



Storm Water Management Design Manual

2019 Update



City of Mason, Ohio

Storm Water Management Design Manual

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Section 1 - Introduction

This manual provides engineering design and construction standards for storm water management, including requirements of the Ohio Environmental Protection Agency (OEPA) permit for Municipal Separate Storm Sewer Systems (MS4) to discharge storm water under the National Pollutant Discharge Elimination System (NPDES). These standards are intended for use by engineers, builders, contractors, land planners, and property owners contemplating some form of land alteration within the City of Mason. Included in this manual, are the City of Mason's storm water design guidelines, including specifics on hydrology, hydraulics, erosion and sediment control, comprehensive storm water management and construction materials and methods.

1.1 Storm Water Policy Goals

There are many goals in storm water management. The most important of these is to protect life and property of the residents and businesses of Mason from damage due to storm water runoff and to establish standards that achieve a level of erosion control and storm water control that will minimize and abate degradation of land and water resources. The regulations that are included in this manual are intended to achieve these primary goals. In addition, this manual provides the following benefits:

- Providing a clear explanation of what is required for storm water management plan submittals and project reviews.
- Assuring that storm water controls are incorporated into site planning and design at the earliest possible stage and that all storm water management practices are properly designed, constructed and maintained.
- Ensuring consistency in review of storm water permit applications and land alteration plans by the Engineering Department staff.
- Improving the ability of contractors to properly and consistently install storm water facilities, with a high level of workmanship, according to the approved storm water management plan.
- Meeting community needs for minimizing the impacts of new and modified development on existing storm water management facilities, and on upstream and downstream properties.
- Meeting community needs for protecting local water resources by encouraging the construction of storm water management practices that serve multiple purposes, such as flood control, erosion control, water quality protection, recreation and habitat preservation.

This manual was developed with the assumption that its user will possess a basic understanding in the area of civil engineering design, construction, or land alteration, depending upon that person's particular area of expertise. *Readers of this manual, who are not qualified by education and experience in the field of construction, engineering, or land alteration, should consult with a Registered Professional Engineer (P.E.), who is qualified or possesses professional expertise in one or more of these fields, prior to application of the requirements set forth herein.*

1.2 Construction Plan Submittal Requirements

1. In Accordance with the City of Mason's Construction Plan Application Procedure, as described in the City of Mason Zoning Ordinances, the contractor/developer shall include with their construction plan application two (2) copies of the drainage boundary map, Storm Water Pollution Prevention Plan (SWP3), Comprehensive Storm Water Management Plan (SWMP) and storm water calculations for the proposed development. These items must be submitted and approved by the City of Mason Engineering and Building Department prior to any grading and/or construction work. The calculations must be completed in accordance with the procedures described in this manual and must meet the storm water management standards established by Ohio EPA: Authorization for Storm Water Discharge Associated with Construction Activities under the National Pollutant Discharge Elimination System (NPDES) Permit and this manual.
2. The contractor/developer shall submit calculations for projected storm water runoff flows, volumes, and timing into and through all storm water management practices for flood control, channel protection, water quality, and the condition of the habitat, stability, and incision of each water resource and it's the floodplain, as required in Section 5 of this manual.
3. The calculations shall be prepared in an organized fashion in order to allow for a complete and accurate review of the results. Any report not prepared in accordance with this manual may be returned to the contractor/developer for re-submittal. The submittal shall be completed for both pre- and post-development land use conditions and shall contain all pertinent information, back-up data, calculations, assumptions, etc. required to support the conclusions of the report and the facility's design. At a minimum, all sets of calculations submitted to the City for review shall contain the following items:
 - a) A report summary shall be included at the beginning of all submittals summarizing the results of the calculations. The summary shall include a site description and site map of the drainage area. The report shall also include the critical storm determination and a list of all assumptions made about said drainage area, including any offsite areas that contribute runoff into the facility's system. The summary must also include a description of the methods used to complete the calculations. The summary shall include the results of the calculations and best management practices utilized, detailing how the facility meets Ohio EPA's Construction Permit and the City's storm water management criteria.
 - b) The submittal shall include copies of all calculations, model outputs, tables, spreadsheets, graphs, etc., used in the development of the report. The basis of all results of the report must be documented with supporting data, information, etc. The calculations and model output for each analysis shall be separated from one another and clearly identified. In addition, all model output must also be provided with a summary of the input data used to develop the model.

