Stormwater and The Wisconsin Plumbing Code
Stormwater II – 10.1.05 version

Part I – History & Introduction

Since 1914, the Wisconsin Uniform Plumbing Code has addressed stormwater drainage. Section 28 of the 1914 plumbing code was titled "Surface and Rain Water Connections." Paragraph (g) of that code stated that "Where no sewer is accessible, or where rain water is prohibited from entering the sanitary sewer, surface inlets and rain water conductors should be drained separately to the curb line where practicable by drain pipes not less than four inches in diameter, and discharge into the public gutter, unless permitted to drain elsewhere."

By 1948 a requirement to protect cistern water quality was added to the plumbing code. It stated, "overflow pipe from cisterns shall not connect directly with any house sewer, but shall discharge into an open fixture, catch basin or floor drain. Overflow pipes from cisterns, however, shall not discharge into sanitary sewers."

In 1972 the title of the section was revised from "Rain water connections" to "Storm and clearwater". In this revision the charts that we know today were added for pipe sizing and the link between clearwater and stormwater was first acknowledged in the code.

January 2001 brought code changes to allow options for plumbing designers to include detention, retention and infiltration systems by permitting storm pipe sizing to be determined in accordance with the tables or a detailed engineering analysis acceptable to the Department. This change also included a table for the use of elliptical pipe

The interaction between stormwater and the plumbing system over the years has sometimes created havoc. Not only flooding, but also safety concerns are inherent to the collection, treatment, dispersal and discharge of stormwater.

Throughout history there are tales of deadly floods, like the Johnstown flood of 1889 where over 2,000 people died, or the floods of the summer of 2002 in Europe where over 150 people died.

Other deadly mishaps aren't necessarily due to huge flood events, but still are a major problem when lives are lost. In Elm Grove in 1998 two boys were swept away and drowned in stormwater. Even professionals aren't immune to the hazards of fast moving stormwater. Firehouse.com reports that of the 95 fire fighters who were killed in the line of duty in the year, 2000, one was swept into a storm sewer in Denver, Colorado.

Not all storm sewer incidents cause fatalities, as the Journal Sentinel reported that a small terrier named Reggie was fished from a storm manhole after spending four days in the Marathon County storm sewer system.

To understand the plumbing stormwater issues, you must first review some terms used in stormwater systems.

<u>Definitions</u>

"Average annual rainfall" means a calendar year of precipitation, excluding snow, which is considered typical.

"Best Management Practice" or "BMP" means structural or non-structural measures, practices, techniques or devices employed to avoid or minimize soil, sediment or pollutants carried in runoff to waters of the state.

"Coefficient" means a numerical measure of a physical or chemical property that is constant for a system under specified conditions.

"Collection" is the "act or process of collecting". In plumbing, collection systems consist of roof drains, area drain inlets, catch basins, curb inlets and other devices intended to collect stormwater.

"Connected Imperviousness" is the situation where impervious areas are connected by means of piping or continuous impervious surfaces.

"Conveyance" systems are usually piping systems the move stormwater from one area to another. Storm systems consist of swales or channels that also serve as conveyance devices.

"Conveyance piping" means piping carrying stormwater that is sized and pitched to drain.

"Design storm" is the largest storm expected to occur in a given period of time specified in the design parameters for the hydraulic project. The NR 151 definition is "a hypothetical discrete rainstorm characterized by a specific duration, temporal distribution, rainfall intensity, return frequency and total depth of rainfall."

"Detention" The act of temporarily storing stormwater during a rainfall event and then releasing the stormwater at a slower rate.

"Dispersal" is the act of spreading out wastewater for assimilation into the environment. In common terms, dispersal systems are called infiltration systems. Dispersal systems may use subsurface chambers, piping systems or surface irrigation.

"Discharge" is the historic endpoint for stormwater systems. Discharge is simply ending a piping system. Plumbing codes have historically addressed the discharge of stormwater.

"Duration" is the length of a storm.

"Frequency" is the means of expressing the probability that a storm of a given size or intensity may occur at a site. The 10 year storm is large enough that it will probably occur once every ten years. The probability of the occurrence of a storm within one year is the reciprocal of the recurrence. That means 10 year storm has a 10 percent chance of happening in any one year. A 100 year storm has a 1 percent chance of occurring in any one year.

"Hydraulic length" means the distance water travels over a designed path.

"Impervious/imperviousness" The ground cover condition where no (or an insignificant amount of) rainfall infiltrates into the ground. Pavement and roofs are considered to be impervious.

"In-fill development" means an undeveloped area of land located within existing urban sewer service areas, surrounded by already existing development or existing development and natural or man-made features where development cannot occur.

"Intensity" is the rate of rainfall shown in inches per hour.

"Karst feature" means an area of surficial geologic feature subject to bedrock dissolution so that it is likely to provide a conduit to groundwater, and my include caves, enlarged fractures, mine features, exposed bedrock surfaces, sinkholes, springs, seeps or swallets.

"Maximum extent practicable" or MEP means a level of implementing best management practices in order to achieve a performance standard specified in this chapter 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.

"Peak shaving" means the act of lowering the peak flow from a site by designing detention or infiltration devices or methods within a site.

"Percent fines" from NR 151 means the percentage of a given sample of soil, which passes through a #200 sieve."

"Predevelopment" means before the time of residential, commercial, industrial or institutional land uses and associated roads.

"Redevelopment" means areas where development is replacing older development.

"Stormwater management plan" means a comprehensive plan designed to reduce the discharge of pollutants from stormwater, after the site has undergone final stabilization, following completion of the construction activity.

"Time of concentration" means the time it takes for water to travel from the farthest design point to a designated inlet.

"Treatment" in plumbing storm systems can take many different forms. Catch basins with sumps are a traditional form of treatment, however there are several other options available for treatment in plumbing systems today including grass filter strips, grease interceptors, activated carbon filters, sand filters and sedimentation chambers. Treatment may also be accomplished within soils that exist on a site or "in situ" soils.

"WPDES permit" means a Wisconsin Pollutant Discharge Elimination System permit issued by the DNR.

With definitions in hand, we're ready to begin learning more about stormwater systems.

Wisconsin's stormwater drainage systems carry stormwater, groundwater and clearwater. Even under dry conditions, 25% of stormwater outlets have flow because of clearwater and groundwater discharges to stormwater systems. This mixture of wastewater and the sporadic and unpredictable nature of stormwater flow patterns influence many design considerations, and more importantly create problems in the state.

There are obvious flooding and safety issues, but the storm system also provides a perfect breeding area for mosquitoes, the carriers of La Crosse Viral Encephalitis and West Nile Virus. (More on mosquito control on page 29)

Aside from safety and health issues, what's the advantage of allowing stormwater to stand in detention, retention and infiltration structures? Why not create huge storm sewer piping systems that convey stormwater instantaneously from a site and discharge the stormwater to a creek or a river?

In the past, one of the basic plumbing principles in the plumbing code required designers and installers to provide drain systems that are "designed, constructed, and maintained to conduct the wastewater or sewage quickly from the fixture to the place of disposal." However, that code requirement didn't adequately address future stormwater issues in Wisconsin. The May 1, 2003 code revisions changed the drain system requirement from "quickly" to "efficiently".

First of all, stormwater in the natural system has many obstacles to detain its travel over the ground surface as it flows to the area drain inlet or water of the state. In order to maintain groundwater levels and stream base flows, that detention must occur to provide time for stormwater to infiltrate. Debris on the ground also prohibits the stormwater from gaining velocities that will erode soil from the site.

From the minute construction crews drive onto a building site, the cycle of water movement begins to change. As the brush and trees are removed, rain falls directly on the ground. As grass and vegetation is removed, less stormwater is infiltrated into the soil and more stormwater runs over the soil surface to accumulate in low spots or drain into area drain inlets. The cycle is endless; more compaction means more runoff. Increased runoff creates gullies and the gullies create more concentrated flow channels that increase erosion and runoff volumes.

Stormwater runoff problems continue after construction's complete. Water runs off impervious areas (roofs, parking lots and streets) picking up contaminants (pollutants) along the way.

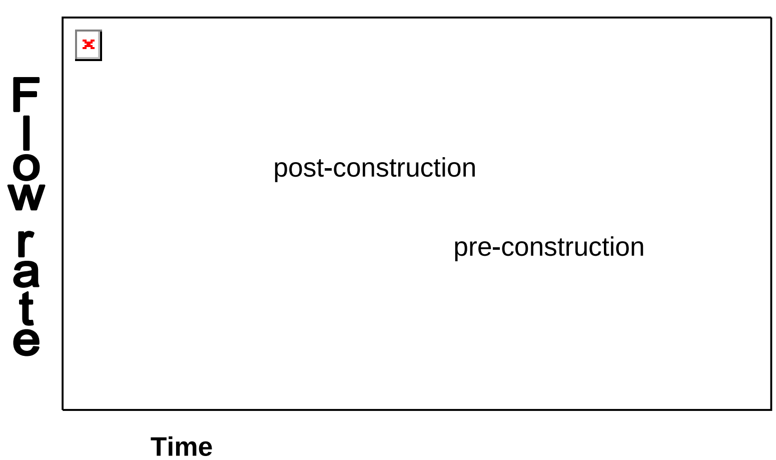

Figure 1 – Pre-construction & Post construction hydrograph representation

Figure 1 shows two hydrographs. One shows the runoff pattern prior to construction and the other after development on the same site. It's evident that the rate of flow increases and decreases quicker in areas that have been developed. It's also evident in figure 1, that the peak flows are higher in developed area than in predevelopment conditions.

