight or where infiltration could result in ground water induced flooding, other alternatives should be used to reduce volume.

The volume control standard in NR 151 has been in effect since October 2004. It requires residential developments to maintain 90% of annual pre-development stay-on volumes with a 1% cap on the site area required for infiltration BMPs and commercial developments to maintain 60% of annual pre-development stay-on volumes with a 2% cap on the site area required for infiltration BMPs. This standard is often referred to as an infiltration standard, however, it is more accurately called a volume control or stay-on standard, because best management practices that utilize evapotranspiration or infiltration can be used to meet the standard. The site area caps can have the effect of reducing the stay-on requirements in the standard and increasing runoff volumes above the target levels in the standard.

In October 2009, the Capital Area Regional Planning Commission requested that its Environmental Resources Technical Advisory Committee (TAC) convene to provide technical recommendations on a more protective stormwater runoff volume control standard than the one currently required under NR 151 and Dane County Chapter 14. The TAC noted that the existing 60% standard for nonresidential development was so low that it did not require any volume control practices in many cases. The TAC recognized the potential benefits of a runoff volume control standard to 100% of pre-development volumes, however it had several concerns related to the achievability and the cost versus benefit of adopting a standard of no increase in pre-development runoff volumes. The TAC proposed that the Commission adopt a runoff volume control standard for all new Urban Service Area Amendments in which both residential and nonresidential developments control sufficient runoff volume so that post-development stay-on volume shall be at least 90% of the pre-development stay-on volume. The TAC also identified additional research efforts, data collection, and model improvements that should be conducted to provide the information needed to further evaluate this issue and set a 5-year time frame for reevaluation of the proposed standard. Implementation of these efforts will require collaboration among and funding by the many agencies involved in water resource management in our region.

6. Groundwater Recharge

Maintaining base flow discharge to streams and the water supply to springs and wetlands are important resource objectives. Annual groundwater recharge rates must be maintained, by promoting infiltration through the use of structural and non-structural methods. Since there are several best management practices that can be used to meet a volume control standard that do not provide groundwater recharge, it is desirable to meet this resource objective with a separate groundwater recharge standard. This approach is currently used in the City of Middleton and has been used in many urban service area amendments.

It is recommended that pre-development groundwater recharge rates be maintained based on the rates in the Wisconsin Geological and Natural History Survey's 2009 report, *Groundwater Recharge in Dane County, Wisconsin, Estimated by a GIS-Based Water-Balance Model* or future updates, or by a site specific analysis. Experience has shown that this criterion is generally met when the volume control standard is achieved by infiltration practices. Improvements in modeling will result in a better understanding of the degree of groundwater recharge that results from infiltration practices.

Other Considerations

7. Chlorides

Dunn's Marsh is part of the monitoring program of the department of Public Health Madison – Dane County. The marsh continues to show seasonal variations in chloride levels attributable to road salt use. It has occasionally exceeded the DNR chronic toxicity level of 395 mg/L chloride often enough to cause adverse effects on the biota (PHMDC, 2010)

Mean chloride concentrations in Badger Mill Creek have ranged from 132 to 236 mg/l (Montgomery Associates, 2008). This is near the EPA chronic exposure level for freshwater aquatic life. Chloride concentrations in Badger Mill Creek are likely due to both road salt in urban stormwater runoff and water softener salt in treated wastewater effluent.

Recent studies by the USGS (Mullaney et. al., 2009 and Corsi et. al., 2010) found that levels of chloride are elevated in many urban streams and groundwater across the northern U.S. Chloride levels above the recommended federal criteria set to protect aquatic life were found in more than 40 percent of urban streams tested according to the study. This is the unintended consequence that salt use for deicing is having on our waters. It is necessary to continue to implement innovative alternatives that reduce salt use without compromising traffic safety. A DNR water resources management specialist was quoted as saying, "The potential for chloride to damage our water systems is more inevitable than climate change" (Lins 2010). Research is needed to identify cost effective and sustainable methods of keeping our roads safe for driving without damaging our lakes, streams and groundwater.

It is recommended that CARPC, in collaboration with other management agencies, prepare a chloride management plan for the region to examine this issue in more depth.

8. Climate Change

The Wisconsin Initiative on Climate Change Impacts (WICCI) released their first report, Wisconsin's Changing Climate: Impacts and Adaptation, in February 2011. In response to the projected changes in precipitation, their Stormwater Working Group recommends that stormwater design and performance standards:

- Include control of the 100-year storm event
- Require regular updating with the most recent rainfall statistics

NOAA is in the process of updating the precipitation frequency data for Wisconsin. The data is scheduled to be ready for web publication in May 2012. It is recommended that municipalities adopt the recommendations of the WICCI Stormwater Working Group.

9. Watershed Management Plans

It is recommended that watershed level management plans be developed for all watersheds in the region. The plans should assess the resources in the watershed, identify the range of potential opportunities for protecting and enhancing the resources, and set goals for improvement. Development of the plans should be led by CARPC in collaboration with other stakeholders, particularly local municipalities and watershed associations.

It is recommended that these watershed management plans include regional rainfall-runoff modeling to identify the impact of development under current conditions. The full flow regime should be taken into consideration when assessing the impacts of stormwater on water resources. Increased stormwater volume is only one aspect of an urban-altered storm hydrograph. Other hydrologic changes include changes in the sequence and frequency of high flows, the rate of rise and fall of the hydrograph, and the season of the year in which high flows can occur. These can all affect both the physical and biological conditions of streams, lakes, and wetlands (National Research Council, 2008). Coincident peak analyses should also be conducted to identify any detrimental effects of coincident peak flows on downstream areas due to multiple detention facilities in series. This analysis should include routing calculations as well as calculation of peak flows, velocities, and hydraulic effects at critical downstream locations including stream confluences, culverts, other channel constrictions, and flood-prone areas. The Hydroecological Integrity Assessment Process (USGS, 2008) and research from the emerging interdisciplinary field of ecohydrology are additional tools that could be used in developing these plans. The regional surface water models resulting from these plans should be continuously maintained and updated by CARPC. They will provide a better tool for understanding and mitigating the potential cumulative impacts of development.

Pilot studies should begin with the following watersheds with sensitive resources; Badger Mill Creek, Black Earth Creek, and Token Creek.

10. Phosphorus

The U.S. Environmental Protection Agency has required development of a Total Maximum Daily Load for phosphorus throughout the Rock River Basin in Wisconsin, and a more detailed study of pollutant loading to the Yahara chain of lakes has been initiated by a memorandum of understanding between Dane County, the City of Madison, the Wisconsin Department of Natural Resources, the Wisconsin Department of Agriculture, and Trade and Consumer Protection. These studies will determine phosphorus load targets for different land uses throughout the Rock River Basin. In June 2010 the state Natural Resources Board approved new phosphorus rules to address both point and non-point sources of phosphorus pollution.

In 2010 the Madison Metropolitan Sewerage District and Dane County initiated a workgroup to discuss local pollutant trading issues. The workgroup is evaluating local opportunities and mechanisms for phosphorus trading between point sources, urban nonpoint sources, and agricultural nonpoint sources. Their goal is to reduce phosphorus discharges to surface waters in a way that is likely to comply with the revised administrative code requirements, anticipated Rock River TMDL requirements, and future requirements of MMSD's WPDES permit limit for effluent phosphorus discharge.

11. Adaptive Management

Continued periodic monitoring of water resources is necessary to evaluate the success of best management practices in meeting the water management goals of protecting and restoring these resources. It is recommended that adaptive management strategies be implemented. This includes monitoring of the resources, as well as, monitoring of the maintenance and performance of the

BMPs with the implementation of corrective actions as needed. There are several potential mechanisms for instituting an adaptive management system. On example is an annual certification requirement, like that used by the City of Madison for the maintenance of stormwater BMPs. Another mechanism is a deed restriction or real estate document; such as the type used by Dane County for stormwater BMP maintenance. A Memorandum of Understanding (MOU) is another commonly used mechanism for enforceable agreements that is suitable for stormwater management.

It is recommended that CARPC, in collaboration with the Dane County Lakes and Watershed Commission, undertake a legal and institutional analysis of workable approaches to BMP monitoring. This analysis should address approaches to meet and enforce the stormwater standards adopted by Dane County and local municipalities as well as the stormwater performance standards established by the CARPC in the conditions of approval for additions to sewer service areas.

Implementation

Water management issues are regional issues. To adequately address them will require a regional approach to stormwater water management with the cooperation and involvement of all of the municipalities and other management agencies. It is recommended that CARPC conduct regular discussions with the relevant management agencies regarding the implementation of the Dane County Water Quality Plan. During these discussions, specific implementation actions should be developed and agreed upon by all of the management agencies involved.

Chapter 5 of the 2004 Summary Plan of the Dane County Water Quality Plan included a Framework for Action that identified short-range priority actions for local designated management agencies and county agencies or departments. When the next Water Quality Plan Summary is prepared in 2013, it is recommended that the Framework for Action be updated to include specific objectives and metrics for assessing the implementation of these urban nonpoint source recommendations.

Research Needs

During their meetings the TAC recommended the following additional research efforts, data collection, and modeling to provide the information needed to further evaluate the volume control standard:

- Use of the SWAT (Soil and Water Assessment Tool) model or other continuous hydraulic/hydrologic/water quality model to evaluate the impacts of runoff volume on the Yahara Lakes watershed.
- Improvements to the SLAMM model to better account for the split between recharge and evapotranspiration that occurs in infiltration / biofiltration practices
- Improvements to RECARGA, SLAMM, or other models to better predict performance during early season and late season infiltration, including frozen ground conditions.
- Information on the performance and life expectancy of infiltration practices currently in place and an assessment of contributing factors if failures occur
- Case studies demonstrating that volume control to 100% of predevelopment volumes can be met by constructed best management practices
- Biological monitoring, such as pre-development and post-development Indexes of Biotic Integrity (IBI)
- An economic analysis of the costs and water quality benefits of runoff volume control

It is recommended that CARPC work with other agencies to ensure that these research needs are carried out in a timely manner.

Glossary

AQUIFER - A geological formation that contains and transports groundwater.

BANKFULL FLOW - The condition where streamflow just fills a stream channel up to the top of the bank and at a point where the water begins to overflow onto a floodplain.

BASE FLOW - The stream discharge from ground water.

BEST MANAGEMENT PRACTICE (BMP) - An activity, procedure, or engineered device implemented to prevent, control, treat, or reduce water pollution from stormwater runoff.

BIORETENTION - A water quality practice that utilizes landscaping and soils to treat urban stormwater runoff by collecting and storing it in shallow depressions, filtering it through an engineered soil media, then infiltrating and evapotranspirating it.

CANOPY DENSITY - The amount of leaf coverage of trees determined by the ratio of leaf area to ground area.

CHANNELIZED FLOW - Runoff within a defined channel, meaning a defined bed and banks.

CLEAN WATER ACT - The federal Clean Water Act, 33 U.S.C.A. §1251 et. seq.

CONNECTED IMPERVIOUS AREA - An impervious surface connected by storm sewer, an impervious flow path (such as a street, driveway, or parking lot), or a minimally pervious flow path (such as less than 20 feet of lawn).

CURVE NUMBER (CN) - A numerical representation of a given area's hydrologic soil group, plant cover, impervious cover, interception and surface storage derived in accordance with Natural Resources Conservation Service methods. This number is used to convert rainfall volume into runoff volume.

DESIGN STORM - A rainfall event of specific depth, intensity, and frequency used to calculate runoff volume and discharge.

DETENTION - The temporary storage of storm runoff in a BMP with the goals of controlling peak discharge rates and providing gravity settling of pollutants.

DURATION - The length of time over which precipitation or runoff occurs.

ECOHYDROLOGY - The study of the functional interrelations between hydrology and biota at the watershed scale. It is also referred to as hydroecology.

EROSION – The detachment and movement of soil or rock fragments by water, wind, ice or gravity.

EVAPORATION - The process of liquid water converting to water vapor determined by wind, temperature and humidity.

EVAPOTRANSPIRATION - The loss of water from the soil by evaporation and by transpiration.

FREQUENCY (Design Storm Frequency) - The recurrence interval of storm events having the same duration and volume. The frequency of a specified design storm can be expressed either in terms of exceedance probability or return period.

> Exceedance probability: The probability that an event having a specified volume and duration will be exceeded in one time period, usually assumed to be one year. If a storm has a one percent chance of occurring in any given year, then it has an exceedance probability of 0.01.
>
> Return period: The average length of time between events having the same volume and duration. If a storm has a one percent chance of occurring in any given year, then it has a return period of 100 years.

INFILTRATION - The downward movement of water through the soil; the downward flow of runoff from the bottom of an infiltration BMP into the soil.

EXTENDED DETENTION - A stormwater design feature that provides for the gradual release of a volume of water over a 12 to 24 hour interval in order to increase settling of urban pollutants and protect downstream channels from frequent storm events.

EXTREME FLOOD - The infrequent but large storm events in which overbank flows approach the floodplain boundaries of the 100-year flood.

FLOODPLAIN - Areas adjacent to a stream or river that are subject to flooding or inundation during a storm event that occurs, on average, once every 100 years (or has a likelihood of occurrence of 1/100 in any given year).

HYDROGRAPH - A graph showing variation in stage (depth) or discharge of a stream of water over a period of time.

HYDROLOGIC CYCLE - A continuous process where water is cycled from surface waters to the atmosphere to the land and back to surface waters.

HYDROLOGIC SOIL GROUP (HSG) - A Natural Resource Conservation Service classification system in which soils are categorized into four runoff potential groups. The groups range from A soils, with high permeability and little runoff production, to D soils, which have low permeability rates and produce much more runoff.

IMPERVIOUS SURFACE – A surfaces, including, but not limited to, paved and compacted roads, parking areas, roofs, driveways, and walkways, that prevent the entry of water into the soil, causing water to run off the surface in greater quantities and at an increased rate of flow, rather than infiltrate.