- c) A hydraulic analysis of the proposed storm sewer system must be submitted for review. The analysis may be prepared in a tabular format similar to that illustrated in Forms 1 and 2 (included in Appendix A).
- d) A Time of Concentration worksheet (Form 3, Appendix A, or similar) shall be submitted.
- e) If a detention/retention basin is designed, a summary report must be included. Detailed information related to the basin, outlet structure, and overflow spillway must be provided. Inflow hydrograph stage-storage-discharge calculations and routed hydrograph must be submitted for the design of all detention basins. Form 4, Appendix A provides the general format that should be followed. In addition, a detailed drawing of the outlet structures, any water quality features and maintenance plan must be provided.
- f) If the basin falls under the design requirements of a “major basin,” as defined in this manual, an SCS method data summary (Form 5, Appendix A, or similar) and curve number determination worksheet (Form 6, Appendix A, or similar), shall be submitted, or other pertinent data for the hydrograph methodology used.
- g) The submittal must include a copy of the drainage map, the Storm Water Pollution Prevention Plan (SWP3) and the Comprehensive Storm Water Management Plan (SWMP) with the construction plan application.

1.3 Symbols & Abbreviations

<i>Symbol</i>	<i>Definition</i>	<i>Units</i>
A	Drainage area	acres, sq mi
BMP	Best Management Practice	-
C	Runoff coefficient	-
C _D	Coefficient of discharge	-
C _f	Frequency factor	-
CN	SCS-runoff curve number	-
D	Normal flow depth	ft.
d	Time interval	hours
g	Acceleration due to gravity	ft/sec ²
H	Head	ft.
I	Rainfall intensity	in/hr
I _a	Initial Abstraction	in
K	Side Slope Correction Factor	-
L	Length	ft
NPDES	National Pollutant Discharge Elimination System	-
n	Manning's roughness coefficient	-
P	Accumulated rainfall/ Precipitation depth	in
P _w	Wetted Perimeter	ft.
Q	Flow rate	cfs
Q _x	Peak flow from the x year rainfall event	cfs
R	Hydraulic radius	ft
Y	Ground slope	ft/ft or %
S	Potential maximum retention	in
SCS	Soil Conservation Service	-
TMDL	Total Maximum Daily Load	-
T _c	Time of concentration	hours
T _d	Maximum shear stress	lbs/ft ²
T _L	Lag time	hours
T _t	Travel Time	hours
V	Velocity	ft/s
WQV	Water quality volume	acre-ft

1.4 Definitions

<i>Term</i>	<i>Definition</i>
Antecedent Moisture Condition	The soil moisture conditions of the watershed at the beginning of a storm.
As-Built Plans	A set of construction or site plans that includes all improvements constructed by the developer/owner, including location and elevations of the improvements. The plans must be certified correct by a registered engineer in the State of Ohio.
Baseflow	The normal flow that exists in a stream that is not directly related to a storm event.
Basin	A detention/retention facility with the primary purpose of providing storm water control.
Best Management Practices (BMPs)	Practices to prevent or reduce the pollution of water resources.
City	The City of Mason and it's authorized agents.
Concentrated Storm Water Runoff	Surface runoff that converges and flows through water conveyance features such as swales, gullies, waterways, channels or storm sewers and exceeds the maximum flow rates of filters or perimeter controls intended to control sheet flow.
Critical Depth	Critical depth is the depth of flow at which the specific energy is a minimum.
Developer	Person or company performing construction work of any kind in the project area.
Erosion	The process by which the land surface is worn away by the action of water, wind, ice or gravity.
Freeboard	Freeboard is an additional depth regarded as a safety factor, above the peak design water elevation.
Grading	Any earth disturbing activity including excavation, stripping, cutting, filling, stockpiling, or any combination thereof.
Hydrograph	A graph of runoff from a watershed with respect to time.
Impervious Area	Any area that does not allow soil adsorption or infiltration to occur; areas that are not pervious.
Infiltration	The process of storm runoff soaking into the ground surface and flowing through the upper soil surface. The infiltration curve is a graph of the infiltration rate with respect to time.
Invert	The flowline of the pipe or conveyance.