Typically, these changes in hydrology affect the local environment in the following ways:

- The frequency and severity of flooding increases because peak flows are two to five times higher than before development.
- Nearby streams become "flashy" or have the tendency to flash flood because high flows occur quickly and affect stream levels.
- Base flow is reduced because the infiltration of stormwater into shallow aquifers that provide the dry period feed for small streams is reduced. Streams that once flowed year around dry up.
- Flooding occurs downstream at higher elevations than prior to urbanization. Under normal conditions a stream develops a channel to accommodate the 2-year storm (a storm that usually occurs no more than once every two years). Development along the stream increases impervious area and runoff. As the peak flows increase, the banks of the stream widen by 2 to 4 times.

Aside from the acute problems to man, the environmental changes caused by differences in stormwater flows are an issue for Wisconsin.

Part II, Stormwater/Runoff Quality

Impervious areas like roofs, parking lots and roads accumulate contaminants from vehicles, the atmosphere and living creatures. Rainfall washes the contaminants off the impervious surface and transports them to groundwater, surface water or into the soil unless a treatment device intercepts the contaminant. Table 1 lists common urban contaminant levels in runoff. Table 2 contains mean values that are specific to Wisconsin.

Table 1 - Contaminant Concentrations in Urban Stormwater[2]

Contaminants found in runoff	Units	Average Concentrations [1]
Total Suspended Solids	mg/l	80
Total Phosphorus	mg/l	0.30
Total Nitrogen	mg/l	2.0
Total Organic Carbon	mg/l	12.7
Fecal Coliform Bacteria	MPN/100 ml	3600
E. coli Bacteria	MPN/100 ml	1450
Petroleum Hydrocarbons	mg/l	3.5
Cadmium	ug/l	2
Copper	ug/l	10
Lead	ug/l	18
Zinc	ug/l	140
Chlorides (winter only)	mg/l	230
Insecticides	ug/l	0.1 to 2.0
Herbicides	ug/l	1 to 5.0

1 – concentrations represent mean or median storm concentrations measured at typical sites and may be greater during individual storms. Also note that mean or median runoff concentrations from stormwater hotspots are 2 to 10 times higher than those shown here.

Units: mg/l – milligrams/liter, ug/l – micrograms/liter, MPN = Most Probable Number

Source areas control the contaminant levels in runoff. Table 2 and Table 3 list contaminant levels from various sources.[3, 4] Different geographical area's runoff is affected by building patterns, salt or sand usage on roads and sidewalks, traffic, land use, building materials (such as lead flashings, galvanized roofs or galvanized gutters and downspouts) and connected imperviousness.

Table 2 - Sources of Pollutants in Wisconsin Stormwater[3]

Geometric Mean concentrations of Contaminants in Runoff from Source-Area and Storm-sewer Outfalls

Contaminant	Feeder Streets	Collector Streets	Arterial Streets	Lawns	Drive-ways	Roofs	Parking Lots	Outfall
	Residential Source Areas							
Total Solids (mg/L)	796	493	-	600	306	91	-	369
Suspended Solids (mg/L)	662	326	-	397	173	27	-	262
Total Phosphorus (mg/L)	1.31	1/07	-	2.67	1.16	.15	-	.66
Total Recoverable Copper (ug/L)	24	56	-	13	17	15		16
Total Recoverable Lead (ug/L)	33	55	-	- -	17	21	-	32
Total Recoverable Zinc (ug/L)	220	339	-	59	107	149	-	203
Fecal Coliform (cfu/100mL)	92,061	56,554	-	42,093	34,294	294	0	175,106
	Commercial Source Areas							
Total Solids (mg/L)	-	---	373	-	-	112	127	---
Suspended Solids (mg/L)	-	---	232	-	-	15	58	---
Total Phosphorus (mg/L)	-	---	.47	-	-	.20	.19	---
Total Recoverable Copper (ug/L)	-	---	46	-	-	9	15	---
Total Recoverable Lead (ug/L)	-	---	50	-	-	9	22	---
Total Recoverable Zinc (ug/L)	-	---	508	-	-	330	178	---
Fecal Coliform (cfu/100mL)	-	---	9,627	-	-	1,117	1,758	---
	Industrial Source Areas							
Total Solids (mg/L)	-	958	879	---	-	78	531	267
Suspended Solids (mg/L)	-	763	690	---	-	41	312	146
Total Phosphorus (mg/L)	-	1.5	.94	---	-	.11	.39	.34
Total Recoverable Copper (ug/L)	-	76	74	---	-	6	41	28
Total Recoverable Lead (ug/L)	-	86	60	---	-	8	38	25
Total Recoverable Zinc (ug/L)	-	479	575	---	-	1,155	304	265
Fecal Coliform (cfu/100mL)	-	8,338	4,587	---	-	144	2,705	5,114

Note: Single dash indicates source area is not in the land use; double dash indicates insufficient data; triple dash indicates values are shared with those above for the same source area;

The relatively large concentrations of zinc in roof runoff indicate that galvanized roofing materials were a source of the zinc. One-third of the residential roofs had galvanized downspouts. Roofing materials also might be a source of copper and lead in the runoff from residential roofs. Concentrations of dissolved copper and total recoverable copper and lead were slightly larger in the residential roof runoff than in runoff from driveways and lawns.

As illustrated by the preceding tables, the number of bacteria in stormwater is lower than the number in domestic wastewater, there are pathogenic (disease causing) bacteria in stormwater including shigella (causes bacillary dysentery), pseudomonas aeruginosa (causes swimmers ear and skin infections) and pathogenic e. coli. There are also viruses that travel in stormwater runoff. Viruses have been found in groundwater below infiltration ponds where no indicator bacteria are present.[9]

How can the plumbing system assist in collection, treatment, dispersal and discharge of stormwater in a way that complies with the plumbing code and protects groundwater quality? The following study sections are intended to help plumbing students learn more about storm systems and begin the transition into designing, installing and maintaining the stormwater systems of the 21st century.

Part III, NR 151

One of the driving forces for change in Wisconsin's plumbing stormwater industry is the creation of NR 151; the Department of Natural Resources code that addresses "nonpoint" pollution. Nonpoint pollution is considered to be any ground or surface water pollution that cannot be traced to a discernable, discreet source, such as a pipe outlet.
The NR 151 rules contain requirements for agricultural and urban areas. The post-construction stormwater rules for urban areas will become effective on October 1, 2004.

Currently all construction sites where $\geq$ 1 acre is disturbed during total construction require that the owner apply for a general WPDES permit from the DNR. In lieu of the DNR permit, a Notice of Intent (NOI) can be filed with Commerce when a building is included in the construction.

Here are the pertinent NR 151 requirements for post-construction stormwater:

There are two terms that are defined for the designer in NR 151.12:

(a) "Post-construction site" means a construction site subject to regulation under this subchapter, after construction is completed and final stabilization has occurred.

(b) Average annual rainfall is determined by the following years and locations: Madison, 1981 (Mar. 12 - Dec. 2); Green Bay, 1969 (Mar. 29 – Nov. 25); Milwaukee, 1969 (Mar. 28 – Dec 6); Minneapolis, 1959 (Mar. 13 – Nov. 4); Duluth, 1975 (Mar. 24 – Nov. 19). Of the 5 locations listed, the location closest to a project site best represents the average annual rainfall for that site.

Exemptions

There are two exemptions (that would affect plumbing systems) for the applicability of NR 151 post-construction standards. One is a site with less than 10% connected imperviousness based on complete development of the post-construction site, provided the cumulative area of all parking lots and rooftops is less than one acre. The second is an exemption for the disturbance caused by underground utility construction such as water, sewer and fiberoptic lines, but not including the construction of any above ground structures associated with utility construction.

Post-construction Requirements
Total suspended solids reduction is required. For new development, 80%; for redevelopment, 40%; for in-fill development 40% - 80%, depending on the development date.

Detention practices must be installed to reduce the discharge rate to pre-development conditions for the 2-year, 24-hour design storm.

Infiltration is required, for residential development either 90% of the predevelopment infiltration volume based on an average annual rainfall, or 25% of the post-development runoff volume from the 2-year, 24-hour design storm with a type II distribution. Infiltration devices are not required to occupy more than 1% of the project site.

Infiltration is required, for non-residential development either 60% of the pre-development infiltration volume based on an average annual rainfall or 10% of the post-development runoff volume from the 2-year, 24-hour design storm with a type II distribution. Nor more than 2% of the project site is required to be used in the design of the infiltration system and the project site for this one issue means the rooftop and parking lot areas, only.

Before infiltrating runoff, pretreatment is required for parking lot runoff and for runoff from new road construction in commercial, industrial and institutional areas that will enter an infiltration system. Pretreatment options may include oil/grease separation, sedimentation, biofiltration, filtration, swales or filter strips.