INFILTRATION RATE - The rate at which water percolates from the surface into the subsoil measured in inches per hour.

INTENSITY - The depth of rainfall divided by duration.

LEVEL SPREADER - A device for distributing stormwater discharge uniformly over the ground surface as sheet flow to prevent concentrated, erosive flows.

MAXIMUM EXTENT PRACTICABLE (MEP) – State and County regulations define MEP as a level of implementing best management practices in order to achieve a performance standard which takes into account the best available technology, cost effectiveness and other competing issues such as human safety and welfare, endangered and threatened resources, historic properties and geographic features.

NPDES - Acronym for the National Pollutant Discharge Elimination System, for the issuance of permits under section 402 of the federal Clean Water Act and includes the Wisconsin administered NPDES program authorized by the federal Environmental Protection Agency.

OUTFALL - The point where water flows from a conduit, stream, or drain.

ONE YEAR STORM - A stormwater event which occurs on average once every year or statistically has a 100% chance on average of occurring in a given year.

ONE HUNDRED YEAR STORM - An extreme flood event which occurs on average once every 100 years or statistically has a 1% chance on average of occurring in a given year.

OPEN CHANNELS - Also known as swales, or grass channels. These systems are used for the conveyance, infiltration and filtration of stormwater runoff.

OUTLET - The point at which water discharges from such things as a stream, river, lake, basin, pipe, channel or drainage area.

PEAK DISCHARGE RATE - The maximum instantaneous rate of flow during a storm, usually in reference to a specific design storm event.

PERFORMANCE STANDARD - An established amount or limit on the amount of runoff and/or pollutants that can be discharged from a site.

PERMEABLE (PERVIOUS) - Material that allows the infiltration or passage of water into the material below it.

PERMEABILITY - The rate of water movement through the soil column under saturated conditions

POLYNUCLEAR AROMATIC HYDROCARBONS (PAHs) - Hydrocarbon compounds with multiple benzene rings. PAHs are typical components of asphalts, fuels, oils, and greases. They are also called Polycyclic Aromatic Hydrocarbons.

POST-DEVELOPMENT - The conditions that are expected to exist after the construction of a building and its associated infrastructure.

PRECIPITATION - Water falling to the earth as rain, snow, hail, mist, or sleet.

PRE-DEVELOPMENT - The conditions that exist when the plans for a development are approved, typically agriculture or woodland.

PRE-SETTLEMENT - The conditions that existed prior to European settlement and the development of agriculture, typically woodland, meadow, or prairie.

RAIN BARREL – A container designed to collect and store rooftop runoff for later use.

RAIN GARDEN – A type of bioretention practice.

RECHARGE RATE - Annual amount of rainfall that contributes to groundwater.

RECEIVING WATER - A stream, river, lake, other watercourse into which wastewater or stormwater is discharged.

REDEVELOPMENT - Any construction, alteration, or improvement in an existing developed area.

RETENTION - Permanent storage of stormwater.

SHALLOW CONCENTRATED FLOW – Runoff that occurs in rills and gullies, after sheet flow and before the flow reaches a defined channel and becomes channelized flow.

SHEET FLOW – Runoff that occurs only over plane surfaces at the head of the watershed. Due to surface irregularities, sheet flow will eventually transition to shallow concentrated flow. The NRCS/SCS has determined that sheet flow for unpaved areas will never occur for more than 300 feet, with a most likely length of 100 feet. Paved areas may have longer lengths of sheet flow until flow becomes channelized in gutters or low areas of parking lots.

STAY-ON - The amount of precipitation on a drainage area that infiltrates into the ground or evapotranspirates and does not escape as runoff. It is the difference between total precipitation and total runoff.

STORMWATER RUNOFF - precipitation, snowmelt, and the material dissolved or suspended in precipitation and snowmelt that runs off impervious surfaces and does not infiltrate into the ground or evapotranspirate.

SEDIMENT - Solid material, both mineral and organic, that is in suspension, is being transported, or has been moved from its site of origin by air, water, gravity, or ice and has come to rest on the earth's surface either above or below sea level.

STORMWATER MANAGEMENT FACILITY - A device that controls stormwater runoff and changes the characteristics of that runoff including, but not limited to, the quantity and quality, the period of release or the velocity of flow.

STREAM BUFFERS - Zones of variable width that are located along both sides of a stream and are designed to provided a protective natural area along a stream corridor.

TEN YEAR STORM - The peak discharge rate associated with a 24 hour storm event which exceeds bankfull capacity and occurs on average once every ten years (or has a likelihood of occurrence of 10% in a given year).

TIME OF CONCENTRATION - The time required for water to flow from the hydrologic most distant point (in time of flow) of the drainage area to the point of analysis (outlet).

TOTAL MAXIMUM DAILY LOAD or TMDL – The calculations and plan for meeting water quality standards approved by the U.S. Environmental Protection Agency (EPA) and prepared pursuant to 33 U.S.C. 1313(d) and federal regulations adopted under that law.

TOTAL RUNOFF VOLUME - The amount of water which exits a watershed as runoff during a given design storm.

TOTAL SUSPENDED SOLIDS - The total amount of soils particulate matter that is suspended in the water column.

TRANSPIRATION - The process by which water vapor is lost to the atmosphere from living plants.

TWO YEAR STORM - The peak discharge rate associated with a 24 hour storm event which exceeds bankfull capacity and occurs on average once every two years (or has a likelihood of occurrence of 1/2 in a given year).

WATERSHED - The total area of land contributing runoff to a specific point of interest within a receiving water.

303(D) LIST - The EPA-approved State of Wisconsin list of impaired waters prepared pursuant to 33 U.S.C. 1313(d).

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National Recommended Water Quality Criteria

View this document online at http://www.epa.gov/ost/criteria/wqctable/

Priority Pollutants

	Priority Pollutant	CAS Number	Freshwater		Saltwater		Human Health for the consumption of		FR Cite / Source
			CMC 1 (acute) (µg/L)	CCC 1 (chronic) (µg/L)	CMC 1 (acute) (µg/L)	CCC 1 (chronic) (µg/L)	Water + Organism (µg/L)	Organism Only (µg/L)	
1	Antimony	7440360					5.6 B	640 B	65 FR 66443
2	Arsenic	7440382	340 A,D,K	150 A,D,K	69 A,D,bb	36 A,D,bb	0.018 C,M,S	0.14 C,M,S	65 FR 31682 57 FR 60848
3	Beryllium	7440417					Z		65 FR 31682
4	Cadmium	7440439	2.0 D,E,K,bb	0.25 D,E,K,bb	40 D,bb	8.8 D,bb	Z		EPA 822R-01-001 65 FR 31682
5a	Chromium (III)	16065831	570 D,E,K	74 D,E,K			Z Total		EPA 820B-96-001 65 FR 31682
5b	Chromium (VI)	18540299	16 D,K	11 D,K	1,100 D,bb	50 D,bb	Z Total		65 FR 31682
6	Copper	7440508	Freshwater criteria calculated using the BLM mm - See Document (epa.gov/waterscience/criteria/copper/)		4.8 D,cc,ff	3.1 D,cc,ff	1,300 U		EPA-822-R-07-001 65 FR 31682 72 FR 7983
7	Lead	7439921	65 D,E,bb,gg	2.5 D,E,bb,gg	210 D,bb	8.1 D,bb			65 FR 31682
8a	Mercury	7439976	1.4 D,K,hh	0.77 D,K,hh	1.8 D,ee,hh	0.94 D,ee,hh			62 FR 42160
8b	Methylmercury	22967926						0.3 mg/kg J	EPA 823R-01-001
9	Nickel	7440020	470 D,E,K	52 D,E,K	74 D,bb	8.2 D,bb	610 B	4,600 B	65 FR 31682
10	Selenium	7782492	L,R,T	5.0 T	290 D,bb,dd	71 D,bb,dd	170 Z	4200	62 FR 42160 65 FR 31682 65 FR 66443

	Priority Pollutant	CAS Number	Freshwater CMC [1] (acute) (µg/L)	Freshwater CCC [1] (chronic) (µg/L)	Saltwater CMC [1] (acute) (µg/L)	Saltwater CCC [1] (chronic) (µg/L)	Human Health for the consumption of Water + Organism (µg/L)	Human Health for the consumption of Organism Only (µg/L)	FR Cite / Source
11	Silver	7440224	3.2 D,E,G		1.9 D,G				65 FR 31682
12	Thallium	7440280					0.24	0.47	68 FR 75510
13	Zinc	7440666	120 D,E,K	120 D,E,K	90 D,bb	81 D,bb	7,400 U	26,000 U	65 FR 31682 65 FR 66443
14	Cyanide	57125	22 K,Q	5.2 K,Q	1 Q,bb	1 Q,bb	140 jj	140 jj	EPA 820B-96001 57 FR 60848 68 FR 75510
15	Asbestos	1332214					7 million fibers/L I		57 FR 60848
16	2,3,7,8-TCDD (Dioxin)	1746016					5.0E-9 C	5.1E-9 C	65 FR 66443
17	Acrolein	107028	3ug/L	3ug/L			6 ll	9 ll	74 FR 27535 74 FR 46587
18	Acrylonitrile	107131					0.051 B,C	0.25 B,C	65 FR 66443
19	Benzene	71432					2.2 B,C	51 B,C	IRIS 01/19/00 65 FR 66443
20	Bromoform	75252					4.3 B,C	140 B,C	65 FR 66443
21	Carbon Tetrachloride	56235					0.23 B,C	1.6 B,C	65 FR 66443
22	Chlorobenzene	108907					130 Z,U	1,600 U	68 FR 75510
23	Chlorodibromomethane	124481					0.40 B,C	13 B,C	65 FR 66443
24	Chloroethane	75003							
25	2-Chloroethylvinyl Ether	110758							
26	Chloroform	67663					5.7 C,P	470 C,P	62 FR 42160

	Priority Pollutant	CAS Number	Freshwater		Saltwater		Human Health for the consumption of		FR Cite / Source
			CMC [1] (acute) (µg/L)	CCC [1] (chronic) (µg/L)	CMC [1] (acute) (µg/L)	CCC [1] (chronic) (µg/L)	Water + Organism (µg/L)	Organism Only (µg/L)	
27	Dichlorobromomethane	75274					0.55 B,C	17 B,C	65 FR 66443
28	1,1-Dichloroethane	75343							
29	1,2-Dichloroethane	107062					0.38 B,C	37 B,C	65 FR 66443
30	1,1-Dichloroethylene	75354					330	7,100	68 FR 75510
31	1,2-Dichloropropane	78875					0.50 B,C	15 B,C	65 FR 66443
32	1,3-Dichloropropene	542756					0.34 C	21 C	68 FR 75510
33	Ethylbenzene	100414					530	2,100	68 FR 75510
34	Methyl Bromide	74839					47 B	1,500 B	65 FR 66443
35	Methyl Chloride	74873							65 FR 31682
36	Methylene Chloride	75092					4.6 B,C	590 B,C	65 FR 66443
37	1,1,2,2-Tetrachloroethane	79345					0.17 B,C	4.0 B,C	65 FR 66443
38	Tetrachloroethylene	127184					0.69 C	3.3 C	65 FR 66443
39	Toluene	108883					1,300 Z	15,000	68 FR 75510
40	1,2-Trans-Dichloroethylene	156605					140 Z	10,000	68 FR 75510
41	1,1,1-Trichloroethane	71556					Z		65 FR 31682
42	1,1,2-Trichloroethane	79005					0.59 B,C	16 B,C	65 FR 66443
43	Trichloroethylene	79016					2.5 C	30 C	65 FR 66443
44	Vinyl Chloride	75014					0.025 C,kk	2.4 C,kk	68 FR 75510
45	2-Chlorophenol	95578					81 B,U	150 B,U	65 FR 66443

	Priority Pollutant	CAS Number	Freshwater		Saltwater		Human Health for the consumption of		FR Cite / Source
			CMC [1] (acute) (µg/L)	CCC [1] (chronic) (µg/L)	CMC [1] (acute) (µg/L)	CCC [1] (chronic) (µg/L)	Water + Organism (µg/L)	Organism Only (µg/L)	
46	2,4-Dichlorophenol	120832					77 B,U	290 B,U	65 FR 66443
47	2,4-Dimethylphenol	105679					380 B	850 B,U	65 FR 66443
48	2-Methyl-4,6Dinitrophenol	534521					13	280	65 FR 66443
49	2,4-Dinitrophenol	51285					69 B	5,300 B	65 FR 66443
50	2-Nitrophenol	88755							
51	4-Nitrophenol	100027							
52	3-Methyl-4-Chlorophenol	59507					U	U	
53	Pentachlorophenol	87865	19 F,K	15 F,K	13 bb	7.9 bb	0.27 B,C	3.0 B,C,H	65 FR 31682
54	Phenol	108952					10,000 II,U	860,000 II,U	74 FR 27535
55	2,4,6-Trichlorophenol	88062					1.4 B,C	2.4 B,C,U	65 FR 66443
56	Acenaphthene	83329					670 B,U	990 B,U	65 FR 66443
57	Acenaphthylene	208968							65 FR 66443
58	Anthracene	120127					8,300 B	40,000 B	65 FR 66443
59	Benzidine	92875					0.000086 B,C	0.00020 B,C	65 FR 66443
60	Benzo(a) Anthracene	56553					0.0038 B,C	0.018 B,C	65 FR 66443
61	Benzo(a) Pyrene	50328					0.0038 B,C	0.018 B,C	65 FR 66443
62	Benzo(b) Fluoranthene	205992					0.0038 B,C	0.018 B,C	65 FR 66443
63	Benzo(ghi) Perylene	191242							65 FR 66443
64	Benzo(k) Fluoranthene	207089					0.0038 B,C	0.018 B,C	65 FR 66443