<i>Term</i>	<i>Definition</i>
National Pollutant Discharge Elimination System (NPDES)	A regulatory program in the Federal Clean Water Act that prohibits the discharge of pollutants into surface waters of the United States without a permit.
Natural Waterway	Waterways that are a part of the natural topography.
Interception	The storage of rainfall on foliage and other intercepting surfaces during a rainfall event.
Peak Discharge	The maximum rate of flow of runoff passing a given point during or after a rainfall event. Also known as peak flow.
Post-Development Conditions	The hydrologic/hydraulic conditions of a site when completely developed with well-established vegetation.
Pre-Development Conditions	The hydrologic/hydraulic conditions prior to the start of construction.
Sheet Flow	Overland water runoff in a thin uniform layer.
Storm Drains	Underground pipe systems designed to intercept and convey to an adequate outlet storm water runoff.
Storm Frequency	The average time interval between equal magnitude rainfall or storm events. For example, a 25-year storm has the probability of occurrence of once every 25 years on the average, or a 4 percent chance of occurrence in any given year.
Storm Water Conveyance System	All storm sewers, channels, streams, ponds, lakes, etc., used for conveying concentrated storm water runoff or storing storm water runoff.
Storm Water Runoff	Excess rainfall after interception, depression storage, infiltration, and evapo-transpiration, that flows off the land.
Subdivision	The division or re-division of a lot, tract or parcel of land by any means into two or more lots, tracts, parcels or other divisions of land.
Tailwater	Standing or running water, and specifically its elevation, outside the downstream or outlet end of a culvert or storm drain system.
Watershed	The drainage area contributing storm water runoff to a single study point (an identified drainage outlet or stream mouth).

Section 2 - Hydrology

2.1 Introduction

Hydrology is generally defined as a science dealing with the interrelationship between water on and under the earth and in the atmosphere. For the purpose of this policy, hydrology will deal with estimating runoff volume and rates of runoff as the result of precipitation. Runoff volume rates are usually considered in terms of peak runoff or discharge in cubic feet per second (cfs), and hydrographs as discharge over time. For structures that are designed to control the volume of runoff (such as detention storage facilities), or where flood routing culverts are used, the entire discharge hydrograph is applicable.

2.2 Approved Methods

The following hydrologic methods will be accepted by the City of Mason:

1. Rational Method: Used for detention facilities (for areas less than 5 acres only) and storm sewer design.
2. SCS Unit Hydrograph: Includes TR-55 and TR-20 computer programs, HYDRO, and HEC-1 Computer Programs. Acceptable for most storm water management applications where hydrograph generation is required.
3. Alternative Method: If another method is preferred, the method must first be calibrated to local conditions and tested for accuracy and reliability. In addition, complete source documentation must be submitted for review and approval by the City Engineer prior to submission of the design plans.

2.3 Design Frequency

The following design frequencies will be used within the City of Mason for the following types of facilities:

1. Storm Sewers: Storm sewer systems shall be designed to accommodate storm water discharge that will pass the 10-year frequency event without surcharging and the 25-year event without exceeding the catch basin/manhole rim.
2. Culverts: Culverts under streets shall be designed to pass the 100-year frequency event without overtopping the road. An easement must be recorded for the peak discharge from the 100-year flow areas on all contiguous property.
3. Swales, Ditches, and Channels: Ditches, channels, and swales between homes or within the City's right-of-way or designed in conjunction with storm water detention facilities shall be designed to pass the 100-year frequency storm. Channels within the FEMA floodplain shall be designed in accordance with the Floodplain Management Regulations.
4. The 100-year discharges specified in the FEMA flood insurance study shall be used to analyze the impacts of a proposed change (fill, stream crossing, encroachment, etc.) on a

regulatory floodplain. If the City Engineer believes that the FEMA hydrology is outdated or incorrect, the owner shall follow the NFIP rules and regulations and submit an application for a hydrological revision through FEMA.

5. Detention Facilities: Detention basins shall be designed to pass the 100-year storm event without overtopping. The detention facility must be designed according to the following criteria:

- a) Local Basins: Local basins are defined as basins with less than 5.0 acres of drainage area and no significant downstream restrictions. Local basins shall be designed so that the 2-year and 10-year developed conditions design storm shall discharge at a rate not greater than the peak discharge from the 2-year and 10-year, existing conditions storm event. Additionally, the discharge from the 100-year developed conditions design storm shall be released at a rate not greater than the peak discharge from the 25-year existing conditions storm event. An additional volume equal to 20% of the WQV shall be incorporated into the design for sediment storage. This volume shall be incorporated into the sections of storm water practices where pollutants will accumulate.