Prohibitions for Infiltration

There are several areas where designed infiltration is prohibited:

1. Areas associated with tier 1 industrial facilities.
2. Storage and loading areas of tier 2 industrial facilities. (Runoff from tier 2 parking and rooftop areas may be infiltrated but may require pretreatment)
3. Fueling and vehicle maintenance areas
4. Areas within 1000 feet upgradient or within 100 feet downgradient of karst features.
5. Areas with less than 3 feet separation distance from the bottom of the infiltration system to the elevation of seasonal high groundwater or the top of bedrock, except this doesn't prohibit the infiltration of rooftop runoff.
6. Areas with runoff from industrial, commercial and institutional parking lots and roads and residential arterial roads with less than 5-foot separation distance from the bottom of the infiltration system to the elevation of seasonal high groundwater or the top of bedrock.
7. Areas within 400 feet of a community water system well as specified in s. NR 811.15(4) or within 100 feet of a private well as specified in s. NR 812.08 (4) for runoff infiltrated from commercial, industrial and institutional land uses or regional devices for residential development.
8. Areas where contaminants of concern, as defined in s. NR 720.03(2), are present in the soil through which infiltration will occur.
9. Any area where the soil does not exhibit one of the following characteristics between the bottom of the infiltration system and the seasonal high groundwater and top of bedrock: at least a 3-foot soil layer with 20 percent fines or greater; or at least a 5-foot soil layer with 10 percent fines or greater. This subdivision paragraph does not apply where the soil medium within the infiltration system provides an equivalent level of protection. This doesn't prohibit the infiltration of rooftop runoff.

Exemptions for Infiltration

There are also "exemptions" to the requirement for infiltration. These include:

1. Areas where the infiltration rate of the soil is less than 0.6 inches/hour measured at the infiltrative surface.
2. Parking areas and access roads less than 5,000 square feet for commercial and industrial development.
3. Redevelopment post-construction sites.
4. In-fill development areas less than 5 acres.
5. Infiltration areas during periods when the soil on the site is frozen.
6. Roads in commercial, industrial and institutional land uses, and arterial residential roads.

Plumbing Use Alternative

NR 151 permits an equivalent infiltration credit for the use of stormwater as a supply for plumbing fixtures. That means that if a designer would like to use an equivalent volume of stormwater for flushing toilets, irrigation or some other plumbing use, the infiltration requirement is met.

There are other requirements in NR 151 that may affect the siting of a stormwater practice. For more information, see NR 151.

Part IV, The Hydrology of the Storm Event

Calculations for runoff or discharge from building clearwater systems or roof drains is currently something that's not required when using Comm 82.36, except as it relates to peak flows. The code simplifies the design process to choosing numbers from a chart based on area. In order to design infiltration, detention or smaller diameter piping systems, the science of hydrology and the calculation of runoff for each particular site is necessary.

The hydrology of the storm event is the basis for all storm system designs including pipe sizing, treatment devices and methods, detention systems, infiltration systems and every combination imaginable.

Websters defines hydrology as "a science dealing with the properties, distribution and circulation of water." The hydrology of the storm event limits this study to a particular precipitation event and the fate of the water that falls during that event.

All methods used to determine volumes and peak flows use historical data. The Weather Bureau and National Oceanic and Atmospheric Administration have provided precipitation and frequency information to designers.[6]

The frequency of a design storm is the chance you'll see that type of storm. "Although precipitation events occur randomly, analysis of their distribution over a long period of time indicates that the frequency of occurrence of a given storm event follows a statistical pattern. This pattern allows designers the ability to characterize storm events based on their frequency of occurrence.[4]

Rainfalls and snowstorms occur as a series of events that have characteristics including rainfall amount, intensity and duration. In order to design the plumbing stormwater system, a particular storm event must be chosen. This is known as the design storm.

The current plumbing code eliminates the necessity for the designer to calculate the peak flow rate based on the time of concentration or the geographic area of the design. The plumbing code pipe sizing charts are based on an unstated design storm and time of concentration. BOCA and SBCCI are now based on the same 100-year, one-hour rainfall (3 inches per hour for Chicago). NAPHCC peak rate is based on 5 inches per hour for one hour for Chicago and SBCCI requires a secondary drain system to be based on 6.6 inches per hour for Chicago.[7]

Dr Steele states that "where there are no unusual conditions a design frequency of ten years should be used for an average site." For the purpose of system design, when recommending a ten-year storm, it's necessary to also specify the duration of the storm. For example, an intensity-duration-frequency curve for Madison may show that a 10-year, 60-minute storm has a rainfall intensity of 2 inches per hour. In the same city, a 10-year, 15-minute storm has a rainfall intensity of approximately 4.0 inches per hour. In 82.36 (4) of the current plumbing code, a 3.75-inch per hour rate is required for pipe sizing. For small sites, this is probably a logical number for estimation, as the time of concentration for a small site, may be 10 to 20 minutes. Many texts recommend a smaller time of concentration for small sites, like 5 minutes.

The Minnesota BMP Manual states that the 2- and 10- year storms are used for subdivisions, industrial and commercial design. 1- and 2-year storms are used to protect channels from sedimentation and erosion. 5- and 10- year events are used for adequate flow conveyance and minor flooding consideration. The 100-year storm defines the limits and flood plains and is used to consider the impacts from major floods.[4]

Infiltration and reuse systems require that volumes be calculated.

The Rational Method

Currently plumbing plan reviewers are accepting the Rational Method for calculating peak flow rates. The Rational Method was first developed to identify peak flow for pipe and culvert sizing. It translates peak intensity of rainfall directly into peak intensity of runoff. When using the Rational Method for pipe sizing on small sites the time of concentration should equal the intensity as those parameters create the highest peak flow rate.

For a small site, the intensity can be entered into the Rational Method formula and a cubic ft per second (cfs) rate can be calculated. Remember in the previous paragraph that we talked about the time of concentration? It seems to vary from one text to another as, for small sites, frequently a minimum time of concentration of 6 minutes is used according to Gribbon.[1]

The Rational Method for our example looks like this:

$$Q = Aci$$

Q = Runoff, cubic feet per second (cfs)
A = Drainage area, acres (43,560 sq ft)
c = Coefficient of runoff, a dimensionless number
i – Intensity of rainfall, inches per hour
(There's a hidden correction factor of 1.008 cfs per a-in/hr)

If we were to insert actual numbers from a 1.5 acre site that has concrete or pavement cover (.90 coefficient) and a 4.0 inches per hour rainfall, the equation would look like this:

$$Q = 1.5 \text{ X } .90 \text{ X } 4.0$$

$$Q = 5.4 \text{ cfs or } (448.8 \text{ X } 5.4 = 2{,}423.5 \text{ gpm})$$

The "c" factor is found in a table. Table 4 is a sample of such a table. Other texts or other sites may have similar, but dissimilar values.

STUDENT PROBLEM #1

Calculate the stormwater discharge rate from a site using the Rational Method with the following circumstances (Use Table 4 for coefficient value):

.5 acre site that's contributing runoff

Flat residential land use, about 60% impervious

A rainfall intensity of 3.7 inches per hour

Student's Answer: _________________

(See the Appendix for the answer to this problem.)

Table 4. Coefficients for use with the Rational Method

Type of Surface or Land Use	"c" value
Individual soil covers	
Forest	0.1 – 0.3
Turf or meadow	0.1 – 0.4
Cultivated field	0.3 – 0.4
Steep grassed area (2:1)	0.5 – 0.7
Bare earth	0.2 – 0.9
Gravel or macadam pavement	0.35 – 0.7
Concrete or asphalt pavement	0.8 – 0.9
Composite Land Uses	
Flat residential, about 30% impervious	.40
Flat residential, about 60% impervious	.55
Sloping residential, about 50% impervious	.65
Flat commercial, about 90% impervious	.80

The current plumbing code will allow the use of the Rational Method without any further site evaluation for estimating the peak rate of runoff for pipe sizing. The intensity must be 3.7 inches per hour. Presently for a submitter to use a lower intensity, a petition for variance must be submitted and approved.

As we've said the rational method assumes that a storm duration that matches a drainage area's time of concentration produces the greatest rate of runoff. So, to be more accurate than just assuming a number the time of concentration could first be estimated by using an appropriate procedure. The FAA (Federal Aviation Agency) has a simple formula for use with the Rational Method that can be used to define the time of concentration for a site.

$$t_c=[1.8(1.1-c)L_h^{1/2}]G^{-1/3}$$

Where:

t_c = time of concentration, in minutes
c = cover factor in the rational formula
L_h = hydraulic length in feet
G = slope along the hydraulic length, in percentage

That formula was further simplified by Bruce Ferguson in his text, Introduction to Stormwater[10]

$$t_c= L_h^{1/2}C_g$$

Where:

t_c = time of concentration, in minutes
L_h = hydraulic length in feet
C_g = factor combining everything except hydraulic length

Ferguson's equation is shown in the chart format, Figure 2. To use the chart, start at the bottom, read up to the line for the watershed's cover factor c, and then to the left to read c_g. then apply the factor to find overland flow time of concentration, $t_c = L_h^{½} c_g$.

STUDENT PROBLEM #2

Using Figure 2, what is the time of concentration for a site where the hydraulic length is 50 feet, the slope is 5% and the cover is grass (use a "c" value of .2).

Student Answer _________________

After the time of concentration is calculated, it must be applied to the design storm for the site. Frequently the 10-year storm is used however, as stated before, the design storm is based on the control intent.

Figure 3 shows the Intensity-duration-frequency curves for Madison, Wisconsin. Using the time of concentration calculated from student problem #2, and a 10-year storm, the rainfall intensity that would be used in the rational method is approximately 5.5 inches per hour. If one were designing for the 2-year storm, the intensity would be about 4 inches per hour.