	Priority Pollutant	CAS Number	Freshwater		Saltwater		Human Health for the consumption of		FR Cite / Source
			CMC 1 (acute) (µg/L)	CCC 1 (chronic) (µg/L)	CMC 1 (acute) (µg/L)	CCC 1 (chronic) (µg/L)	Water + Organism (µg/L)	Organism Only (µg/L)	
65	Bis(2-Chloroethoxy) Methane	111911							
66	Bis(2-Chloroethyl) Ether	111444					0.030 B,C	0.53 B,C	65 FR 66443
67	Bis(2-Chloroisopropyl) Ether	108601					1,400 B	65,000 B	65 FR 66443
68	Bis(2-Ethylhexyl) Phthalatex	117817					1.2 B,C	2.2 B,C	65 FR 66443
69	4-Bromophenyl Phenyl Ether	101553							
70	Butylbenzyl Phthalatew	85687					1,500 B	1,900 B	65 FR 66443
71	2-Chloronaphthalene	91587					1,000 B	1,600 B	65 FR 66443
72	4-Chlorophenyl Phenyl Ether	7005723							
73	Chrysene	218019					0.0038 B,C	0.018 B,C	65 FR 66443
74	Dibenzo(a,h)Anthracene	53703					0.0038 B,C	0.018 B,C	65 FR 66443
75	1,2-Dichlorobenzene	95501					420	1,300	68 FR 75510
76	1,3-Dichlorobenzene	541731					320	960	65 FR 66443
77	1,4-Dichlorobenzene	106467					63	190	68 FR 75510
78	3,3'-Dichlorobenzidine	91941					0.021 B,C	0.028 B,C	65 FR 66443
79	Diethyl Phthalatew	84662					17,000 B	44,000 B	65 FR 66443
80	Dimethyl Phthalatew	131113					270,000	1,100,000	65 FR 66443
81	Di-n-Butyl Phthalatew	84742					2,000 B	4,500 B	65 FR 66443
82	2,4-Dinitrotoluene	121142					0.11 C	3.4 C	65 FR 66443
83	2,6-Dinitrotoluene	606202							

			Freshwater		Saltwater		Human Health for the consumption of		
	Priority Pollutant	**CAS Number**	**CMC [1] (acute) (µg/L)**	**CCC [1] (chronic) (µg/L)**	**CMC [1] (acute) (µg/L)**	**CCC [1] (chronic) (µg/L)**	**Water + Organism (µg/L)**	**Organism Only (µg/L)**	**FR Cite / Source**
84	Di-n-Octyl Phthalate	117840							
85	1,2-Diphenylhydrazine	122667					0.036 B,C	0.20 B,C	65 FR 66443
86	Fluoranthene	206440					130 B	140 B	65 FR 66443
87	Fluorene	86737					1,100 B	5,300 B	65 FR 66443
88	Hexachlorobenzene	118741					0.00028 B,C	0.00029 B,C	65 FR 66443
89	Hexachlorobutadiene	87683					0.44 B,C	18 B,C	65 FR 66443
90	Hexachlorocyclopentadiene	77474					40 U	1,100 U	68 FR 75510
91	Hexachloroethane	67721					1.4 B,C	3.3 B,C	65 FR 66443
92	Ideno(1,2,3-cd)Pyrene	193395					0.0038 B,C	0.018 B,C	65 FR 66443
93	Isophorone	78591					35 B,C	960 B,C	65 FR 66443
94	Naphthalene	91203							
95	Nitrobenzene	98953					17 B	690 B,H,U	65 FR 66443
96	N-Nitrosodimethylamine	62759					0.00069 B,C	3.0 B,C	65 FR 66443
97	N-Nitrosodi-n-Propylamine	621647					0.0050 B,C	0.51 B,C	65 FR 66443
98	N-Nitrosodiphenylamine	86306					3.3 B,C	6.0 B,C	65 FR 66443
99	Phenanthrene	85018							
100	Pyrene	129000					830 B	4,000 B	65 FR 66443
101	1,2,4-Trichlorobenzene	120821					35	70	68 FR 75510

	Priority Pollutant	CAS Number	Freshwater		Saltwater		Human Health for the consumption of		FR Cite / Source
			CMC [1] (acute) (µg/L)	CCC [1] (chronic) (µg/L)	CMC [1] (acute) (µg/L)	CCC [1] (chronic) (µg/L)	Water + Organism (µg/L)	Organism Only (µg/L)	
102	Aldrin	309002	3.0 G		1.3 G		0.000049 B,C	0.000050 B,C	65 FR 31682 65 FR 66443
103	alpha-BHC	319846					0.0026 B,C	0.0049 B,C	65 FR 66443
104	beta-BHC	319857					0.0091 B,C	0.017 B,C	65 FR 66443
105	gamma-BHC (Lindane)	58899	0.95 K		0.16 G		0.98	1.8	65 FR 31682 68 FR 75510
106	delta-BHC	319868							
107	Chlordane	57749	2.4 G	0.0043 G,aa	0.09 G	0.004 G,aa	0.00080 B,C	0.00081 B,C	65 FR 31682 65 FR 66443
108	4,4'-DDT	50293	1.1 G,ii	0.001 G,aa,ii	0.13 G,ii	0.001 G,aa,ii	0.00022 B,C	0.00022 B,C	65 FR 31682 65 FR 66443
109	4,4'-DDE	72559					0.00022 B,C	0.00022 B,C	65 FR 66443
110	4,4'-DDD	72548					0.00031 B,C	0.00031 B,C	65 FR 66443
111	Dieldrin	60571	0.24 K	0.056 K,O	0.71 G	0.0019 G,aa	0.000052 B,C	0.000054 B,C	65 FR 31682 65 FR 66443
112	alpha-Endosulfan	959988	0.22 G,Y	0.056 G,Y	0.034 G,Y	0.0087 G,Y	62 B	89 B	65 FR 31682 65 FR 66443
113	beta-Endosulfan	33213659	0.22 G,Y	0.056 G,Y	0.034 G,Y	0.0087 G,Y	62 B	89 B	65 FR 31682 65 FR 66443
114	Endosulfan Sulfate	1031078					62 B	89 B	65 FR 66443
115	Endrin	72208	0.086 K	0.036 K,O	0.037 G	0.0023 G,aa	0.059	0.060	65 FR 31682 68 FR 75510
116	Endrin Aldehyde	7421934					0.29 B	0.30 B,H	65 FR 66443
117	Heptachlor	76448	0.52 G	0.0038 G,aa	0.053 G	0.0036 G,aa	0.000079 B,C	0.000079 B,C	65 FR 31682 65 FR 66443

	Priority Pollutant	CAS Number	Freshwater		Saltwater		Human Health for the consumption of		FR Cite / Source
			CMC 1 (acute) (µg/L)	CCC 1 (chronic) (µg/L)	CMC 1 (acute) (µg/L)	CCC 1 (chronic) (µg/L)	Water + Organism (µg/L)	Organism Only (µg/L)	
118	Heptachlor Epoxide	1024573	0.52 G,V	0.0038 G,V,aa	0.053 G,V	0.0036 G,V,aa	0.000039 B,C	0.000039 B,C	65 FR 31682 65 FR 66443
119	Polychlorinated Biphenyls (PCBs)			0.014 N,aa		0.03 N,aa	0.000064 B,C,N	0.000064 B,C,N	65 FR 31682 65 FR 66443
120	Toxaphene	8001352	0.73	0.0002 aa	0.21	0.0002 aa	0.00028 B,C	0.00028 B,C	65 FR 31682 65 FR 66443

Footnotes

A This recommended water quality criterion was derived from data for arsenic (III), but is applied here to total arsenic, which might imply that arsenic (III) and arsenic (V) are equally toxic to aquatic life and that their toxicities are additive. In the arsenic criteria document (PDF) (74 pp., 3.2 MB) (EPA 440/5-84-033, January 1985), Species Mean Acute Values are given for both arsenic (III) and arsenic (V) for five species and the ratios of the SMAVs for each species range from 0.6 to
1.7. Chronic values are available for both arsenic (III) and arsenic (V) for one species; for the fathead minnow, the chronic value for arsenic (V) is 0.29 times the chronic value for arsenic (III). No data are known to be available concerning whether the toxicities of the forms of arsenic to aquatic organisms are additive.

B This criterion has been revised to reflect The Environmental Protection Agency's q1* or RfD, as contained in the Integrated Risk Information System (IRIS) as of May 17, 2002. The fish tissue bioconcentration factor (BCF) from the 1980 Ambient Water Quality Criteria document was retained in each case.

C This criterion is based on carcinogenicity of 10^{-6} risk. Alternate risk levels may be obtained by moving the decimal point (e.g., for a risk level of 10^{-5}, move the decimal point in the recommended criterion one place to the right).

D Freshwater and saltwater criteria for metals are expressed in terms of the dissolved metal in the water column. The recommended water quality criteria value was calculated by using the previous 304(a) aquatic life criteria expressed in terms of total recoverable metal, and multiplying it by a conversion factor (CF). The term "Conversion Factor" (CF) represents the recommended conversion factor for converting a metal criterion expressed as the total recoverable fraction in the water column to a criterion expressed as the dissolved fraction in the water column. (Conversion Factors for saltwater CCCs are not currently available. Conversion factors derived for saltwater CMCs have been used for both saltwater CMCs and CCCs). See "Office of Water Policy and Technical Guidance on Interpretation and Implementation of Aquatic Life Metals Criteria (PDF)," (49 pp., 3MB) October 1, 1993, by Martha G. Prothro, Acting Assistant Administrator for Water, available from the Water Resource center and 40CFR§131.36(b)(1). Conversion Factors applied in the table can be found in Appendix A to the Preamble-Conversion Factors for Dissolved Metals.

E The freshwater criterion for this metal is expressed as a function of hardness (mg/L) in the water column. The value given here corresponds to a hardness of 100 mg/L. Criteria values for other hardness may be calculated from the following: CMC (dissolved) = $\exp\{m_A [\ln(\text{hardness})] + b_A\}$ (CF), or CCC (dissolved) = $\exp\{m_C [\ln(\text{hardness})] + b_C\}$ (CF)

and the parameters specified in Appendix B-Parameters for Calculating Freshwater Dissolved Metals Criteria That Are Hardness-Dependent.

F Freshwater aquatic life values for pentachlorophenol are expressed as a function of pH, and are calculated as follows: CMC = exp(1.005(pH)-4.869); CCC = exp(1.005(pH)-5.134). Values displayed in table correspond to a pH of 7.8.

G This Criterion is based on 304(a) aquatic life criterion issued in 1980, and was issued in one of the following documents: Aldrin/Dieldrin (PDF) (153 pp., 7.3 MB) (EPA 440/5-80-019), Chlordane (PDF) (68 pp., 3.1 MB) (EPA 440/5-80-027), DDT (PDF) (175 pp., 8.3 MB) (EPA 440/5-80-038), Endosulfan (PDF) (155 pp., 7.3 MB) (EPA 440/5-80-046), Endrin (PDF) (103 pp., 4.6 MB) (EPA 440/5-80-047), Heptachlor (PDF) (114 pp., 5.4 MB) (EPA 440/5-80-052), Hexachlorocyclohexane (PDF) (109 pp., 4.8 MB) (EPA 440/5-80-054), Silver (EPA 440/5-80-071). The Minimum Data Requirements and derivation procedures were different in the 1980 Guidelines than in the 1985 Guidelines (PDF) (104 pp., 3.3 MB) . For example, a "CMC" derived using the 1980 Guidelines was derived to be used as an instantaneous maximum. If assessment is to be done using an averaging period, the values given should be divided by 2 to obtain a value that is more comparable to a CMC derived using the 1985 Guidelines.

H No criterion for protection of human health from consumption of aquatic organisms excluding water was presented in the 1980 criteria document or in the *1986 Quality Criteria for Water*. Nevertheless, sufficient information was presented in the 1980 document to allow the calculation of a criterion, even though the results of such a calculation were not shown in the document.

I This criterion for asbestos is the Maximum Contaminant Level (MCL) developed under the Safe Drinking Water Act (SDWA).

J This fish tissue residue criterion for methylmercury is based on a total fish consumption rate of 0.0175 kg/day.

K This recommended criterion is based on a 304(a) aquatic life criterion that was issued in the 1995 Updates: Water Quality Criteria Documents for the Protection of Aquatic Life in Ambient Water, (EPA 820-B-96-001, September 1996). This value was derived using the GLI Guidelines (60 FR 15393-15399, March 23, 1995; 40CFR132 Appendix A); the difference between the 1985 Guidelines and the GLI Guidelines are explained on page iv of the 1995 Updates. None of the decisions concerning the derivation of this criterion were affected by any considerations that are specific to the Great Lakes.

L The CMC = 1/[(f1/CMC1) + (f2/CMC2)] where f1 and f2 are the fractions of total selenium that are treated as selenite and selenate, respectively, and CMC1 and CMC2 are 185.9 g/l and 12.82 g/l, respectively.

M EPA is currently reassessing the criteria for arsenic.

N This criterion applies to total pcbs, (e.g., the sum of all congener or all isomer or homolog or Aroclor analyses.)

O The derivation of the CCC for this pollutant (Endrin) did not consider exposure through the diet, which is probably important for aquatic life occupying upper trophic levels.

P Although a new RfD is available in IRIS, the surface water criteria will not be revised until the National Primary Drinking Water Regulations: Stage 2 Disinfectants and Disinfection Byproducts Rule (Stage 2 DBPR) is completed, since public comment on the relative source contribution (RSC) for chloroform is anticipated.

Q This recommended water quality criterion is expressed as g free cyanide (as CN)/L.

R This value for selenium was announced (61 FR 58444-58449, November 14, 1996) as a proposed GLI 303(c) aquatic life criterion. EPA is currently working on this criterion and so this value might change substantially in the near future.

S This recommended water quality criterion for arsenic refers to the inorganic form only.