Local Basin Detention Facility Summary

<i>Developed Conditions Peak Discharge</i>		<i>Pre-Developed Conditions Peak Discharge</i>
1-year Frequency	Must be less than	45% of the 2-year Frequency
2-year Frequency	Must be less than	45% of the 2-year Frequency
10-year Frequency	Must be less than	10-year Frequency
100-year Frequency	Must be less than	25-year Frequency

- b) Major Basins: Basins that have greater than 5 acres of drainage or have significant downstream restrictions. **Forms 5 and 6** (in Appendix A) may be completed and included in the submittal for major basins. Design frequency is determined by first calculating the percent change in runoff volume using the SCS methodology. This is accomplished by the following:
 - i) Determine the percent increase in runoff volume for a one-year frequency, 24-hour storm occurring on the developed site.
 - ii) Determine the critical storm frequency for which additional control is needed by using **Table 3** and the percent increase in runoff volume (derived Step i).
 - iii) Control the post-development storms of a frequency between the one-year and the critical storm (determined in Step ii above), so as to be equal or less than the pre-development peak runoff rate for a 24-hour, one-year frequency storm.

- iv) For all storms larger than the critical storm, provide controls so that the post-development peak discharge is less than the pre-development peak discharge for each storm, up to and including the 100-year storm frequency.
- v) Control the post-development peak discharge for both the 1-year and the 2-year storm to 45% of the pre-development peak discharge for the 2-year storm.
- vi) An additional volume equal to 20% of the WQV shall be incorporated into the design for sediment storage. This volume shall be incorporated into the sections of storm water practices where pollutants will accumulate.
- vii) A private drainage easement must be recorded for the peak discharge from the 100-year storm event flow areas on all property contiguous to the 100-year water surface elevation line. An emergency spillway must be included in the design of any detention/retention facility. The emergency spillway shall be designed to pass the 50-year storm event, assuming the principal spillway is plugged. The invert of the emergency spillway must be set above the water surface elevation identified for the 100-year design storm.

Table 3: Determining Storm Frequency for which Control Is Needed

<i>Percent increase in runoff volume from a 1-year frequency, 24-hour storm</i>		<i>Storm Frequency (Years)</i>
<i>Equal or Greater Than (Percent)</i>	<i>Less Than (Percent)</i>	
-	10	1
10	20	2
20	50	5
50	100	10
100	250	25
250	500	50
500	-	100

2.4 Hydrologic Models

1. When designing storm water facilities, stream flow measurements for determining a flood frequency relationship at a site are the best hydrological method, but they are usually unavailable. In lieu of stream flow data, empirical and simulation models can be used to estimate hydrographs and peak discharges. The use for each hydrologic model is outlined in this manual.
2. An estimation of peak runoff rates for design conditions is generally adequate for small, localized conveyance systems such as storm drains or open channels. However, if the

design must include runoff routing (e.g., detention/retention basins, floodplain analysis or complex conveyance networks), a flood hydrograph is required. Although the development of runoff hydrographs (typically more complex than estimating peak runoff rates) is often accomplished using computer programs, some methods are adaptable to nomographs or other desktop procedures.

2.5 Rational Method

1. Background: The rational method may be utilized for estimating the design storm's peak runoff for areas up to 5 acres for storm sewer design only. The design engineer should observe the following cautions when using the rational method.
 - a) The first step in applying the rational method is to obtain a good topographic map and define the boundaries of the drainage area in question. A field inspection of the area should also be made to determine if the natural drainage divides have been altered.
 - b) This method should not be used for detention basin design when the time of concentration (T_c) exceeds 20 minutes.
 - c) In determining the runoff coefficient C value for the drainage area, thought should be given to future changes in land use that might occur during the service life of the proposed facility, and that could result in an inadequate drainage system. Also, the effects of offsite flows must be taken into account.
 - d) The charts, graphs, and tables included in this section are not intended to replace reasonable and prudent engineering judgment, which should permeate each step of the design process.
2. Characteristics: Characteristics of the rational method include:
 - a) The rate of runoff resulting from any rainfall intensity is a maximum when the rainfall intensity lasts as long or longer than the time of concentration. That is, the entire drainage area does not contribute to the peak discharge until the time of concentration has elapsed.
 - b) The frequency of peak discharge is the same as that of the rainfall intensity for the given time of concentration.
 - c) The fraction of rainfall that becomes runoff (C) is independent of rainfall intensity or volume.
 - d) The peak rate of runoff is sufficient information for the design.
3. Methodology: The rational formula estimates the peak rate of runoff at any location in a watershed as a function of the drainage area, runoff coefficient, and mean rainfall intensity for a duration equal to the time of concentration (the time required for water to

flow from the most remote point of the basin to the location being analyzed). The rational formula to account for higher intensity storms is expressed as follows:

$$Q = CIA$$

Where:

Q = maximum rate of runoff, cfs

C = runoff coefficient representing a ratio of runoff to rainfall

I = average rainfall intensity for a duration equal to the time of concentration, for a selected return period, in/hr.