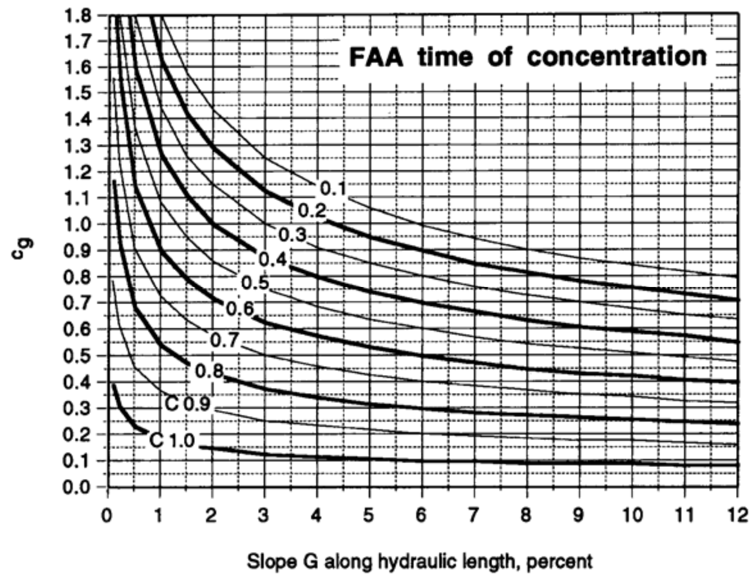

Figure 2. Time of Concentration

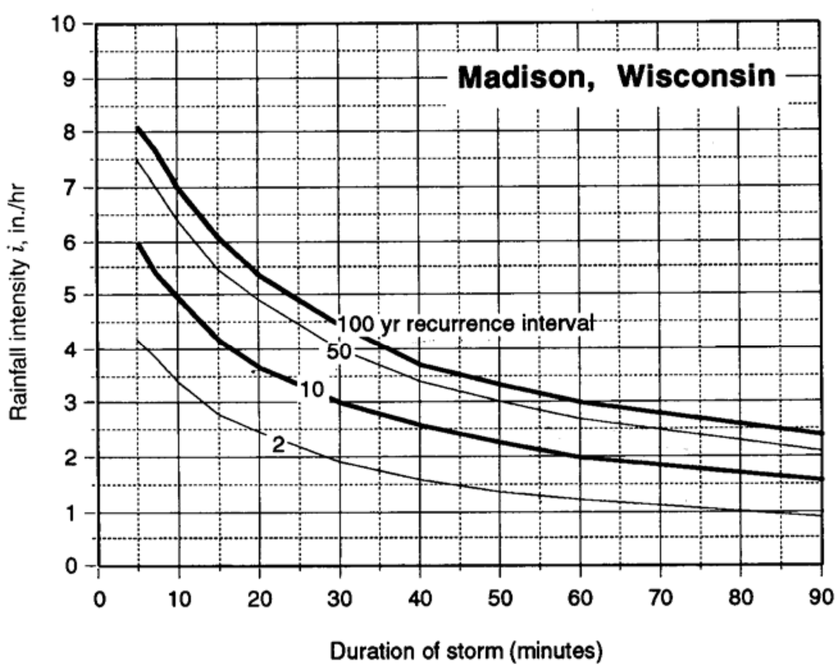

Figure 3. Intensity-Duration-Frequency Curve

The Rational Method, however only provides a peak flow rate. This rate permits the piping system to be sized so as to safely carry the peak flow to a treatment device or to a point of dispersal or discharge. The Rational Method was not intended to be used for calculating volume so this system does not provide any information for the designer of a detention or infiltration system.

Other programs and equations are acceptable for calculating volumes and rates of flow. The volumes should be calculated based on a 100- year, 1- hour storm. The code revision team is considering the adoption of other standards for the design of the storm system. These include releasing at the pre-development 2 year, 24 hour storm rate and safely withstand the 100-year storm.

TR – 55

Technical Release 55 (TR-55), Urban Hydrology for Small Watersheds, was first issued in 1975. It was designed to provide a simplified procedure to calculate storm runoff volume, peak flow, hydrographs and storage volumes required for stormwater management structures.

TR-55 is a model. The new Windows version has specific capabilities and limitations, including those shown in Table 5.

Table 5. Win TR-55 Capabilities & Limitations

Variable	Limits
Minimum area	No absolute minimum is included in the software. The user should carefully examine results from sub-areas less than 1 acre.
Maximum area	25 square miles (6,500 hectares)
Number of Subwatersheds	1 – 10
Time of concentration for any sub-area	0.1 hour $\leq T_c \leq$ 10 hour
Number of reaches	0-10
Types of reaches	Channel or Structure
Reach Routing	Muskingum-Cunge
Structure Routing	Storage-Indication
Structure Types	Pipe or Weir
Structure Trial Sizes	1-3
Rainfall Depth	Default or user-defined 0 - 50 inches (0 - 1,270 mm)
Rainfall Distributions	RNCS Type I, IA, II, III, NM60, NM65, NM70, NM75, or user-defined
Rainfall Duration	24-hour
Dimensionless Unit Hydrograph	Standard peak rate factor 484, or user-defined (e.g. Delmarva – see Example 3)
Antecedent Moister Condition	2 (average)

There are certain data requirements that must be entered into the TR-55 main window. These data include:

- Identification data (user, state, county, project, and subtitle)
- Dimensionless Unit Hydrograph
- Storm Data
- Rainfall Distribution
- Sub-Area Data

A user of TR-55 must be familiar with the entry information.
To learn more about TR-55, visit the website at
www.wcc.nrcs.usda.gov/water/quality/common/tr55/tr55.html
DNR staff have provided a simple worksheet that may be used on 5 acre or smaller sites. The following two pages contain this worksheet.

Runoff Volume Calculation for Typical Wisconsin Commercial Sites

Purpose: The purpose of this worksheet is to calculate runoff volumes from pervious and impervious areas using a simplified TR-55 approach. The complete version of TR-55 (210-VI-TR-55, Second Ed., June 1986) can be obtained at the NRCS web site.

Step 1: Select the runoff values from Table 1 for the municipality closest to the site. *Impervious areas* have one value while *pervious areas* have three different values depending on the *hydrologic soil group*. Pick the hydrologic soil group which best represents the site.

TABLE 1
Rainfall (inches) for Selected Municipalities

Parameters	Madison	Milwaukee	Green Bay	Eau Claire	Duluth	La Crosse	Wausau
Rainfall (2-yr 24-hr)	2.8	2.6	2.4	2.7	2.5	3.0	2.8
Corresponding Runoff Quantities (feet)							
Runoff Impervious Area	0.214	0.198	0.181	0.206	0.189	0.231	0.214
Runoff Pervious Area (A – B Soils)	0.048	0.039	0.032	0.043	0.035	0.056	0.048
Runoff Pervious Area (C Soils)	0.087	0.076	0.064	0.081	0.070	0.099	0.087
Runoff Pervious Area (D Soils)	0.113	0.099	0.087	0.106	0.093	0.127	0.113

Step 2: Determine the impervious and pervious *contributing areas*. *(Note: For conversion purposes 1 acre equals 43,560 square feet)*

Impervious Area: ______________ (square feet)

Pervious Area: ______________ (square feet)

Step 3: Determine runoff volumes.

Impervious Area (ft^2) * Impervious Runoff (feet) = Impervious Volume (ft^3)

_____________ * __________________ = __________________

Pervious Area (ft^2) * Pervious Runoff (feet) = Pervious Volume (ft^3)

_____________ * _______________ = ___________________

Total = Impervious Volume + Pervious Volume = _________________ (ft^3)

Note: Per NR 151.12, the infiltration device must infiltrate 10% of the total runoff volume for commercial sites and 25% for residential sites as calculated using a 2-year 24 hour design storm.

Definitions:

Impervious Area: Constitutes roof tops, parking lots, and other paved areas where water is unable too effectively infiltrate. For these calculations impervious areas are assigned a curve number of 98.

Pervious Areas: For these calculations pervious areas are characterized by urban grass cover in fair condition overlaying soils from one of the hydrologic soil groups listed below.

Hydrologic Soil Groups:

- A – B: Soils characterized as sand, loamy sand, or silt loam and having low runoff conditions and moderate infiltration rates. Due to compaction, type A soils are rarely encountered on construction sites.

- C: Soils characterized as loamy or sandy clay loams. Have moderate runoff potential and low infiltration rates.

- D: Soils consisting chiefly of clays, silt clays, sandy clays, and clay loams. Have high runoff potential and very low to no infiltration capacity.

Information on a soil's specific hydrologic soil class can be obtained from soil surveys. However, the textural class listed above provides an adequate means of determining the hydrologic soil group.

Contributing Areas: Areas from which runoff enters the device via overland flow, ditched flow, or piped flow. Areas that are off-site that contribute runoff must also be accounted for during the design but may not be needed when determining the amount of water required to infiltrate.

Assumptions and Notes:

This worksheet is based on TR-55 and provides a simple and quick method to calculate runoff volumes from commercial sites. Calculation of runoff peaks and flow times (time of concentration) requires use of TR-55.

This worksheet assumes the following conditions:

- Pervious areas are assumed to be under average antecedent moisture conditions

- Pervious areas are characterized as grass under fair conditions modified by the soil class. Curve numbers of 69, 79, and 84 are used to characterize A-B, C, and D soils respectively. If an alternate land use is required refer to TR-55 to calculate the runoff volume. For most commercial applications, the numbers utilized in this worksheet will adequately characterize grassed areas and small planting areas.