T This recommended water quality criterion for selenium is expressed in terms of total recoverable metal in the water column. It is scientifically acceptable to use the conversion factor (0.996-CMC or 0.922-CCC) that was used in the GLI to convert this to a value that is expressed in terms of dissolved metal.

U The organoleptic effect criterion is more stringent than the value for priority toxic pollutants.

V This value was derived from data for heptachlor and the criteria document provides insufficient data to estimate the relative toxicities of heptachlor and heptachlor epoxide.

W Although EPA has not published a completed criteria document for butylbenzyl phthalate it is EPA's understanding that sufficient data exist to allow calculation of aquatic criteria. It is anticipated that industry intends to publish in the peer reviewed literature draft aquatic life criteria generated in accordance with EPA Guidelines. EPA will review such criteria for possible issuance as national WQC.

X There is a full set of aquatic life toxicity data that show that DEHP is not toxic to aquatic organisms at or below its solubility limit.

Y This value was derived from data for endosulfan and is most appropriately applied to the sum of alpha-endosulfan and beta-endosulfan.

Z A more stringent MCL has been issued by EPA. Refer to drinking water regulations (40 CFR 141) or Safe Drinking Water Hotline (1-800-426-4791) for values.

aa This criterion is based on a 304(a) aquatic life criterion issued in 1980 or 1986, and was issued in one of the following documents: Aldrin/Dieldrin (PDF) (153 pp., 7.3 MB) (EPA 440/5-80-019), Chlordane (PDF) (68 pp., 3.1 MB) (EPA 440/5-80027), DDT (PDF) (175 pp., 8.3 MB) (EPA 440/5-80-038), Endrin (PDF) (103 pp., 4.6 MB) (EPA 440/5-80-047), Heptachlor (PDF) (114 pp., 5.4 MB) (EPA 440/5-80-052), Polychlorinated biphenyls (EPA 440/5-80-068), Toxaphene (EPA 440/5-86-006). This CCC is currently based on the Final Residue Value (FRV) procedure. Since the publication of the Great Lakes Aquatic Life Criteria Guidelines in 1995 (60 FR 15393-15399, March 23, 1995), the Agency no longer uses the Final Residue Value procedure for deriving CCCs for new or revised 304(a) aquatic life criteria. Therefore, the Agency anticipates that future revisions of this CCC will not be based on the FRV procedure.

bb This water quality criterion is based on a 304(a) aquatic life criterion that was derived using the 1985 Guidelines (PDF) (104 pp., 3.3 MB) (*Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses*, PB85-227049, January 1985) and was issued in one of the following criteria documents: Arsenic (PDF) (74 pp., 3.2 MB) (EPA 440/5-84-033), Cadmium (EPA 822-R-01-001), Chromium (EPA 440/5-84-029), Copper (PDF) (150 pp., 6.2 MB) (EPA 440/5-84-031), Cyanide (PDF) (67 pp., 2.7 MB) (EPA 440/5-84-028), Lead (EPA 440/5-84-027), Nickel (EPA 440/5-86-004), Pentachlorophenol (EPA 440/5-86-009), Toxaphene, (EPA 440/5-86-006), Zinc (EPA 440/5-87-003).
cc When the concentration of dissolved organic carbon is elevated, copper is substantially less toxic and use of Water-Effect Ratios might be appropriate.

dd The selenium criteria document (EPA 440/5-87-006, September 1987) provides that if selenium is as toxic to saltwater fishes in the field as it is to freshwater fishes in the field, the status of the fish community should be monitored whenever the concentration of selenium exceeds 5.0 g/L in salt water because the saltwater CCC does not take into account uptake via the food chain.

ee This recommended water quality criterion was derived on page 43 of the mercury criteria document (PDF) (144 pp., 6.4 MB) (EPA 440/5-84-026, January 1985). The saltwater CCC of 0.025 ug/L given on page 23 of the criteria document is based on the Final Residue Value procedure in the 1985 Guidelines. Since the publication of the Great Lakes Aquatic Life Criteria Guidelines in 1995 (60 FR 15393-15399, March 23, 1995), the Agency no longer uses the Final Residue Value procedure for deriving CCCs for new or revised 304(a) aquatic life criteria.

ff This recommended water quality criterion was derived in *Ambient Water Quality Criteria Saltwater Copper Addendum* (Draft, April 14, 1995) and was promulgated in the Interim final National Toxics Rule (60 FR 22228-222237, May 4, 1995).

gg EPA is actively working on this criterion and so this recommended water quality criterion may change substantially in the near future.

hh This recommended water quality criterion was derived from data for inorganic mercury (II), but is applied here to total mercury. If a substantial portion of the mercury in the water column is methylmercury, this criterion will probably be under protective. In addition, even though inorganic mercury is converted to methylmercury and methylmercury bioaccumulates to a great extent, this criterion does not account for uptake via the food chain because sufficient data were not available when the criterion was derived.

ii This criterion applies to DDT and its metabolites (i.e., the total concentration of DDT and its metabolites should not exceed this value).

jj This recommended water quality criterion is expressed as total cyanide, even though the IRIS RFD we used to derive the criterion is based on free cyanide. The multiple forms of cyanide that are present in ambient water have significant differences in toxicity due to their differing abilities to liberate the CN-moiety. Some complex cyanides require even more extreme conditions than refluxing with sulfuric acid to liberate the CN-moiety. Thus, these complex cyanides are expected to have little or no 'bioavailability' to humans. If a substantial fraction of the cyanide present in a water body is present in a complexed form (e.g., $Fe_4[Fe(CN)_6]_3$), this criterion may be over conservative.

kk This recommended water quality criterion was derived using the cancer slope factor of 1.4 (LMS exposure from birth).

ll This criterion has been revised to reflect the Environmental Protection Agency's cancer slope factor (CSF) or reference dose (RfD), as contained in the Integrated Risk Information System (IRIS) as of (Final FR Notice June 10, 2009). The fish tissue bioconcentration factor (BCF) from the 1980 Ambient Water Quality Criteria document was retained in each case.

mm The available toxicity data, when evaluated using the procedures described in the "Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses" indicate that freshwater aquatic life should be protected if the 24-hour average and four-day average concentrations do not respectively exceed the acute and chronic criteria concentrations calculated by the Biotic Ligand Model.

Non Priority Pollutants

	Non Priority Pollutant	CAS Number	Freshwater		Saltwater		Human Health for the consumption of		FR Cite / Source
			CMC (acute) (µg/L)	CCC (chronic) (µg/L)	CMC (acute) (µg/L)	CCC (chronic) (µg/L)	Water + Organism (µg/L)	Organism Only (µg/L)	
1	**Alkalinity**	—		20000 F					Gold Book
2	**Aluminum pH 6.5 – 9.0**	7429905	750 G,I	87 G,I,L					53 FR 33178
3	**Ammonia**	7664417	FRESHWATER CRITERIA ARE pH, Temperature and Life-stage DEPENDENT — SEE DOCUMENT D SALTWATER CRITERIA ARE pH AND TEMPERATURE DEPENDENT						EPA 822-R99-014 EPA 440-588-004
4	**Aesthetic Qualities**	—	NARRATIVE STATEMENT — SEE DOCUMENT						Gold Book
5	**Bacteria**	—	FOR PRIMARY RECREATION AND SHELLFISH USES — SEE DOCUMENT						Gold Book
6	**Barium**	7440393					1,000 A		Gold Book
7	**Boron**	—	NARRATIVE STATEMENT — SEE DOCUMENT						Gold Book
8	**Chloride**	16887006	860000 G	230000 G					53 FR 19028
9	**Chlorine**	7782505	19	11	13	7.5	C		Gold Book
10	**Chlorophenoxy Herbicide (2,4,5,-TP)**	93721					10 A		Gold Book
11	**Chlorophenoxy Herbicide (2,4-D)**	94757					100 A,C		Gold Book
12	**Chloropyrifos**	2921882	0.083 G	0.041 G	0.011 G	0.0056 G			Gold Book
13	**Color**	—	NARRATIVE STATEMENT — SEE DOCUMENT F						Gold Book
14	**Demeton**	8065483		0.1 F		0.1 F			Gold Book
15	**Ether, Bis(Chloromethyl)**	542881					0.00010 E,H	0.00029 E,H	65 FR 66443
16	**Gases, Total Dissolved**	—	NARRATIVE STATEMENT — SEE DOCUMENT F						Gold Book

	Non Priority Pollutant	CAS Number	Freshwater		Saltwater		Human Health for the consumption of		FR Cite / Source
			CMC (acute) (µg/L)	CCC (chronic) (µg/L)	CMC (acute) (µg/L)	CCC (chronic) (µg/L)	Water + Organism (µg/L)	Organism Only (µg/L)	
17	**Guthion**	86500		0.01 F		0.01 F			Gold Book
18	**Hardness**	—	NARRATIVE STATEMENT — SEE DOCUMENT						Gold Book
19	**Hexachlorocyclo-hexane-Technical**	608731					0.0123 H	0.0414 H	EPA 440/5-80-054
20	**Iron**	7439896		1000 F			300 A		Gold Book
21	**Malathion**	121755		0.1 F		0.1 F			Gold Book
22	**Manganese**	7439965					50 A,O	100 A	Gold Book
23	**Methoxychlor**	72435		0.03 F		0.03 F	100 A,C		Gold Book
24	**Mirex**	2385855		0.001 F		0.001 F			Gold Book
25	**Nitrates**	14797558					10,000 A		Gold Book
26	**Nitrosamines**	—					0.0008	1.24	Gold Book
27	**Dinitrophenols**	25550587					69	5300	65 FR 66443
28	**Nonylphenol**	84852153	28ug/L	28ug/L	7ug/L	7ug/L			71 FR 9337
29	**Nitrosodibutylamine, N**	924163					0.0063 A,H	0.22 A,H	65 FR 66443
30	**Nitrosodiethylamine, N**	55185					0.0008 A,H	1.24 A,H	Gold Book
31	**Nitrosopyrrolidine, N**	930552					0.016 H	34 H	65 FR 66443
32	**Oil and Grease**	—	NARRATIVE STATEMENT — SEE DOCUMENT F						Gold Book
33	**Oxygen, Dissolved Freshwater Oxygen, Dissolved Saltwater**	7782447	WARMWATER AND COLDWATER MATRIX — SEE DOCUMENT N SALTWATER — SEE DOCUMENT						Gold Book EPA 822-R00-012
34	**Diazinon**	333415	0.17ug/L	0.17ug/L	0.82ug/L	0.82ug/L			71 FR 9336

	Non Priority Pollutant	CAS Number	Freshwater		Saltwater		Human Health for the consumption of		FR Cite / Source
			CMC (acute) (µg/L)	CCC (chronic) (µg/L)	CMC (acute) (µg/L)	CCC (chronic) (µg/L)	Water + Organism (µg/L)	Organism Only (µg/L)	
35	**Parathion**	56382	0.065 J	0.013 J					Gold Book
36	**Pentachlorobenzene**	608935					1.4 E	1.5 E	65 FR 66443
37	**pH**	—		6.5 – 9 F		6.5 – 8.5 F,K	5 – 9		Gold Book
38	**Phosphorus Elemental**	7723140				0.1 F,K			Gold Book
39	**Nutrients**	—	See EPA's Ecoregional criteria for Total Phosphorus, Total Nitrogen, Chlorophyll *a* and Water Clarity (Secchi depth for lakes; turbidity for streams and rivers) (& Level III Ecoregional criteria)						P
40	**Solids Dissolved and Salinity**	—						250,000 A	Gold Book
41	**Solids Suspended and Turbidity**	—	NARRATIVE STATEMENT—SEE DOCUMENT F						Gold Book
42	**Sulfide-Hydrogen Sulfide**	7783064		2.0 F		2.0 F			Gold Book
43	**Tainting Substances**	—	NARRATIVE STATEMENT—SEE DOCUMENT						Gold Book
44	**Temperature**	—	SPECIES DEPENDENT CRITERIA—SEE DOCUMENT M						Gold Book
45	**Tetrachlorobenzene,1,2,4,5**	95943					0.97 E	1.1 E	65 FR 66443
46	**Tributyltin (TBT)**	—	0.46 Q	0.072 Q	0.42 Q	0.0074 Q			69 FR 342
47	**Trichlorophenol,2,4,5**	95954					1,800 B,E	3,600 B,E	65 FR 66443

Footnotes

A This human health criterion is the same as originally published in the Red Book (EPA 440/9-76-023, July, 1976) which predates the 1980 methodology and did not utilize the fish ingestion BCF approach. This same criterion value is now published in the Gold Book (Quality Criteria for Water: 1986. EPA 440/5-86-001).

B The organoleptic effect criterion is more stringent than the value presented in the non priority pollutants table.

C A more stringent Maximum Contaminant Level (MCL) has been issued by EPA under the Safe Drinking Water Act. Refer to drinking water regulations 40CFR141 or Safe Drinking Water Hotline (1-800-426-4791) for values.

D According to the procedures described in the *Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses*, except possibly where a very sensitive species is important at a site, freshwater aquatic life should be protected if both conditions specified in Appendix C to the Preamble-Calculation of Freshwater Ammonia Criterion are satisfied.

E This criterion has been revised to reflect EPA's q1* or RfD, as contained in the Integrated Risk Information System (IRIS) as of May 17, 2002. The fish tissue bioconcentration factor (BCF) used to derive the original criterion was retained in each case.

F The derivation of this value is presented in the Red Book (EPA 440/9-76-023, July, 1976).

G This value is based on a 304(a) aquatic life criterion that was derived using the 1985 Guidelines (*Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses*, PB85-227049, January 1985) and was issued in one of the following criteria documents: Aluminum (EPA 440/5-86-008); Chloride (EPA 440/5-88001); Chloropyrifos (EPA 440/5-86-005).

H This criterion is based on carcinogenicity of 10^{-6} risk. Alternate risk levels may be obtained by moving the decimal point (e.g., for a risk level of 10^{-5}, move the decimal point in the recommended criterion one place to the right).

I This value for aluminum is expressed in terms of total recoverable metal in the water column.

J This value is based on a 304(a) aquatic life criterion that was issued in the *1995 Updates: Water Quality Criteria Documents for the Protection of Aquatic Life in Ambient Water* (EPA 820-B-96-001). This value was derived using the GLI Guidelines (60 FR 15393-15399, March 23, 1995; 40CFR132 Appendix A); the differences between the 1985 Guidelines and the GLI Guidelines are explained on page iv of the 1995 Updates. No decision concerning this criterion was affected by any considerations that are specific to the Great Lakes.

K According to page 181 of the Red Book (EPA 440/9-76-023, July, 1976): For open ocean waters where the depth is substantially greater than the euphotic zone, the pH should not be changed more than 0.2 units from the naturally occurring variation or any case outside the range of 6.5 to 8.5. For shallow, highly productive coastal and estuarine areas where naturally occurring pH variations approach the lethal limits of some species, changes in pH should be avoided but in any case should not exceed the limits established for fresh water, i.e., 6.5-9.0.

L There are three major reasons why the use of Water-Effect Ratios might be appropriate.

The value of 87 µg/l is based on a toxicity test with the striped bass in water with pH = 6.5–6.6 and hardness <10 mg/L. Data in "Aluminum Water-Effect Ratio for the 3M Plant Effluent Discharge, Middleway, West Virginia" (May 1994) indicate that aluminum is substantially less toxic at higher pH and hardness, but the effects of pH and hardness are not well quantified at this time.

In tests with the brook trout at low pH and hardness, effects increased with increasing concentrations of total aluminum even though the concentration of dissolved aluminum was constant, indicating that total recoverable is a more appropriate measurement than dissolved, at least when particulate aluminum is primarily aluminum hydroxide particles. In surface waters, however, the total recoverable procedure might measure aluminum associated with clay particles, which might be less toxic than aluminum associated with aluminum hydroxide.

EPA is aware of field data indicating that many high quality waters in the U.S. contain more than 87 g aluminum/L, when either total recoverable or dissolved is measured.

M U.S. EPA. 1973. Water Quality Criteria 1972. EPA-R3-73-033. National Technical Information Service, Springfield, VA.; U.S. EPA. 1977. Temperature Criteria for Freshwater Fish: Protocol and Procedures. EPA 600/3-77-061. National Technical Information Service, Springfield, VA.

N U.S. EPA. 1986. Ambient Water Quality Criteria for Dissolved Oxygen. EPA 440/5-86-003. National Technical Information Service, Springfield, VA.

O This criterion for manganese is not based on toxic effects, but rather is intended to minimize objectionable qualities such as laundry stains and objectionable tastes in beverages.

P Lakes and Reservoirs in Nutrient Ecoregion: II EPA 822-B-00-007, III EPA 822-B-01-008, IV EPA 822-B-01-009, V EPA 822-B-01-010, VI EPA 822-B-00-008 , VII EPA 822-B-00-009, VIII EPA 822-B-01-015, IX EPA 822-B-00-011, XI EPA 822-B-00-012, XII EPA 822-B-00-013, XIII EPA 822-B-00-014, XIV EPA 822-B-01-011; Rivers and Streams in Nutrient Ecoregion: I EPA 822-B-01-012, II EPA 822-B-00-015, III EPA 822-B-00-016, IV EPA 822-B-01-013, V EPA 822-B-01-014, VI EPA 822-B-00-017, VII EPA 822-B-00-018, VIII EPA 822-B-01-015, IX EPA 822-B-00-019, X EPA 822-B-01-016, XI EPA 822-B-00-020, XII EPA 822-B-00-021, XIV EPA 822-B-00-022; and Wetlands in Nutrient Ecoregion (PDF) (77 pp., 257 K) XIII EPA 822-B-00-023.

Q EPA announced the availability of a draft updated tributyltin (TBT) document on August 7, 1997 (62 FR 42554). The Agency has reevaluated this document and anticipates releasing an updated document for public comment in the near future.

Organoleptic Effects (e.g., taste and odor)

	Pollutant	CAS Number	Organoleptic Effect Criteria (µg/L)	FR Cite/ Source
1	Acenaphthene	83329	20	Gold Book
2	Monochlorobenzene	108907	20	Gold Book
3	3-Chlorophenol	—	0.1	Gold Book
4	4-Chlorophenol	106489	0.1	Gold Book
5	2,3-Dichlorophenol	—	0.04	Gold Book
6	2,5-Dichlorophenol	—	0.5	Gold Book
7	2,6-Dichlorophenol	—	0.2	Gold Book
8	3,4-Dichlorophenol	—	0.3	Gold Book
9	2,4,5-Trichlorophenol	95954	1	Gold Book
10	2,4,6-Trichlorophenol	88062	2	Gold Book
11	2,3,4,6-Tetrachlorophenol	—	1	Gold Book
12	2-Methyl-4-Chlorophenol	—	1800	Gold Book
13	3-Methyl-4-Chlorophenol	59507	3000	Gold Book
14	3-Methyl-6-Chlorophenol	—	20	Gold Book
15	2-Chlorophenol	95578	0.1	Gold Book
16	Copper	7440508	1000	Gold Book
17	2,4-Dichlorophenol	120832	0.3	Gold Book
18	2,4-Dimethylphenol	105679	400	Gold Book
19	Hexachlorocyclopentadiene	77474	1	Gold Book
20	Nitrobenzene	98953	30	Gold Book
21	Pentachlorophenol	87865	30	Gold Book
22	Phenol	108952	300	Gold Book
23	Zinc	7440666	5000	45 FR79341

Notes

1. These criteria are based on organoleptic (taste and odor) effects. Because of variations in chemical nomenclature systems, this listing of pollutants does not duplicate the listing in Appendix A of 40 CFR Part 423. Also listed are the Chemical Abstracts Service (CAS) registry numbers, which provide a unique identification for each chemical.

Additional Notes

1. Criteria Maximum Concentration and Criterion Continuous Concentration

The Criteria Maximum Concentration (CMC) is an estimate of the highest concentration of a material in surface water to which an aquatic community can be exposed briefly without resulting in an unacceptable effect. The Criterion Continuous Concentration (CCC) is an estimate of the highest concentration of a material in surface water to which an aquatic community can be exposed indefinitely without resulting in an unacceptable effect. The CMC and CCC are just two of the six parts of an aquatic life criterion; the other four parts are the acute averaging period, chronic averaging period, acute frequency of allowed exceedence, and chronic frequency of allowed exceedence. Because 304(a) aquatic life criteria are national guidance, they are intended to be protective of the vast majority of the aquatic communities in the United States.

2. Criteria Recommendations for Priority Pollutants, Non Priority Pollutants and Organoleptic Effects

This compilation lists all priority toxic pollutants and some non priority toxic pollutants, and both human health effect and organoleptic effect criteria issued pursuant to CWA §304(a). Blank spaces indicate that EPA has no CWA §304(a) criteria recommendations. For a number of non-priority toxic pollutants not listed, CWA §304(a) "water + organism" human health criteria are not available, but EPA has published MCLs under the SDWA that may be used in establishing water quality standards to protect water supply designated uses. Because of variations in chemical nomenclature systems, this listing of toxic pollutants does not duplicate the listing in Appendix A of 40 CFR Part 423. Also listed are the Chemical Abstracts Service CAS registry numbers, which provide a unique identification for each chemical.

3. Human Health Risk

The human health criteria for the priority and non priority pollutants are based on carcinogenicity of 10-6 risk. Alternate risk levels may be obtained by moving the decimal point (e.g., for a risk level of 10-5, move the decimal point in the recommended criterion one place to the right).

4. Water Quality Criteria published pursuant to Section 304(a) or Section 303(c) of the CWA

Many of the values in the compilation were published in the California Toxics Rule. Although such values were published pursuant to Section 303(c) of the CWA, they represent the Agency's most recent calculation of water quality criteria and are thus the Agency's 304(a) criteria.

5. Calculation of Dissolved Metals Criteria

The 304(a) criteria for metals, shown as dissolved metals, are calculated in one of two ways. For freshwater metals criteria that are hardness-dependent, the dissolved metal criteria were calculated using a hardness of 100 mg/l as CaCO3 for illustrative purposes only. Saltwater and freshwater metals' criteria that are not hardness-dependent are calculated by multiplying the total recoverable criteria before rounding by the appropriate conversion factors. The final dissolved metals' criteria in the table are rounded to two significant figures. Information regarding the calculation of hardness dependent conversion factors are included in the footnotes.

6. **Maximum Contaminant Levels**

The compilation includes footnotes for pollutants with Maximum Contaminant Levels (MCLs) more stringent than the recommended water quality criteria in the compilation. MCLs for these pollutants are not included in the compilation, but can be found in the appropriate drinking water regulations (40 CFR 141.11-16 and 141.60-63), or can be accessed through the Safe Drinking Water Hotline (800-426-4791) or online.

7. **Organoleptic Effects**

The compilation contains 304(a) criteria for pollutants with toxicity-based criteria as well as non-toxicity based criteria. The basis for the non-toxicity based criteria are organoleptic effects (e.g., taste and odor) which would make water and edible aquatic life unpalatable but not toxic to humans. The table includes criteria for organoleptic effects for 23 pollutants. Pollutants with organoleptic effect criteria more stringent than the criteria based on toxicity (e.g., included in both the priority and non-priority pollutant tables) are footnoted as such.

8. **Gold Book**

The Gold Book is Quality Criteria for Water: 1986. EPA 440/5-86-001.

9. **Correction of Chemical Abstract Services Number**

The Chemical Abstract Services number (CAS) for Bis(2-Chlorisoprpyl) Ether, has been revised in IRIS and in the table. The correct CAS number for this chemical is 108-60-1. The previous CAS number for this pollutant was 39638-32-9.

10. **Contaminants with Blanks**

EPA has not calculated criteria for contaminants with blanks. However, permit authorities should address these contaminants in NPDES permit actions using the States' existing narrative criteria for toxics.

11. **Specific Chemical Calculations**

Selenium — Aquatic Life This compilation contains aquatic life criteria for selenium that are the same as those published in the proposed CTR. In the CTR, EPA proposed an acute criterion for selenium based on the criterion proposed for selenium in the Water Quality Guidance for the Great Lakes System (61 FR 58444). The GLI and CTR proposals take into account data showing that selenium's two prevalent oxidation states in water, selenite and selenate, present differing potentials for aquatic toxicity, as well as new data indicating that various forms of selenium are additive. The new approach produces a different selenium acute criterion concentration, or CMC, depending upon the relative proportions of selenite, selenate, and other forms of selenium that are present. EPA is currently undertaking a reassessment of selenium, and expects the 304(a) criteria for selenium will be revised based on the final reassessment (63 FR 26186). However, until such time as revised water quality criteria for selenium are published by the Agency, the recommended water quality criteria in this compilation are EPA's current 304(a) criteria.

Appendices

Appendix A — Conversion Factors for Dissolved Metals

Metal	Conversion Factor			
	freshwater CMC	freshwater CCC	saltwater CMC	saltwater CCC[1]
Arsenic	1.000	1.000	1.000	1.000
Cadmium	1.136672-[(ln hardness)(0.041838)]	1.101672-[(ln hardness)(0.041838)]	0.994	0.994
Chromium III	0.316	0.860	—	—
Chromium VI	0.982	0.962	0.993	0.993
Copper	0.960	0.960	0.83	0.83
Lead	1.46203-[(ln hardness)(0.145712)]	1.46203-[(ln hardness)(0.145712)]	0.951	0.951
Mercury	0.85	0.85	0.85	0.85
Nickel	0.998	0.997	0.990	0.990
Selenium	—	—	0.998	0.998
Silver	0.85	—	0.85	—
Zinc	0.978	0.986	0.946	0.946

Appendix B — Parameters for Calculating Freshwater Dissolved Metals Criteria That Are Hardness-Dependent

Chemical	mA	bA	mC	bC	Freshwater Conversion Factors (CF)	
					CMC	CCC
Cadmium	1.0166	-3.924	0.7409	-4.719	1.136672[(*ln*hardness)(0.041838)]	1.101672[(*ln*hardness)(0.041838)]
Chromium III	0.8190	3.7256	0.8190	0.6848	0.316	0.860
Copper	0.9422	-1.700	0.8545	-1.702	0.960	0.960
Lead	1.273	-1.460	1.273	-4.705	1.46203[(*ln*hardness)(0.145712)]	1.46203[(*ln*hardness)(0.145712)]
Nickel	0.8460	2.255	0.8460	0.0584	0.998	0.997
Silver	1.72	-6.59	—	—	0.85	—
Zinc	0.8473	0.884	0.8473	0.884	0.978	0.986

Hardness-dependant metals' criteria may be calculated from the following:

$CMC\ (dissolved) = \exp\{m_A\ [\mathit{ln}(hardness)] + b_A\}\ (CF)$

$CCC\ (dissolved) = \exp\{m_C\ [\mathit{ln}(hardness)] + b_C\}\ (CF)$

Appendix C — Calculation of Freshwater Ammonia Criterion

1. The one-hour average concentration of total ammonia nitrogen (in mg N/L) does not exceed, more than once every three years on the average, the CMC (acute criterion) calculated using the following equations:

- Where salmonid fish are present:

  $CMC = (0.275/(1 + 10^{7.204-pH})) + (39.0/(1 + 10^{pH-7.204}))$

- Or where salmonid fish are not present:

  $CMC = (0.411/(1 + 10^{7.204-pH})) + (58.4/(1 + 10^{pH-7.204}))$

2. A. The thirty-day average concentration of total ammonia nitrogen (in mg N/L) does not exceed, more than once every three years on theaverage, the CCC (chronic criterion) calculated using the following equations:

   - When fish early life stages are present:

     - $CCC = ((0.0577/(1 + 10^{7.688-pH})) + (2.487/(1 + 10^{pH-7.688}))) \times MIN\ (2.85,\ 1.45 \bullet 10^{0.028 \bullet (25-T)})$

   - When fish early life stages are absent:

     - $CCC = ((0.0577/(1 + 10^{7.688-pH})) + (2.487/(1 + 10^{pH-7.688}))) \times 1.45 \bullet 10^{0.028 \bullet (25-MAX(T,7))}$

   B. In addition, the highest four-day average within the 30-day period should not exceed 2.5 times the CCC.

Attachment B
Municipal Stormwater Ordinance Summary

Chapter 14 of the Dane County Ordinances establishes the minimum standards for storm water management within the county. These requirements are described in the Local Ordinances section of this report and summarized below. Municipalities that have adopted more protective stormwater management standards than those required by Dane County are summarized in the following table. All municipalities will be required to update their ordinances to include peak rate control for the 1-yr 24-hr design storm, adopted in NR 151 in January 2011 and the 90% min. pre-development volume control standard adopted by Dane County in March 2011.