- To help account for the effects of soil compaction, group A soils have been combined with group B soils and utilize group B curve numbers.

- This worksheet assumes that impervious areas are directly connected. Impervious areas are considered connected if runoff from it flows directly into the drainage system. Unconnected impervious is defined by runoff that flows over pervious areas before discharging to the drainage system.

- Rainfall values for the 2-year 24-hour storm were obtained from TP-40 for seven municipal areas to account for the variation in rainfall patterns across the state.

STUDENT PROBLEM #3

A strip mall is being constructed in DeForest. The site is 3 acres in size with a building footprint (rooftop) of 25,000 square feet and 67,500 square feet of parking. The site has silt loam soils. The developer is using a combination of stormwater detention ponds and an infiltration basin to meet NR 151 requirements. The site is graded so all runoff will be directed to these devices. What is the volume of runoff for the 2-year 24 –hour storm and what volume of runoff is required to be infiltrated?

Volume of runoff for the 2-year, 24-hour storm? ______________

What volume of runoff is required to be infiltrated? _____________

See the appendix for the answer to this Student Problem.

Stormwater Worksheet for Small Sites (< 5 acres)

Pre-Development Calculations			
	Calculating Time of Concentration		
	Inputs:		
		Cover factor (runoff coefficient)	0.2
		Hydraulic length (in feet)	250
		Slope along hydraulic length (%)	4
	Time of Concentration equals -	16.2	*minutes*
		(must be greater than 10 minutes)	
	Calculating Peak Flow for the Small Site (< 5 acres)		
	Inputs:		
		Intensity of Rainfall (related to time of conc.) =	2.8
		Size of area that contributes (in acres) =	1
		Runoff coefficient (same as above) =	0.2
	Peak discharge rate in cubic feet per second (cfs) =		0.56
	Peak discharge rate in gallons per minute (gpm) =		251
Post-Development Calculations			
	Calculating Time of Concentration (Sites with >10% imperviousness, only)		
	Inputs:		
		Cover factor (runoff coefficient)	0.33
		Hydraulic length (in feet)	300
		Slope along hydraulic length (%)	4
	Time of Concentration equals -	8.1	*minutes*
		(must be $\geq$ 5 minutes and not > 1/2 pre-development toc)	
	Calculating Peak Flow for the Small Site (< 5 acres)		
	Inputs:		
		Intensity of Rainfall (related to time of conc.) =	3.8
		Size of area tha contributes (in acres) =	1
		Runoff coefficient (same as above) =	0.33
	Peak discharge rate in cubic feet per second (cfs) =		1.254
	Peak discharge rate in gallons per minute (gpm) =		563

To compute required detention volume - complete page 2

Page 2

Required Detention Volume Calculation Worksheet

<u>Pre-development rate / Post-development rate</u>

0.56	divided by	1.254	0.446571	*cubic feet per second*

Use Required Detention Storage Graph to Determine % of runoff volume that is required in storage

Enter % required from graph in this box -	0.46

Calculate Runoff Volume

Impervious area in acres =	0.18
Pervious area in acres =	0.8

Impervious area runoff for nearest city from Table 1 =	0.231
Pervious area runoff for nearest city from Table 1 =	0.099

Total runoff volume=	5261.2	*cubic feet*

Calculate Required Detention Storage

Required Detention Storage=Total runoff volume X % required storage

Required dentention storage =	2420.1	*cubic feet*

Pipe Diameter Required for Orifice

Discharge Coefficient for orifice from graph	0.8
Height of water above center of orifice, ft.	3.3
Pipe Diameter required, in inches	2.964

Part V, Collection Systems

Inlets

There are several incidences of humans entrapped and drowned by the force of water entering an inlet or sucked into a stormwater inlet by a vortex or high velocity flow. The designer can help eliminate the high velocity, high volume safety hazards by separating flow into inlets rather than concentrating flow at the surface, within reach of people.

At the very start of any stormwater collection system is the inlet. Inlets come in many shapes and sizes and are critical to a responsible stormwater design.
While currently there are limited requirements for inlets (See s. 82.36 (17) (a) 4.), in the future the plumbing code may require inlet calculations. There are several hydraulic issues to be considered when designing inlets; not only the design of the inlet, but the condition where the piping is installed.

There are many types of inlets including manhole grates, curb inlets, gutter inlets, combination inlets and multiple inlets.

Inlet control is where water is backed up at the pipe or culvert entrance. The submerged inlet behaves very much like an orifice with the increased head creating an increased pressure that increases the discharge rate. See Figure 4 for an illustration of inlet control.

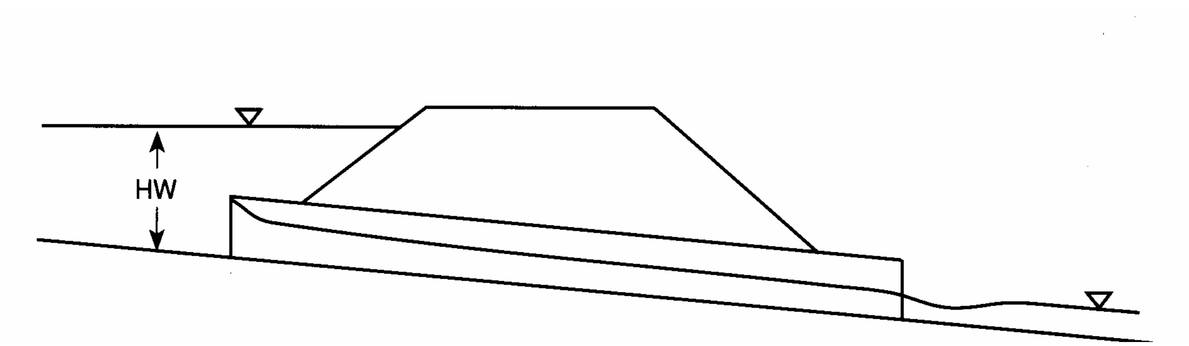

Figure 4 - Inlet control shown for a pipe or culvert

Outlet control is a situation where the pipe outlet is submerged by ponding or a slower flow rate. This also affects the capacity of the system. See Figure 5 for an illustration of one type of outlet control. There are other conditions that affect flow when an outlet is submerged.

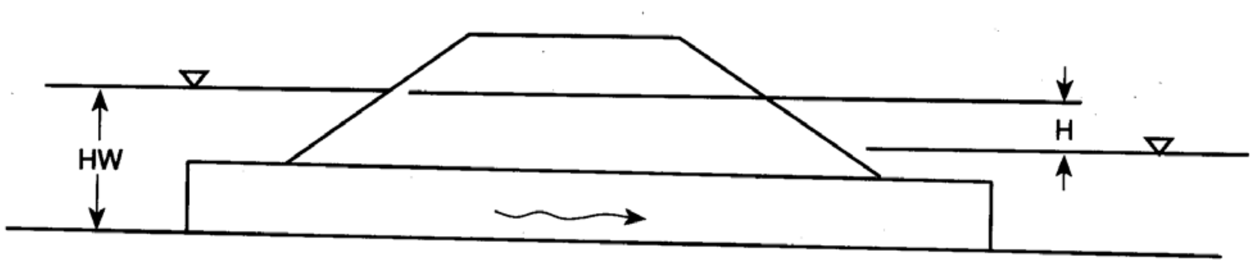

Figure 5 – Outlet control shown for a pipe or culvert

Steele's Advanced Plumbing Design includes an equation for calculating the capacity of a catch basin or manhole style inlet in cfs:

$$Q = 2/3\ A\ C\ (2gh)^{1/2}$$

Where: Q = the capacity of the inlet, cfs
2/3 = a factor to correct for assumed blockage of 1/3 of the inlet's net open area
A = the net open area of the inlet, sq ft
C = an orifice coefficient, usually taken as 0.60
g = a constant , 32.2 ft/sec/sec
h = the head, in feet on the inlet, or the depth of water on top of the inlet, usually not more than two or three inches.

As a rule of thumb, the 4 cfs per inlet may be used for calculations.[1]
Manufacturers of manholes, catch basins and curb inlets can provide the designer with more accurate information on flow through inlets when the variable of water height about the inlet is entered into an equation. An example can be found on Neenah Foundry's website at www.neenahfoundry.com/

STUDENT PROBLEM #4

What is the capacity of an inlet with a net open area of .5 sq ft and a head of 3 inches?

Student Answer: ____________

Part VI, Conveyance

The storm conveyance systems were the exclusive approach to stormwater management until about 1965 (footnote Intro to Stormwater). A conveyance system was designed to handle the peak flow rate during a design storm

Today it seems strange the current Wisconsin Plumbing Code states that "Drain systems shall be designed, constructed, and maintained to conduct the waste water or sewage quickly from the fixture to the place of disposal, with velocities which will prevent clogging, fouling and the depositing of solids, and shall have adequate cleanouts so arranged that the drain pipes may be readily cleaned." s. Comm 82.10 (8). At the time that basic plumbing principle was written, the drainage system had one purpose: to drain water quickly from a site.