Municipality	Ordinance Chapter / Section	Peak Runoff Rate Control							Volume Control Standard	Groundwater Recharge Standard
		Max. Ag. CN[1]	-yr, 24-hr Design Storms							
			1	2	5	10	25	100		
Dane County[2]	14	68		X		X			90%	
City of Fitchburg	27	68		X		X		X	60% / 90%	
City of Madison	37	68		X		X		X	90%	
City of Middleton[3]	26	58		X		X	X	X	60% / 90%	7.6" / yr.
City of Sun Prairie[4]	15	68		X		X	X		60% / 90%	
City of Verona	15-2	58		X		X		X	60% / 90%	
Village of Cottage Grove	163	68		X		X		X	60% / 90%	
Village of DeForest	24	68	X	X	X	X	X	X	100%	predevelopment
Village of Marshall	15-2	68		X		X		X	60% / 90%	
Village of Mazomanie	215	68		X		X		X	60% / 90%	
Village of McFarland	8-18	58		X		X	X	X	60% / 90%	
Village of Mount Horeb[5]	20	68		X		X		X	60% / 90%	
Village of Oregon	22	58		X		X		X	60% / 90%	
Town of Westport	10-2, 10-4	68		X	X	X	X	X	100-yr 24-hr	

[1] Maximum pre-development runoff curve number allowed for agricultural land use with Hydrologic Soil Group B soils.
[2] Dane County adopted a 90% pre-development volume control standard for all land uses in March 2011.
[3] 100-yr event peak runoff rate control for is only required for the Badger Mill Creek Watershed. The City of Madison adopted peak rate control for the 1-yr, 24-hr storm and a 90% pre-development volume control standard for all land uses in March 2011.
[4] 10, and 25-yr post development peak runoff rate control is to the 5-yr pre development rate.

Attachment C

Management Practices for Urban Nonpoint Source Pollution

Bioretention System

Bioretention systems collect and filter stormwater through layers of mulch, soil and plant root systems. Pollutants such as bacteria, nitrogen, phosphorus, heavy metals, oil and grease are retained, degraded and absorbed. Treated stormwater is then infiltrated into the ground as groundwater, evapotranspirated by the plants, or collected by an under-drain system and discharged to storm sewer.

Benefits

Bioretention areas are suitable stormwater treatment practices for all land uses, as long as the contributing drainage area is appropriate for the size of the facility. Common bioretention opportunities include landscaping islands, cul-de-sacs, parking lot margins, commercial setbacks, open space, rooftop drainage and street terraces (i.e., between the curb and sidewalk). Bioretention is extremely versatile because of its ability to be incorporated into landscaped areas. The versatility of the practice also allows for bioretention areas to be frequently used as stormwater retrofits.

The National Pollutant Removal Performance Database (CWP, 2007) reports the following third quartile pollutant removal percentages for bioretention practices:

Pollutant	% Removal Rate
Suspended Solids	74
Total Phosphorous	30
Total Nitrogen	55
Metals	95 – 97

It also notes that the range of pollutant removal performance can be quite high.

Photo: Sequoya Commons - Madison

Costs

Typical costs for bioretention are $13,000 to $30,000 per acre-foot according to the *Stormwater Runoff Reduction Program Final Report* (MMSD, 2007)

Considerations

The *WDNR Technical Standard Number 1004* and the *Dane County Erosion Control and Stormwater Management Manual* provide useful guidelines and additional references for planning, designing, constructing, and maintaining this type of stormwater management practice.

Examples

Bioretention systems are becoming common in our region, particularly for parking lot runoff. The stormwater management section of the CAPRC web site contains a map with locations and photos of good examples of BMPs in our region.

Constructed Wetlands

Constructed wetlands are created for stormwater management and are not natural wetlands. Constructed wetlands systems are designed to mimic the complicated, interdependent contaminant removal mechanisms of natural wetlands. In general, they remove pollutants through physical, chemical, and biological processes including absorption, adsorption, filtration, microbial transformation (biodegradation), precipitation, sedimentation, uptake by vegetation, and volatilization. Stormwater wetlands are similar in design to stormwater ponds and mainly differ by their variety of water depths and associated vegetative complex.

Benefits

Constructed wetlands are widely applicable stormwater treatment practices that provide both water quality treatment and water quantity control. They are best suited for drainage areas of at least 10 acres. When designed and maintained properly, constructed wetlands can be an important aesthetic feature of a site. Typically, constructed wetlands are more effective at removing suspended solids and pollutants that adsorb to solids, than at removing dissolved pollutants.

The National Pollutant Removal Performance Database (CWP, 2007) reports the following third quartile pollutant removal percentages for constructed wetlands:

Pollutant	% Removal Rate
Suspended Solids	86
Total Phosphorous	76
Total Nitrogen	55
Metals	63 – 68
Bacteria	88

It also notes that the range of pollutant removal performance can be quite high.

Photo Credit: F.X. Browne Inc. Lansdale, PA

Costs

Typical costs for constructed wetlands are $60,000 per acre-foot according to the *Stormwater Runoff Reduction Program Final Report* (MMSD, 2007)

Considerations

The *Wisconsin Stormwater Manual* and the *Dane County Erosion Control and Stormwater Management Manual* provide useful guidelines and additional references for planning, designing, constructing, and maintaining this type of stormwater management practice

A maintenance plan that includes harvesting of the plant material is important to the phosphorus removal potential of constructed wetlands.

Examples

There are no known examples of constructed wetlands for stormwater management in our region.

Dry Detention Basin

A dry basin temporarily retains stormwater and gradually releases it.

Benefits

Dry basins reduce stormwater peak flow rates and trap some sediment particles. By trapping sediment, associated pollutants are also removed. Dry basins are designed to drain completely within 48 hours of the storm event. They are often utilized in thermally sensitive watersheds, as they do not increase the temperature of the runoff.

The National Pollutant Removal Performance Database (CWP, 2007) reports the following third quartile pollutant removal percentages for dry ponds:

Pollutant	% Removal Rate
Suspended Solids	71
Total Phosphorous	25
Total Nitrogen	31
Metals	42 – 59
Bacteria	92

It also notes that the range of pollutant removal performance can be quite high.

Costs

There is no published information available on the typical costs for dry detention basins in our region.

Considerations

The *Dane County Erosion Control and Stormwater Management Manual* provides useful guidelines and additional references for planning, designing, constructing, and maintaining this type of stormwater management practice.

Photo: Wellness and Athletic Center – Stoughton

Dry detention basins provide only limited pollutant removal and accumulated sediment is often resuspended by subsequent storm events. As a result, these structures are not well suited for providing sediment control, but can be suitable practices for peak flow rate control. The use of gabions outlets or underdrains can improve the filtration performance of these systems. They can be useful for providing detention in areas where thermal control is required, provided they are part of a treatment train and preceded by other BMPs for sediment control.

Examples

The stormwater management section of the CAPRC web site contains a map with locations and photos of good examples of BMPs in our region.

Filter / Vegetated Buffer Strips

Filter strips are typically bands of close-growing vegetation, usually grass, planted between pollutant source areas and a downstream receiving waterbody. They also can be used as outlet or pretreatment devices for other stormwater control practices.

Benefits

Vegetated buffers are strips of vegetation, either natural or planted, around sensitive areas such as waterbodies, wetlands, woodlands, or highly erodible soils. In addition to protecting sensitive areas, vegetated strips help to reduce stormwater runoff impacts by trapping sediment and sediment-bound pollutants, providing some infiltration, and slowing and dispersing stormwater flows over a wide area.

The National Pollutant Removal Performance Database (CWP, 2007) reports the following third quartile pollutant removal percentages for filtering practices:

Pollutant	% Removal Rate
Suspended Solids	92
Total Phosphorous	66
Total Nitrogen	47
Metals	67 – 91
Bacteria	70

It also notes that the range of pollutant removal performance can be quite high.

Costs

Typical costs for filter strips are $13,000 to $30,000 per acre according to the *Stormwater Runoff Reduction Program Final Report* (MMSD, 2007).

Photo: Wingra Creek – Madison

Considerations

The *Wisconsin Stormwater Manual* and the *Dane County Erosion Control and Stormwater Management Manual* provide useful guidelines and additional references for planning, designing, constructing, and maintaining this type of stormwater management practice.

This practice is not effective in situations with concentrated flow.

Examples

The stormwater management section of the CAPRC web site contains a map with locations and photos of good examples of BMPs in our region.

Green Roofs

Green roofs are rooftops that are covered with vegetation. Green roofs have a waterproof layer on top of which lies a drainage system and a layer of engineered soil that can be planted with a variety of vegetation. Rain that falls on a green roof will be absorbed by the soil, taken up by the vegetation and transpired back into the atmosphere, reducing rooftop runoff. There are two types of green roofs: extensive, which are constructed with a minimal soil layer (less than 6") and support primarily dense, low growing, drought-resistant vegetation; and intensive, which have a thick layer of soil (greater than 6") and can support all types of vegetation, including shrubs and trees. Some green roofs are open to the public and may look similar to an urban park.

Photo: First Unitarian Church – Shorewood Hills

Benefits

Volume attenuation and flow reduction are the primary stormwater benefits associated with green roofs. The volume of rain water a green roof can retain will vary with thickness and porosity of the soil medium and size of the vegetated area. Generally, green roofs can retain 70% - 90% of rainfall in the summer and 25% - 40% of winter precipitation. Additionally, green roofs can reduce peak flows by 50% - 90% during a single storm event. The soil medium and vegetation of a green roof can act as a filter for water running off non-vegetated portions of a roof or rooftop runoff from above and can prevent runoff from particulates and nutrients accumulated from atmospheric depositions. Green roofs add extra insulation to a building, reducing overall energy costs, and protect the underlying roofing materials from destructive ultra violet rays, extending the lifespan of the roof.

Costs

Typical costs for green roofs are $8 to $15 per square foot according to the *Stormwater Runoff Reduction Program Final Report* (MMSD, 2007).

Considerations

The plant communities must be carefully selected from those that are tolerant of the extreme weather conditions found on roofs. Roofs must be structurally capable of supporting the load of saturated soils. Extensive green roofs can be constructed on roofs with up to a 40% slope, however, roofs with a greater than 15% slope may require extra structural supports to hold soil medium and vegetation in place.

Examples

The stormwater management section of the CAPRC web site contains a map with locations and photos of good examples of BMPs in our region.

Infiltration Basins

Infiltration basins provide runoff volume control by detaining runoff and slowly releasing the water into the ground. By diverting a significant portion of the runoff into the soil, infiltration basins can recharge groundwater, preserve base flows in streams, protect downstream biota, and help reduce erosion and flooding downstream.

Benefits

The performance of infiltration basins depends on how much water is diverted to groundwater. Their ability to capture nutrients depends on the soil and the basin's detention volume. Pretreatment should be included to prevent premature clogging of the basins and to minimize the potential for groundwater contamination. Recommended pretreatment options include presettling basins, sand filters, sediment sumps, biofiltration swales, and vegetative filter strips.

The National Pollutant Removal Performance Database (CWP, 2007) reports the following third quartile pollutant removal percentages for infiltration practices:

Pollutant	% Removal Rate
Suspended Solids	96
Total Phosphorous	96
Total Nitrogen	65
Metals	83 – 89

It also notes that the range of pollutant removal performance can be quite high.

Costs

There is no published information available on the typical costs for infiltration basins in our region.

Photo: Arboretum Dr. - Waunakee

Considerations

The *WDNR Technical Standard Number 1003*, the *Wisconsin Stormwater Manual*, and the *Dane County Erosion Control and Stormwater Management Manual* provide useful guidelines and additional references for planning, designing, constructing, and maintaining this type of stormwater management practice.

Infiltration practices are highly dependent on the infiltration capacity of the underlying soils. Low soil infiltration capacity requires structures with larger infiltration surface area and storage capacity to account for slower infiltration rates. Higher soil infiltration rates allow for smaller infiltration structures. Accurate field measurements of infiltration rates or laboratory analysis of soil particle sizes are critical for the successful design and implementation of stormwater treatment practices that rely on infiltration of stormwater to underlying soils.

Examples

The stormwater management section of the CAPRC web site contains a map with locations and photos of good examples of BMPs in our region.

Infiltration Trenches

An infiltration trench, also called a French drain, or a Dutch drain, is an excavated trench that has been backfilled with stone to form a subsurface basin. Stormwater runoff is diverted into the trench and is stored until it can be infiltrated into the soil, usually over a period of several days.

Benefits

Infiltration trenches are very adaptable practices, and the availability of many practical configurations makes them ideal for small urban drainage areas. They are most effective and have a longer life cycle when some form of pretreatment is included in their design. Pretreatment may include techniques like vegetated filter strips or grassed swales.

The National Pollutant Removal Performance Database (CWP, 2007) reports the following third quartile pollutant removal percentages for infiltration practices:

Pollutant	% Removal Rate
Suspended Solids	96
Total Phosphorous	96
Total Nitrogen	65
Metals	83 – 89

It also notes that the range of pollutant removal performance can be quite high.

Costs

Typical costs for French drains are $15 to $17 per square foot according to the *Stormwater Runoff Reduction Program Final Report* (MMSD, 2007).

Photo: PDQ Century Ave. – Middleton

Considerations

The *Wisconsin Stormwater Manual* and the *Dane County Erosion Control and Stormwater Management Manual* provide useful guidelines and additional references for planning, designing, constructing, and maintaining this type of stormwater management practice.

Infiltration practices are highly dependent on the infiltration capacity of the underlying soils. Low soil infiltration capacity requires structures with larger infiltration surface area and storage capacity to account for slower infiltration rates. Higher soil infiltration rates allow for smaller infiltration structures. Accurate field measurements of infiltration rates or laboratory analysis of soil particle sizes are critical for the successful design and implementation of stormwater treatment practices that rely on infiltration of stormwater to underlying soils. Care must be taken to avoid clogging of infiltration trenches, especially during site construction activities. Collection boxes or an equivalent for silt or other debris are recommended for roof runoff and parking lots.

Examples

The stormwater management section of the CAPRC web site contains a map with locations and photos of good examples of BMPs in our region.

Improving Soil Porosity

Increasing soil porosity induces subsurface flow and increases the rate at which stormwater is removed from the surface of the land. This decreases the amount of water that runs across the land surface, especially in areas that have highly impermeable soils.

Benefits

It has been shown in many studies that earthworm channel building (macroporosity building) increases infiltration rates. On agricultural lands with no-till practices there can be up to a 17 percent increase in field holding capacity; in areas where there is earthworm activity the cumulative rainfall intake into the soil was increased by one half. Water infiltration rates in soils with earthworms are 4 to 10 times faster than in soils without worms (Edwards & Bohlen, 1996).

Compost amendments increase the organic matter and provide more tilth in the soil, which in turn, restores some of the soil's lost porosity. Once porosity is restored, the soil is better able to store and infiltrate runoff. In addition to reducing bulk density, (Kolsti et al., 1995) reported that soils amended with compost reduced the volume of surface runoff by 29 to 50 percent. The chisel-plowed and deep-tilled treatment reduced the volume of runoff by 36 to 53 percent. When compost was added, the reduction in runoff volume increased substantially to 74 to 91 percent (Balousek 2003).

Lawn aeration is another method of improving soil porosity. Aerating creates macropores, allowing more oxygen and water to move into the soil and provides a haven for root growth. The accelerated root growth improves nutrient and water uptake. This in turn stimulates grass growth and results in increased lawn infiltration.

Photo credit: Organic Solutions

Costs

Typical costs for compost amendments are $1 to $2 per square foot according to the *Stormwater Runoff Reduction Program Final Report* (MMSD, 2007).

Considerations

The *WDNR Technical Standard Number S100* provides useful guidelines and additional references for planning, designing, constructing, and maintaining this type of stormwater management practice

The UW-Extension publication, *Lawn Aeration and Topdressing*, provide useful guidance for this type of stormwater management practice.

Examples

Compaction mitigation with deep tilling to improve soil porosity is very common plat construction practice in our region.

Level Spreader

Photo credit: Lake County Illinois

A level spreader typically is an outlet designed to convert concentrated runoff to sheet flow and disperse it uniformly across a slope or wetland to prevent erosion and concentrated flow. One type of level spreader is a shallow trench filled with crushed stone. .

Benefits

The benefit of a level spreader is to convert concentrated runoff to sheet flow and disperse it uniformly in a thin layer (usually less than 1 inch in depth) over a wide surface. This prevents concentrated flow that can cause erosion. Level spreaders are used in conjunction with other BMPs.

Costs

There is no published information available on the typical costs for level spreaders in our region. Considerations

Considerations

The lower edge of the level spreader must be exactly level if the spreader is to work properly.

The North Carolina Extension publication, *Level Spreaders: Overview, Design, and Maintenance*, provides useful guidance for this type of stormwater management practice.

Examples

Level spreaders are used routinely in our region, particularly for discharges to wetlands. The stormwater management section of the CAPRC web site contains a map with locations and photos of good examples of BMPs in our region.

Native Plants

Native prairie plant species have deep roots systems that can extend as deep as 15 feet below the surface. These plants often have greater biomass below the surface than above. In comparison the root depth of turf grasses is only several inches.

Benefits

Native plants have extensive root systems that improve the ability of the soil to infiltrate water and withstand wet or erosive conditions. Many native prairie plants also have the ability to penetrate clay soils with their root systems. One-third of the roots die each year creating long channels to transport water, oxygen and microbes. They cycle minerals from deep in the soil to the top horizons. The roots allow water infiltration from the surface to deep depths and they mine that same water during dry periods. The root films provide habitat for microbes that are excellent at purifying recharge groundwater.

Costs

Native plant seed is available from many local suppliers. Typical seed costs are $1,350 per acre. The costs for mature plants typically range from $1 to $3 each depending on the type and quantity.

Considerations

The *Dane County Erosion Control and Stormwater Management Manual* provide useful guidelines and additional references for selecting, installing, and maintaining this type of stormwater management practice.

Establishing native plants from seed can take several years and requires initial maintenance. Companies like Agrecol have developed a “prairie sod” product, which significantly reduces the establishment period and initial maintenance requirements.

Photo credit: Prairie Nursery

Examples

The stormwater management section of the CAPRC web site contains a map with locations and photos of good examples of BMPs in our region.

Oil and Grease Filter

Oil and grease filters are proprietary devices that are designed to remove oil, grease, sediments, trash, and other debris from stormwater by passing them through a filtering device. Oil and grease filters are most often used at gas stations, industrial sites, parking lots, loading areas, and other locations where hydrocarbons are likely to be present in large quantities.

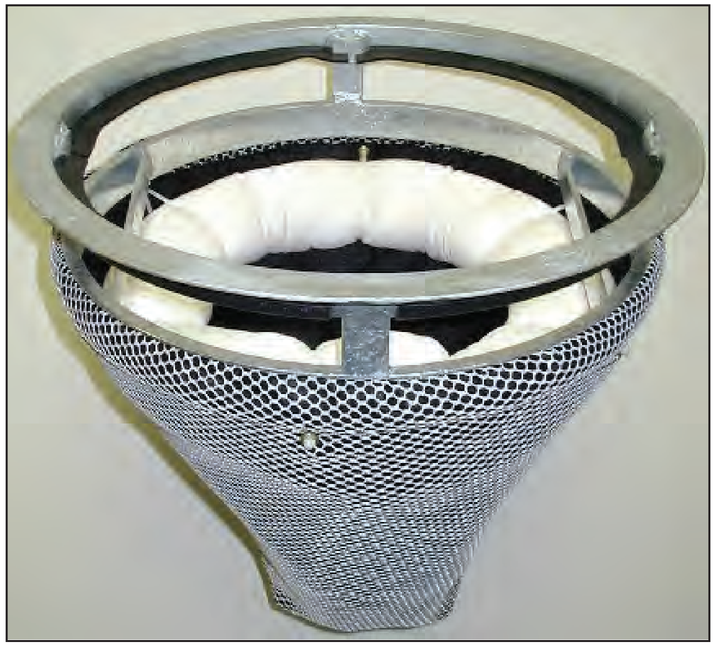

Photo Credit: Marathon Materials, Inc.

Benefits

The primary benefit of this type of BMP is as a pre-treatment device for the removal of trash, debris, large diameter sediment particles, oil and grease.

Costs

Costs will vary by project size. Project specific quotes can be obtained by contacting product vendors.

Considerations

In high flow situations, the volume of water may exceed the capacity of the filter chamber and stormwater may bypass the device without treatment. As a result, these practices are best used in conjunction with other management practices.

The *Dane County Erosion Control and Stormwater Management Manual* provides useful guidelines and additional references for the design, installation, and maintenance of this type of stormwater management practice.

Examples

Oil and grease filter inserts for storm sewer inlets are very common in our region for parking lots. There are many local examples.

Porous Pavement

Porous pavements include a number of different structurally strong, pervious, surfacing materials that allow the infiltration of stormwater below the pavement surface. They include porous concrete, porous asphalt, porous glass paving material, modular paving blocks, and structural grids filled with porous materials. It is recommended that porous pavements have a subbase of sand or aggregate so that runoff water is not stored in the surface matrix. This makes damage from freezing unlikely to occur.

Benefits

Pervious pavement reduces stormwater runoff flow rate and volume, recharges groundwater and maintains stream base flows. The subgrade also filters pollutants. Pervious pavement is less prone to cracking or buckling from freezing and thawing. Studies indicate it requires less frequent repair and patching than conventional paving. In some cases, pervious pavement may reduce or eliminate the need for an underground storm drain system or a curb and gutter system. Pervious pavement is an effective method of managing stormwater runoff without limiting use of the space.

Costs

Typical costs for porous pavement is $2 to $4 per square foot according to the *Stormwater Runoff Reduction Program Final Report* (MMSD, 2007).

Considerations

The *Dane County Erosion Control and Stormwater Management Manual* provides useful guidelines and additional references for the design, installation, and maintenance of this type of stormwater management practice.

Photo Credit: Milwaukee Metro. Sewerage Dist.

Examples

The stormwater management section of the CAPRC web site contains a map with locations and photos of good examples of BMPs in our region.

Proprietary Stormwater Filtration Device

A proprietary stormwater filtration device is a chamber or set of chambers (which may include internal baffles or other equipment and associated piping) that is provided as a defined product by a commercial vendor, and is warranted by that vendor to provide specific storm water pollutant removal performance under specified conditions. These devices can consist of prefabricated equipment supplied by a manufacturer, structures constructed on-site, or a combination thereof.

Benefits

These type of devices have the advantage of being underground, easy to install, and easy to maintain.

Research has shown that these devices are 80 to 90% effective at controlling soil particle sizes of 7 microns or greater, which is equivalent to fine silt.

Field testing of a unit installed in Madison (Horwatich and Bannerman, 2009) showed the following pollutant removal percentages for the StormFilter:

Pollutant	% Removal Rate
Suspended Solids	25
Total Phosphorous	36
Metals	8

It also notes that the range of pollutant removal performance can vary considerably between different sites.

Costs

The StormFilter in the 0.92-acre parking lot at Madison Gas & Electric cost $120,000 including installation.

Photo Credit: Madison Gas & Electric

Considerations

The *Dane County Erosion Control and Stormwater Management Manual* provides useful guidelines and additional references for selecting, installing, and maintaining this type of stormwater management practice. A WDNR Technical Standard is being prepared for this type of BMP.

Examples

The StormFilter device installed in the parking lot at Madison Gas & Electric is one example in our region. The stormwater management section of the CAPRC web site contains a map with locations and photos of good examples of BMPs in our region.

Proprietary Stormwater Sedimentation Device

A proprietary stormwater sedimentation device is a chamber or set of chambers (which may include internal baffles or other equipment and associated piping) that is provided as a defined product by a commercial vendor, and is warranted by that vendor to provide specific storm water pollutant removal performance under specified conditions. These devices can consist of prefabricated equipment supplied by a manufacturer, structures constructed on-site, or a combination thereof.

Photo Credit: Hydro International

Benefits

These type of devices have the advantage of being underground, easy to install, and easy to maintain.

Research has shown that these devices are only effective at controlling soil particle sizes of 250 microns or greater, which is equivalent to medium sand.

Field testing of a unit installed in Madison (Earth Tech 2007) showed the following pollutant removal percentages for the Downstream Defender:

Pollutant	% Removal Rate
Suspended Solids	24
Phosphorous	19
Metals	-13

It also notes that the range of pollutant removal performance can vary considerably between different sites.

Costs

There is no published information available on the typical costs for proprietary stormwater sedimentation devices in our region.

Considerations

The *WDNR Technical Standard Number 1006* and the *Dane County Erosion Control and Stormwater Management Manual* provide useful guidelines and additional references for selecting, installing, and maintaining this type of stormwater management practice.

Examples

The Downstream Defender device installed in the parking lot at the Madison Water Utility is one example in our region. The stormwater management section of the CAPRC web site contains a map with locations and photos of good examples of BMPs in our region.

Rain Gardens

Rain gardens are landscaped, shallow depression areas that collect and treat stormwater runoff using bioretention. Bioretention systems collect and filter stormwater through layers of mulch, soil and plant root systems. Pollutants such as bacteria, nitrogen, phosphorus, heavy metals, oil and grease are retained, degraded and absorbed. Treated stormwater is then infiltrated into the ground as groundwater or evapotranspirated by the plants. Rain gardens look similar to traditional landscaped areas, but they differ in design and function. Rain gardens can be planted with a variety of perennials, grasses, shrubs and small trees. Native plants are typically preferred. Rain gardens are a valuable addition to both residential and commercial sites.

Photo Credit: Roger Bannerman

Benefits

Rain gardens reduce stormwater runoff volume, flow rate and temperature. They have a host of additional benefits; they trap and break down pollutants, recharge ground water, restore natural habitat, attract wildlife, add aesthetic beauty, and improve the soil.

The National Pollutant Removal Performance Database (CWP, 2007) reports the following third quartile pollutant removal percentages for bioretention practices:

Pollutant	% Removal Rate
Suspended Solids	74
Total Phosphorous	30
Total Nitrogen	55
Metals	95 – 97

It also notes that the range of pollutant removal performance can be quite high.

Costs

Cost will vary depending on the garden's size, the types of vegetation used, and whether or not the work is done by a professional or landowner. Typical costs for rain gardens are $5 to $10 per square foot according to the *Stormwater Runoff Reduction Program Final Report* (MMSD, 2007).