In fact, even in Advanced Plumbing Technology, written by Dr Alfred Steele, P.E., CIPE, in 1984 there were still references to the design of "site drainage". Dr. Steele wrote "The primary objective of a site drainage system is to collect and convey all excess storm water from the site to a convenient and safe discharge point." [11]

Currently the tables in Wisconsin's 82.36 address peak flows. A copy of the current sizing tables is included in the appendix of this paper. (See page 28) The designer may use the tables in the code or a formula such as Manning's to calculate velocity and that information can then be used to calculate capacity. Manning's formula was proposed first in 1890 by Robert Manning. It's simpler in the metric system, but when converted to the English system it looks like this:

$$V = 1.486/n \times R^{2/3} \times S^{1/2}$$

Where: V = Velocity of flow in feet per second, fps

n = A coefficient representing roughness of pipe surface, degree of fouling and pipe diameter.

R = Hydraulic radius (hydraulic mean depth of flow) in feet, ft.

S = Hydraulic slope of surface of flow in feet per foot, ft./ft.

The quantity rate of flow is equal to the cross-sectional area of flow times the velocity of flow. This can be expressed as:

$$Q = AV$$

Where: Q= Quantity rate of flow in cubic feet per second, cfs

A = Cross-sectional area of flow in square feet, sq. ft.

V = Velocity of flow, fps

By substituting the value of V from Manning's Formula, we obtain

$$Q = A \times 1.486/n \times R^{2/3} \times S^{1/2}$$

It's important to note the units in the equation and follow them in solving the formula.

The hydraulic radius of a pipe is the ratio of the cross-sectional area of flow to the wetted perimeter of the pipe surface.

$$R = \text{area of flow}/\text{wetted perimeter}$$

For conditions of half flow the hydraulic radius is:

$$R = (\pi D^2/8)/(\pi D/2) = D/4$$

(Remember that the area of a circle is $\pi D^2/4$)

For full flow conditions, such a storm sewer piping, the hydraulic radius is calculated as shown in the following equation:

$R = (\pi D^2/4)/(\pi D) = D/4$

So it's evident that the hydraulic radius is exactly the same whether the pipe is flowing ½ full or full. It also follows that velocity is the same whether the pipe is flowing full or ½ full.

The quantity varies, however as the cross section area of flow increases.

STUDENT PROBLEM #5

Using the derivative of Manning's formula, calculate the quantity rate of flow from a 12- inch diameter sewer that is flowing ½ full and installed at 1/8" per foot slope. Use .013 for a coefficient of friction. (Gravity flow)

Student Answer: ___________________

What's changed in collection systems since 1984? First of all, the plumbing stormwater system's primary objective isn't always to collect and convey stormwater quickly to a discharge point. In fact there are many objectives in today's stormwater system.

Some plumbing systems are designed to detain stormwater in the conveyance piping so the post construction runoff hydrograph closely resembles the pre-development hydrograph of the site. This is called "peak shaving". The detention system may include controlled flow roof drainage systems, oversized piping grids, tank systems or subsurface gravel beds that are lined to prohibit infiltration. Because the systems are meant to detain stormwater, the required slopes for most plumbing drainage piping aren't required for detention systems.

82.36 (6) states that "All horizontal drain piping shall be installed at a pitch which will produce a computed velocity of at least one foot per second when flowing full." Piping designed to "drain" is required to be installed to produce the velocity of at least one foot per second. Piping systems designed to "detain" stormwater may be designed to create less than that one-foot per second velocity. Section V will address plumbing detention systems.

82.36 (6) (a) allows stormwater drain piping systems to be designed and installed to allow the use of the tables for assigning pitch or by using another method that's "otherwise approved by the department."

Although currently there are no stated velocity maximums in section 82.36, there are maximum velocities permitted by the manufacturers of pipe materials. These velocities must be maintained.

Other plumbing systems perform the joint function of collection-infiltration systems. As requirements of municipal stormwater plans and NR 151 become widely used, more of these systems will be designed and installed. In part VIII there will be further discussion of infiltration systems.

The following equations and methods are acceptable for sizing conveyance piping:

- Haestad's Flowmaster
- "Stormy" Excel file created by Safety and Building's Plumbing Program
- Manning's equation for gravity flow
- Hazen-Williams equation for pressurized flow

When a change in pipe diameter occurs at a manhole or catch basin, the alignment of the incoming and the outgoing pipes should be so that the crown of the pipes line up, not the inverts. This installation promotes a smooth water flow and helps to prevent backwater in the upstream piping.[1] Figure 6 illustrates this rule.

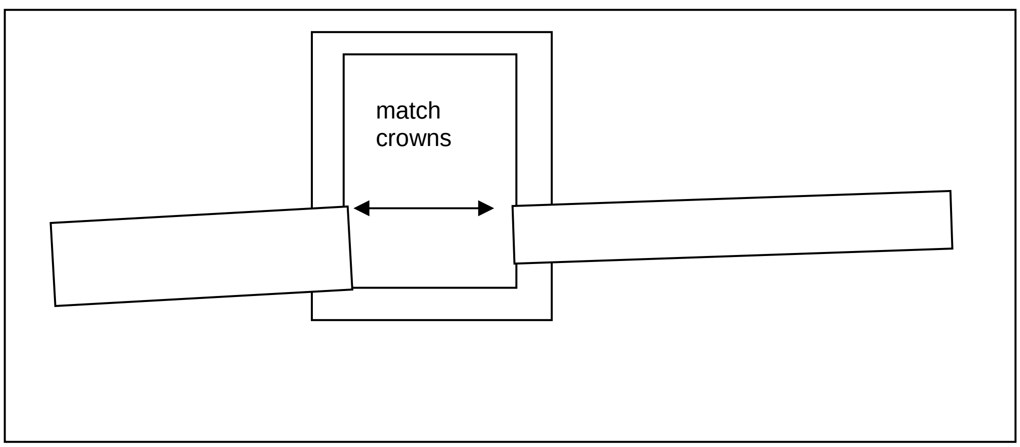

Figure 6 - Crown alignments on storm sewer piping.

Although there will be some changes to interior pipe sizing and system design, the majority of storm design change will probably occur outside the building.

Part VII, Detention

Detention systems are designed to modify the conveyance system to slow the rate of flow from an area. Detention systems may be designed using piping systems, tanks, reservoirs or surface ponds or paved areas. Subsurface detention systems included in the plumbing system currently require review by the department or agent municipality only when the number of inlets or fixtures in a project is greater than 15. There are several arrangements that may be used as subsurface detention.

A detention system poses no risk to the groundwater, as there is no interaction between the groundwater and the stormwater in a detention system. A combination detention/infiltration system, however may represent a source of contamination. Unless a detention system is lined with a synthetic liner, it is considered to be an infiltration system and must meet the infiltration system siting requirements.

Piping systems designed to detain stormwater may be installed with a slope of less than that required for drainage piping. If there is less than 1 foot/second velocity the system must have access ports for cleaning or an equivalent method for removing solids. These installations currently do not require a petition for variance, as they are more like a tank than conveyance piping. This includes restrictor plates or oversized piping. A downstream restriction should occur in a manhole or be accessible.

Above ground detention systems are not regulated by Commerce. Detention on parking lots by restricted piping systems or inlets must allow ponding only to a height of 6 inches in parking lots and not allow water to enter the building. Cities may have more stringent requirements for the allowance of surface detention on parking lots.

Detention tanks. There are several designs including tanks that are currently used and there will probably be many more designs that will appear in the future. A lined subsurface gravel-filled void is one example. Another is the concrete structure. No product review is required for these tanks at this time. The revision of Comm 82.36 may address these structures more fully.

Controlled flow roof drainage. Plumbing systems may use controlled flow roof drain designs as a mode of detention. The adoption of the Wisconsin Building Code in 2002 created some changes in the code requirements for secondary drainage systems serving roof areas. See Section 1611 of the Wisconsin Enrolled Commercial Building Code for more information.

Part VIII, Infiltration

Currently Table 82.20 -1 permits the subsurface infiltratioin of stormwater only with department approval. The method for obtaining approval is to submit a plan to one of the Safety and Building's offices that reviews subsurface infiltration systems. At this time that would be La Crosse, Hayward or Green Bay. No agent cities are currently approved to perform infiltration system plan review and approval, however there will soon be approval for several cities to perform these reviews.

A subsurface infiltration system could look like a conventional "gravity dispersal system" (septic system) or it may resemble a subsurface created wetland. There are as many options for these designs as there are stormwater infiltration designers in Wisconsin.

S. Comm 82.365 contains the requirements for infiltration systems. Contact one of the plumbing staff for help in infiltration system design.

Infiltration System Approval

- Comm 85 must be followed for site evaluation. S. 85.10 (1) allows the soil evaluation to be performed by certified soil tester or a professional soil scientist.
- A stipulation of the approval will be that no substances should be discharged into the infiltration system that would cause an exceedence of groundwater standards.
- Load rates should be based on s. 82.365 (3) (c). Talbe 82.365-1, -2 and –3 all have a relationship to dispersal of stormwater into in situ soils.
- Vertical setbacks to zones of seasonal soil saturation are addressed in Table 82.365-1. Groundwater mounding must be taken into account when designing an infiltration system more than 15 feet wide. More information on calculating groundwater mounding is available from the plumbing plan reviewers.
- A sand blanket consisting of engineered soils to treat stormwater may be added to an in situ soil that doesn't meet the vertical setback requirements.
- Drain down time should be less than 72 hours.
- The separation setbacks in NR 811 and NR 812 must be adhered to. There must be a 100-foot separation from private wells and a 400-foot separation to public wells for infiltration basins or trenches, this does not apply to irrigation systems.
- The load rate as shown on table 6 permitted for infiltration must comply with the requirements in Table 82.365-1. Although stormwater and it's quality impact on the environment is a fairly new concept, the groundwater law in Wisconsin requires that all state agencies' rules protect these waters of the state.
- Parking lots and industrial stormwater discharge requires pretreatment prior to infiltration.
- DNR has requirements that they're notified of the installation of a class V injection well. Rich Roth of DNR may be contacted at 608-266-2438 for the forms required for registration.