Considerations

The *WDNR Technical Standard Number 1004* and the *Dane County Erosion Control and Stormwater Management Manual* and the *USGS rain garden study* (Selbig et. al., 2010) provide useful guidelines and additional references for planning, designing, constructing, and maintaining this type of stormwater management practice.

Examples

In the last decade, rain gardens have become a very popular method of managing stormwater runoff. There are over 300 documented rain gardens throughout our region. The stormwater management section of the CAPRC web site contains a map with locations and photos of good examples of BMPs in our region.

Rainwater Harvesting

Rainwater harvesting is the collection of rainwater before it becomes runoff. It includes practices such as rain barrels and cisterns. The collected rainwater is then used for watering gardens or other non-potable water uses.

Photo Credit: Steve Wagner

Benefits

Rain barrels operate by retaining a predetermined volume of rooftop runoff (i.e., they provide permanent storage for a design volume); an overflow pipe provides some detention beyond the retention capacity of the rain barrel. Rain barrels also can be used to store runoff for later reuse in lawn and garden watering. Stormwater runoff cisterns are roof water management devices that provide retention storage volume in underground storage tanks. On-lot storage with later reuse of stormwater also provides an opportunity for water conservation and the possibility of reducing water utility costs.

Costs

Rain barrels and cisterns are low-cost, effective, and easily maintainable retention devices applicable to residential, commercial, and industrial sites. A single rain barrel and diverter system costs around $100.

Considerations

A single 55-gallon rain barrel can contain approximately the first 0.05 inches of runoff from a typical 1,900 square foot roof area. About 35% of the rain events in Dane County are less than or equal to this amount of rainfall. Several rain barrels can be connected to increase storage capacity.

Examples

In the last decade, rain barrels have become a very popular method of managing stormwater. There are over 500 documented rain barrels throughout our region. The stormwater management section of the CAPRC web site contains a map with locations and photos of good examples of BMPs in our region.

Roof Drain Management

Roof drains or downspouts direct runoff down from the roof and away from the building. Connected roof drains are those that are piped directly to the storm sewer as well as those that discharge to an impervious surface, such as a driveway or sidewalk, which is connected to the storm sewer system. Unconnected roof drains are those that drain to pervious surfaces such as lawns and gardens or a storage device such as a rain barrel or cistern. Downspouts can be disconnected on residential, commercial and industrial properties. The system you choose can be as simple or complex as your goals and site requirements allow.

Benefits

Roof downspouts that are connected to the storm sewer system result in much higher peak flow rates and runoff volumes than roof downspouts that are unconnected. The simple act of redirecting the downspout to a pervious, vegetated area such as lawn or landscaped area allows a significant percentage of the water to be absorbed into the ground before entering a storm drain.

Costs

Disconnection is simple, inexpensive, effective, and easily integrated into the landscape design. Materials such as elbows and extensions are readily available at hardware, building supply, and home improvement stores at a nominal cost.

Considerations

Generally, rainwater must flow over at least 20 feet of pervious surface such as a lawn to absorb water. In many cases, a splash block at the end of the extension conveys water away from foundations and prevents erosion. Make sure the discharge from the pipe does not flow toward the building or neighboring property. The discharge point should be at least six feet away from basements and two feet away from crawl spaces and porches.

Photo: WDNR Service Center - Fitchburg

Examples

Roof drain disconnection is very common in our region. There are many local examples. The stormwater management section of the CAPRC web site contains a map with locations and photos of good examples of BMPs in our region.

Stormwater Planter

A stormwater planter is a small, contained vegetated area that collects and treats stormwater using bioretention. Bioretention systems collect and filter stormwater through layers of mulch, soil and plant root systems, where pollutants such as bacteria, nitrogen, phosphorus, heavy metals, oil and grease are retained, degraded and absorbed. Treated stormwater is then infiltrated into the ground as groundwater (Infiltration Planter) or, if infiltration is not appropriate, discharged into a traditional stormwater drainage system (Flow-Through Planter). Stormwater planters typically contain native, hydrophilic flowers, grasses, shrubs and trees.

Benefits

Stormwater planters do not require a large amount of space and can add aesthetic appeal and wildlife habitat to city streets, parking lots, and commercial and residential properties.

The National Pollutant Removal Performance Database (CWP, 2007) reports the following third quartile pollutant removal percentages for bioretention practices:

Pollutant	% Removal Rate
Suspended Solids	74
Total Phosphorous	30
Total Nitrogen	55
Metals	95 – 97

It also notes that the range of pollutant removal performance can be quite high.

Photo Credit: City of Portland, OR

Costs

Costs vary depending on size and materials. For new development and redevelopment, infiltration planters are often less expensive than more conventional stormwater management facilities.

Considerations

Flow through planters are recommended where soils don't drain well. Infiltration planters are recommended where soils have good infiltration rates.

Examples

There are no known examples of constructed wetlands for stormwater management in our region.

Street Sweeping

Impervious areas accumulate sediment, lawn and leaf trimmings, trash, and other debris, along with heavy metals and other pollutants. As stormwater flows over these surfaces, these substances are carried along with it, polluting waterways and increasing the sediment load of the water body. Sweeping streets and parking lots prevents sediment, heavy metals, and other pollutants from reaching receiving waters by removing them from impervious areas before they reach storm drains.

Benefits

The report, *Evaluation of Street Sweeping as a Stormwater-Quality-Management Tool in Three Residential Basins in Madison, Wisconsin*. (Selbig and Bannerman 2007) concluded that while street sweeping is effective for the control of litter and floatables, there is little probability that street sweeping, regardless of street-sweeper type, had any measurable affect on the quality of runoff. The regenerative-air and vacuum-assist sweepers had similar pickup efficiencies of 25 and 30 percent, respectively. The mechanical broom sweeper operating at high frequency was considerably less efficient, removing an average of 5 percent of street-dirt yield.

The study showed that sand-size particles (greater than 63 micrometers) recorded the greatest overall reduction. Reductions of street-dirt yield decreased with decreasing particle size for all sweepers. The high-frequency mechanical broom and regenerative air sweepers were unable to adequately pick up particles less than 250 and 125 micrometers, respectively. Only the vacuum-assist sweeper was capable of reducing street-dirt yield across the entire range of particle sizes measured. Even at the smallest particle-size fraction, less than 63 micrometers, the vacuum-assist sweeper was able to reduce a percentage of the street-dirt yield by incorporating a powerful vacuum that extends into the curb, overlapping part of the gutter-broom. The vacuum appears to capture most of what the gutter broom cannot.

Photo: Elgin Sweeper

However, such large changes in basin street-dirt yield were not consistent with the pickup efficiencies observed at the street level for each machine. The relatively large change in basin street-dirt yield may be explained by the mechanical action of the gutter broom increasing the amount of fines available for washoff. Increasing the amount of fines on a street can change the washoff characteristics of a street, because rain can be more effective at removing smaller particles from a street than street sweeping. If the amount of solids washed off the street is increased by the action of the street sweepers, the reduction in basin street dirt yield could be a function of both the street sweepers' pickup efficiency and the increased effect of rainfall. Street sweeping as a stormwater-quality-management tool appears to be limited by the extreme variability in stormwater quality loads.

Swales

Vegetated swales are shallow, vegetated channels which treat and convey stormwater runoff. Unlike typical stormwater conveyance structures, such as pipes, concrete channels or drainage channels, vegetated swales slow runoff velocity, filter out stormwater pollutants, reduce runoff temperatures and, under certain conditions, infiltrate runoff into the ground.

Benefits

Dry swales provide both quantity (volume) and quality control by facilitating stormwater infiltration. Wet swales use residence time and natural growth to reduce peak discharge and provide water quality treatment before discharge to a downstream location. Wet swales typically have water tolerant vegetation permanently growing in the retained body of water. SLAMM modeling shows that using swales instead of curb and gutter can reduce the annual runoff volume by 26 to 44% in a typical development.

The National Pollutant Removal Performance Database (CWP, 2007) reports the following third quartile pollutant removal percentages for open channels:

Pollutant	% Removal Rate
Suspended Solids	87
Total Phosphorous	46
Total Nitrogen	76
Metals	77 – 79
Bacteria	-25

It also notes that the range of pollutant removal performance can be quite high. Conveyance channels that do not employ specially designed soil mediums will not remove pollutants as efficiently as vegetated swales and are not appropriate for use in areas where phosphorus is a pollutant of concern.

Photo: E. Cheryl Parkway - Fitchburg

Costs

Typical costs for swales are $700 per acre according to the *Stormwater Runoff Reduction Program Final Report* (MMSD, 2007).

Considerations

Vegetated swales require a dense vegetative cover to reduce erosion. Swales can include a drainage layer and underdrain, if necessary, to temporarily store and convey runoff to a stormwater pipe or additional stormwater facility.

The *WDNR Technical Standard Number 1005*, and the *Dane County Erosion Control and Stormwater Management Manual* provide useful guidelines and additional references for planning, designing, constructing, and maintaining this type of stormwater management practice.

Examples

The stormwater management section of the CAPRC web site contains a map with locations and photos of good examples of BMPs in our region.

Trees

Tree planting improves water quality and watershed health primarily by decreasing the quantity of storm water runoff and pollutant loads that reach surface waters.

Benefits

Trees reduce storm water runoff through rainfall interception by the tree canopy, by releasing water into the atmosphere through evapotranspiration, and by promoting infiltration of water through the soil and storage of water in the soil and forest litter.

The presence of trees helps to slow down or attenuate storm water runoff, which promotes infiltration of water through the soil. In addition, tree roots and organic matter from leaf litter create soil conditions that increase the capacity to infiltrate rainfall, which further reduces the volume of water that runs off the land surface. Tree roots increase infiltration by creating interconnected pathways in the soil called macropores.

Leaf litter and other organic matter produced by trees also work to reduce the amount of runoff by holding water and promoting infiltration rather than allowing rainfall to run off the surface as overland flow

Costs

Costs vary with the type and size of the tree, but the general range is $20 to $100 each, not including planting.

Considerations

The ability of a tree to intercept rainfall is influenced by its branching structure, canopy density, leaf texture, and bark texture. Choose trees suitable for the soil type, amount and intensity of sunlight and space requirements. *Urban Watershed Forestry Manual* (Center for Watershed Protection 2005) provides useful guidelines and additional references for this type of stormwater management practice.

Photo: WDNR Service Center – Fitchburg

Rainfall interception for individual trees ranges from 10% to 68% of a rainfall event and is dependent on the tree species and rainfall characteristics. Rainfall interception is higher for evergreens because they have the ability to intercept rainfall all year round. Intercepted rainwater is either evaporated directly into the atmosphere, absorbed by the canopy surfaces or transmitted to the ground via stems, branches, and other tree surfaces.

The uptake of soil water by tree roots increases soil water storage potential, effectively lengthening the amount of time before rainfall becomes runoff. In general, a mature tree can transpire 100 gallons per day. Many factors influence transpiration rates, including leaf shape, size, number of pores (stomata), and waxiness of the leaf surface (Center for Watershed Protection 2005),. Generally, evergreens have lower transpiration rates because they are more efficient than deciduous trees at retaining moisture, due to the structure of their leaves.

Underground Infiltration Galleries

Underground Infiltration Galleries are pre-manufactured treatment trains that typically consist of a water quality unit that provides pretreatment through the process of sedimentation, and an infiltration unit that performs like a leach field. They are typically constructed from concrete or high-density polyethylene (HDPE) modules.

Benefits

In general, they are best suited to locations where space is at a premium, and are often used in urban areas, where they generally are located beneath parking lots and other transportation infrastructure.

These systems have demonstrated excellent water quality treatment performance and a significant capacity to reduce peak flows during testing at the University of New Hampshire Stormwater Center.

The National Pollutant Removal Performance Database (CWP, 2007) reports the following third quartile pollutant removal percentages for infiltration practices:

Pollutant	% Removal Rate
Suspended Solids	96
Total Phosphorous	96
Total Nitrogen	65
Metals	83 – 89

It also notes that the range of pollutant removal performance can be quite high.

Photo Credit: Advanced Drainage Systems, Inc.

Costs

The typical cost to install an underground infiltration gallery system large enough to treat runoff from one acre of impervious surface is about $50,000. While these systems tend to be more expensive than conventional stormwater treatments, the cost is ameliorated by the increase in available space for development.

Considerations

As with any infiltration system, care must be taken when locating these systems near pollution hotspots, or where seasonal high groundwater levels may lead to groundwater contamination. In such cases, the systems should be lined to prevent infiltration into groundwater, and outfitted with subdrains that discharge to the surface.

Examples

There are no known examples of underground infiltration galleries for stormwater management in our region.

Wet Detention Basin

Detention basins are excavated areas designed to impede flow by storing runoff and releasing the stored volume at a reduced rate. A wet detention basin has a permanent pool of water and storage capacity above the pool's surface to provide temporary storage for peak runoff reduction. Water quality treatment is accomplished through physical and biological processes in the permanent pool.

Benefits

They are used to reduce peak flow rates and provide protection to areas that are susceptible to flooding.

The National Pollutant Removal Performance Database (CWP, 2007) reports the following third quartile pollutant removal percentages for wet ponds:

Pollutant	% Removal Rate
Suspended Solids	88
Total Phosphorous	76
Total Nitrogen	41
Metals	72 – 74
Bacteria	94

It also notes that the range of pollutant removal performance can be quite high.

Costs

Typical costs for wet detention basins are about $4 per square foot according to the University of New Hampshire Stormwater Center.

Photo: Longford Terrace - Fitchburg

Considerations

The *WDNR Technical Standard Number 1001*, the *Wisconsin Stormwater Manual* and the *Dane County Erosion Control and Stormwater Management Manual* provide useful guidelines and additional references for planning, designing, constructing, and maintaining this type of stormwater management practice

Examples

Wet detention basins are very common in our region. There are many local examples. The stormwater management section of the CAPRC web site contains a map with locations and photos of good examples of BMPs in our region.