Table 6 (Table 82.365-2) illustrates infiltration rates for various qualities by several sources. Many of the infiltration rates in Table 6 are based on the references in Table 7.

TABLE 6
Table 82.365 -2
DESIGN INFILTRATION RATES FOR SOIL TEXTURES
RECEIVING STORMWATER

Inches per Hour

Soil Texture[a]	Design Infiltration Rate without Measurement inches/hour [b]
Coarse sand or coarser	3.60
Loamy coarse sand	3.60
Sand	3.60
Loamy sand	1.63
Sandy loam	0.5
Loam	.24
Silt loam	.13
Sandy clay loam	.11
Clay loam	0.03
Silty clay loam	0.04[c]
Sandy clay	0.04
Silty clay	.07
Clay	.07

[a] Use sandy loam design infiltration rates for fine sand, loamy fine sand, very fine sand and loamy fine sand soil texture.
[b] Infiltration rates represent the lowest value for each textural class presented: based on Rawls et al. 1998 (Use of Soil Texture, Bulk Density and Slope of Water Retention Curve to Predict Saturated Hydraulic Conductivity. ASAE Vol. 41 (20, pp. 983-988)
[c] Infiltration rate is an average, based on Rawls, et al. 1982 (Estimation of Soil Water Properties. Transactions of the American Society of Agricultural Engineers Vol. 25, No. 5 pp.1316-1320 and 1328) and Clapp & Hornberger, 1978 (Empirical equations for some hydraulic properties. Water Resources Research 14:601-604).

In looking at the table, it's evident that all textural classes are represented. The very low hydraulic load rates on the finer textured soils would allow irrigation practices. Minnesota discourages infiltration on sites where soils are > 30% clay or > 40% silt.[4]

Table 7
Load Rates from Various Texts based on Water Quality
Load Rates in Inches/Hour

Texture	Structure	Rawls et al 1982[14]	Tyler 1991 [16]	Siegrist 1987[17]	Highly Treated Comm 83	Effluent Comm 83	Meadow Surface Storm.[15]
Coarse sand			0.9	0.4	0.1	0.05	1.39
Sand	unstructured	8.27	0.9	0.4	0.1	0.05	1.39
Very fine sand			0.1	0.2	0.04	0.03	
Fine sand	moderate or strong				0.1	0.03	
Fine sand	weak or massive		0.1	0.2	0.04	0.03	
Loamy sand	weak to strong				0.1	0.05	1.39
Loamy sand		2.41	0.9	0.4	0.05	0.03	
Loamy v fine sand			0.1	0.2	0.04	0.03	
Loamy fine sand	moderate or strong				0.1	0.03	1.39
Loamy fine sand			0.1	0.2	0.04	0.03	
Sandy loam	unstructured	1.02	0.03	0.1	0.03	0.02	1.39
Loam	moderate or strong		0.3	0.3	0.05	0.03	.99
Loam	weak		0.1	0.2	0.04	0.03	.99
Loam	unstructured	0.52	0.03	0.1	0.03	0.02	.99
Silt loam	moderate or strong		0.3	0.3	0.05	0.03	.99
Silt loam	weak		0.1	0.2	0.02	0.01	.99
Silt loam	unstructured	0.27			0.01	0	.99
Sandy loam	moderate or strong		0.3	0.3	0.1	0.03	
Sandy clay loam	moderate or strong		0.1	0.2	0.04	0.03	.57
Sandy clay loam	weak		0.03	0.1	0.02	0.01	.57
Sandy clay loam	unstructured	0.17					.57
Clay loam	moderate or strong		0.1	0.2	0.04	0.03	
Clay loam	weak		0.03	0.1	0.02	0.01	
Clay loam	unstructured	0.09			0	0	
Silty clay, low c	moderate or strong		0.03	0.1	0.02	0.01	
Silty clay loam	moderate or strong		0.1	0.2	0.02	0.01	
Silty clay loam	weak		0.03	0.1	0	0	
Silty clay loam	unstructured	0.06			0	0	
Sandy clay	moderate or strong		0.03	0.1	0.02	0.01	.57
Sandy clay	unstructured	0.05			0	0	
Silty clay	unstructured	0.04			0	0	
Clay	moderate or strong		0.03	0.1	0.02	0.01	.57
Clay	unstructured	0.02			0	0	

Part IX - Treatment

In NR 151, there are requirements for treatment, however the extent of required treatment is not measurable. Treatment is required for parking lot runoff and for runoff from new road construction in commercial, industrial and institutional areas. There is a vertical distance required between high groundwater, bedrock and the infiltrative surface of any infiltration device unless the engineered soils of the device offer equivalent protection.

Aside from the NR 151 requirements, the Wisconsin Uniform Plumbing Code has the requirement that all stormwater (with the exception of roof runoff) to be infiltrated require pretreatment for suspended solid and grease and oil at a minimum. The plumbing code requires approval of devices or systems that claim treatment capability of stormwater for reuse or infiltration.

DNR has completed preliminary research on the treatment capability of several treatment devices. Table 8 contains this preliminary data.

Table 8
Treatment Efficiency of Stormwater Devices

Practice	% Efficiency	Median Effluent Concentration of TSS mg/L
Pressurized sand filter	85	7.5
Stormwater management filter	- -	16
Detention Pond	88	35
MCTT	80	5 (232 influent)
Vortechnics	- -	64
Vortechnics	78	29
Stormceptor	33	102

Table 82.70 requires pretreatment of stormwater to the following values.

< 15 mg/L oil and grease
< 60 mg/L TSS

For treatment related to stormwater use, see Part X – Stormwater Use.

The Wisconsin Plumbing Product Register contains a list of approved stormwater treatment devices that have been approved to date.

Part X - Stormwater Use (Harvesting)

NR 151 has an allowance that reuse may be substituted as an equivalency to the required infiltration volume. For a 1.5 acre disturbed site, NR 151 may require an infiltration device designed to infiltrate 1.0 inches of stormwater from the 16,000 square foot roof. This would actually be a design that would infiltrate (.083 X 16,000) X 7.48 gallons of water, or 9,933 gallons. If this water could be stored and used for toilet flushing or irrigation, it would also meet the requirements of NR 151.

In order to be used for an additional purpose, stormwater must be treated to comply with the requirements of Table 1 in Comm 82.70. Further requirements are listed in Comm 82.34, 82.40 and 82.41.

For more information concerning stormwater use, contact Tom Braun at 715-340-5387.

Part XI - Accessibility and Maintenance

ALL plumbing systems require maintenance. It seems to be a given that when the water closet doesn't flush, someone fixes the water closet. When a stormwater detention system becomes filled with silt or groundwater contamination occurs when an infiltration system fails, it's a more complicated situation, but it still needs repair and maintenance.

Designers need to plan for that maintenance. The future stormwater code may contain specific management requirements for storm systems, however the current code, s.Comm 82.20 (2), says that "All plumbing systems, both existing and new, and all parts thereof, shall be maintained in a safe and sanitary condition. All devices or safeguards which are required by this chapter shall be maintained in good working order. The owner shall be responsible for the maintenance of plumbing systems." In addition, s. 82.36 (13) requires that "An operation and maintenance plan shall be implemented for all stormwater plumbing systems for drainage areas of one or more acres that are installed on or after December 1, 2004."

With infiltration system approvals, maintenance requirements may be included in the department's stipulations.

Cleanouts are required in the current code language. S. Comm 82.35 (3) contains requirements for storm building sewers 10 inches or less in diameter that include:

a. Cleanouts are located not more than 100 feet apart;
b. Manholes are located not more than 400 feet apart;
c. The distance from a cleanout to a manhole located upstream is not more than 200 feet;
d. Or; the distance from a manhole to a cleanout located upstream is not more than 300 feet.

Storm building sewers 12 inches or larger in diameter are required to have manholes at:

a. Every change of direction of 45 degrees or more
b. Every change in pipe diameter, and
c. Intervals of not more than 400 feet.

As velocity decreases or contaminant load increases more cleanouts or accessibility ports (e.g. manholes) could be required during a review of detention or infiltration systems.

Part XII - Vector Control

Vector control is an important issue that's tied to maintenance. The most dangerous vector related to stormwater is currently the mosquito.

In 1998 the California Department of Health Services Vector-Borne Disease Section conducted a study to learn whether storm practices supported vector populations. The results left no questions that mosquitoes use the standing water in stormwater devices as homes. It was evident that requiring stormwater devices has allowed many species to greatly expand their range and increase their numbers. Even small breeding areas combine to make big problems.

There are two types of mosquitoes; the permanent water species and the flood water species. One lays its eggs in quiet water and the other lays eggs on damp soil where the next flooding event will allow a hatch.

The research done in California shows the Aedes, Culex and Anopheles mosquitoes are most often associated with stormwater devices.

With recent concerns over West Nile Virus and continuing issues with La Crosse Viral Encephalitis, the industry and stormwater regulators should consider that construction of new habitats has the potential of making a bad situation worse.[5] Maintenance schedules that ensure system's operation as designed is critical for vector control. Laurie Garrett reports that "For most insect experts it came as no surprise that even a one-year slackening in mosquito control efforts could result in a surge in the bugs and the microbes that they carried." [13]

How could plumbing designs be modified to reduce mosquito breeding sites? First of all, drain down times should be reduced to a time period below 72 hours. The current proposal for infiltration devices by the Technical Standard group is a maximum drain down time of 24 hours.

Secondly, subsurface system inlets can be sealed or screened to prevent mosquito entry. A third way of providing a preventative measure for surface standing water is to fill the area with rock so as to eliminate mosquito habitat.

Part XIII, Inspection Checklist

As the Wisconsin Uniform Plumbing code is going through this period of transition, careful inspection is necessary. Following is an inspection checklist for use with 82.36.

If there are questions, please call a plumbing plan reviewer or consultant in your area.

STORM INSPECTION CHECKLIST – 2005

ISSUE	REQUIREMENT	CODE/POLICY	O.K.
Interior clearwater systems	Plan approval required if > 15 fixtures in project.	Table 82.20 – 1 or –2	
	Code compliant materials	84.30-1, -2	
	Sizing by charts or engineering analysis (1 ft per second flowing full)	82.30 (3) & (4)	
	Pitch - <3” min. 1/8”/ft ≥3” 1/16”/ft minimum	82.36 (6) (e)	
	Traps on interior clearwater inlets	82.36 (12) (a)	
	Vents on interior clearwater traps (separate from sanitary system)	82.36 (12) (b)	
	Connections downstream of stacks (20 X ID of building drain)	82.36 (6) (f)	
	Inlets 1” above floor level	82.36 (9)	
	Cleanouts on horizontal drains	82.35 (3) (a)	
Subsoil Drains (foundation drains)	Accessible backwater valve (if subject to backwater)	82.36 (7) (b)	
	Discharge to area drain, manhole or storm sewer, trapped receptor or sump & pump	82.36 (7) (a)	
	Materials	84.30-7	
Roof Drain Systems	Plan review required for >15 fixtures in project.	82.20-1 & -2	
	Cleanouts in conductors (if installed must be 28-60” above lowest floor level)	82.35 (3) (k)	
	Materials	84.30-1 (may use black steel)	
	Sizing: Horizontal	82.36 (6)	
	Sizing: Vertical	82.36 (6)	
Roof Inlets	Option 1: Strainers ≥ 4” above roof surface. Strainer inlet area ≥1 ½ X open area of conductor Option 2: Flat roof. Strainer flat on roof. Strainer inlet area ≥ 2 X open area of conductor.	82.36 (10)	
Controlled Flow Roof Drain Systems	Dept of Commerce Review	82.20-1 & -2	
	See manufacturer’s requirements		
Interior Sump & Pump	Rim ≥ 1 inch above floor (except sealed cover elevator & meter pit)	82.36 (8) (a) 2.	
	Removable cover with adequate strength	82.36 (8) (a) 2.	
	15 feet from well (25’ from well if perforated sump)	82.36 (18) (a) 3. and NR 812	
	Clearwater sump min. size – 14-16 X 22 minimum	82.36 (8) (a) 4.	

	Discharge to building drain or sewer requires check valve.	82.36 (7) (d) 3.	
Storm Building Drain	Materials	84.30 –1 or –2	
	Backflow protection if backflow could be a problem.	82.36 (7) (d) 3.	
	Pitch	82.36 (6)	
	Sizing (per charts or per 1 ft/second flowing full)	82.36 – 1 – 5	
Storm Sewers	Plan review for PIMS > 4" diameter	Table 82.20-2	
	Plan review for > 15 fixtures in project	Table 82.20- 2	
	Pass through or under one building to serve another.	82.36 (7) (c)	
	Insulation as required as per 82.30 (11) If clearwater is discharged and subject to freezing..	82.36 (7) (d) 7	
	Materials	84.30 – 6	
Area Drain Inlets	Watertight & of approved materials	84.30 (3) (f)	
	Grates of adequate strength	82.36 (9) (b) c.	
	Inlet area must be <u>adequate</u>	82.16 (9) (b) 2.	
Subsurface Drains	≤ 50 sq. ft. require drains, may drain to: • subsoil drains with a minimum 2" dia. • subsoil drains via gravel trench • storm building drain, storm sewer, storm subdrain, via 3" min. dia. pipe	82.36 (9) (c)	
	> 50 sq. ft. require area drain inlet to storm sewer, subdrain or storm building drain. NOT to subsoil, footing or foundation drain.	82.36 (9) (d)	
Maintenance Plan	Required for drainage area of 1 acre or more	82.36 (13)	
Detention Systems	No contact permitted with in situ soils on site.		
	Cleanouts/ports to provide access where needed.	82.10 (13)	
	Calculations with TR-55 or other model.		
	Materials that fit use, no product approval required at this time.		
	Plan review required for > 15 fixtures in project.	82.20 –1 & -2	
Infiltration Systems	ALL PLUMBING STORMWATER INFILTRATION SYSTEMS REQUIRE STATE LEVEL PLAN REVIEW.	82.20	
	Soils match those shown in soil & site evaluation.		
	Installed on dry day, with soil moisture appropriate for installation.		
	Materials, sizing, etc. as per plan approval.		

	Pre-treatment as required on plan installed.		

References

1 - Hydraulics and Hydrology for Stormwater Management. John E Gribbin, P.E. 1994. Delmar Publishers. http://www.delmar.com/delmar.html

2 – Maryland's Stormwater Manual.

3 – "Sources of Pollutants in Wisconsin Stormwater" R.T. Bannerman, etal. 1993. Wisconsin Department of Natural Resources. Madison, WI 53707

4 - Minnesota Urban Small Sites Best Management Practice Manual. Minnesota Urban Small Sites. Metropolitan Council/Barr Engineering Co.

5 – Stormwater/The Dark Side of Stormwater Runoff Management. Marco Metzger, PhD, etal. 2002. Forester Communications, Inc. wysiwyg:/199/http://www.Forester.net/sw-02030_dark.html

6 – Filling In the Missing Rainfall Data. Larry Thornton, P.E. Fluor Daniel Inc., Kansas City, MO " Plumbing Engineer" May 1992

7 – "Rainfall Rates: How Much Rain Is Enough In Design?" Julius Ballanco, P.E. JP Engineering, Munster, IN. "Plumbing Engineer"

8 – Wastewater and Stormwater Systems

9 – Groundwater Contamination from Stormwater Infiltration. Pitt, etal. 1996. Ann Arbor Press, Inc. Chelsea, Michigan.

10 – Introduction to Stormwater. Bruce K Ferguson. 1998. John Wiley & Sons, Inc. New York.

11 – Advanced Plumbing Technology. Dr. Alfred Steele, P.E., C.I.P.E.. 1984. Construction Industry Press. Elmhurst, IL.

12 – "Design of Stormwater Filtering Systems". Richard A. Claytor & Thomas R. Schueler. 1996. The Center for Watershed Protection. Silver Spring, MD.

13 – The Coming Plague. Laurie Garrett. 1994. Penguin Books. New York.

14 – Estimation of Soil Water Properties, Transactions of the American Society of Agricultural Engineers, vol. 25, no. 5, pp 1316-1320, 1328.

15 – Handbook of Applied Hydrology. Musgrave, G.W. & Holtan, H.N. 1964. McGraw-Hill. New York.

16 – Estimating Wastewater loading rates using soil morphological descriptions. Tyler, et. al. 1991 Proceedings of the Sixth National Symposium on Individual and Small Community Sewage Systems. ASAE. p 192-200

17 – Hydraulic loading rates for soil absorption systems based on wastewater quality. Siegrist, R. L. 1987. Proceedings of the Fifth National Symposium on Individual and Small Community Sewage Systems. ASAE p. 179-190

18 - Wisconsin Uniform Plumbing Code, Chapters 81-87. 2002

APPENDIX

Answers to Student Problems

Problem # 1, Page 12. 1.0175 cfs or 456.6 gpm

Problem #2, Page 13. 6.7 minutes

Problem #3. Page 18.

<u>Solution:</u>

1. Determine rainfall: DeForest is closest to Madison so use the Madison rainfall numbers from Table 1.

2. Determine hydrologic soil group and runoff numbers: Based on the textural descriptions, silt loam soils fall under hydrologic group B so from Table 1 the pervious runoff is 0.048 feet and the impervious runoff is 0.214 feet (for Madison).

3. Calculate areas: The impervious contributing area is the sum of the parking and rooftop thus we have 25,000 ft^2 plus 67,500 ft^2 for a total of 92,500 ft^2. The pervious area by default is the 3 acres minus the 92,500 ft^2 of impervious area. This leaves 38,180 ft^2 of pervious area.

4. Runoff volumes:

   - Impervious = 92,500 ft^2 * 0.214 ft = 19,795 ft^3
   - Pervious = 38,180 ft^2 * 0.048 ft = 1,831 ft^3

5. Total runoff volume equals 21,625 ft^3. Since the infiltration volume for a commercial site is 10% of the total runoff, 2,163 ft^3 of runoff needs to be infiltrated.

Problem #4. Page 20. .8 cfs. or 361.7 gpm

Problem #5. Page 21. 1.82 cfs or 816.8 gpm