A = drainage area tributary to the design location, acres

4. Frequency Factor: The coefficient, C, given in the above equation, is applicable for storms of 5-year to 10-year frequencies. Less frequent, higher intensity storms will require modification of the coefficient because infiltration and other losses have a proportionally smaller effect on runoff. With the adjustment of the rational method formula by a frequency factor C_f , the rational formula now becomes:

$$Q = CC_fIA$$

C_f values are listed below in **Table 4**. The product of C_f times C shall not exceed 1.0.

Table 4: Frequency Factors for Rational Formula	
<i>Recurrence Interval (years)</i>	C_f
25	1.1
50	1.2
100	1.25

The results of using the rational formula to estimate peak discharges are very sensitive to the parameters that are used. The designer must use good engineering judgment in estimating values that are used in the rational method. The following is a discussion of the different input variables used in the rational method and is applicable to many other methodologies as well.

5. Variables

a) Time of Concentration

- i) Time of concentration is the time required for water to flow from the hydraulically most remote point of the drainage area to the point under investigation. For a developed urban drainage basin, the time of concentration

consists of the over-land flow time to the inlet plus the time of flow in a closed conduit or open channel to the design point. Over-land flow time is the time required for runoff to flow over the surface to the nearest inlet and is primarily a function of the length of overland flow, the slope of the drainage basin, and surface cover. Pipe or open channel flow time can be estimated from the hydraulic properties of the conduit or channel.

- ii) To obtain the total time of concentration, the pipe or open channel flow time must be calculated and added to the over-land flow time.
- iii) Sheet Flow: For developed conditions, the over-land flow to the inlet consists of sheet flow and shallow concentrated flow. Sheet flow is flow over a level plane surface, such as yards and driveways, and is generally less than 0.1 foot in depth. Sheet flow should never be longer than 50 feet in flow length for post developed conditions and is normally much shorter. Travel time, (T_t) for sheet flow is calculated using the following equation and **Table 5**.

$$T_t = \frac{0.007(nL)^{0.8}}{P_2^{0.5} S^{0.4}}$$

Where:

T_t = travel time, hours.

L = flow length, feet.

n = Manning's value from Table 5.

P_2 = 2-year 24-hour rainfall, inches.

S = slope of the sheet flow area, ft/ft.

Table 5: Manning's Values	
<i>Surface Description</i>	<i>Manning's n-Value</i>
Range, short grass, athletic fields	0.15
Cultivated Soils (row crops)	0.17
Grass, lawns, yards	0.24
Woods, brush, un-mowed fields	0.50
Smooth surfaces, concrete, bare earth, pavement, roofs, etc.	0.011

- iv) **Shallow Concentration Flows:** Shallow concentrated flow occurs where sheet flow ceases to exist, where flow depth is equal to or greater than 0.1 foot, and where geometry concentrates the flow in rills, swales, etc. This type of flow is not concentrated in a defined channel. Shallow flow is a function of the slope and the flow type and is estimated as follows:

$$T_t = \frac{L}{3600V}$$

Where:

T_t = travel time in hours

L = flow length in feet

V = velocity in feet/sec

For unpaved flow:

$$V = 16.13(S)^{0.5}$$

For paved flow:

$$V = 20.33(S)^{0.5}$$

Where:

V = average velocity in ft/sec

S = surface slope in ft/ft

- v) **Manning's Equation:** Once overland flow reaches an inlet, defined swale, channel, storm sewer, or curb and gutter, Manning's Equation should be used to estimate average flow velocity. The Engineer may use actual flow depth or assume full flow for this analysis. However, the assumption must be uniform within the submitted calculations.

Manning's Equation is:

$$V = \frac{1.49(R^{2/3}S^{1/2})}{n}$$

Where:

V = average velocity, ft/sec

S = slope of the hydraulic grade line, ft/ft

n = Manning's roughness coefficient for open channel flow (0.013 for concrete gutters or storm sewer pipe)

R = hydraulic radius, which is equal to $\frac{A}{P_w}$

Where:

A = cross sectional flow area, sq. ft.

P_w = wetted perimeter, ft.

- vi) **Detention Basin Flow:** Special considerations should be taken into account when the time of concentration is routed through a detention basin or lake. For these procedures the T_t for flow through a lake is very small and can be assumed to be zero. This condition sometimes occurs at a culvert or bridge where the structure acts as a reservoir outlet. In these cases, the Rational Method cannot accurately determine the peak discharge for the watershed.

vii) Common Errors. Two common errors that should be avoided when calculating T_c are as follows:

- In some cases, runoff from a portion of the drainage area that is highly impervious may result in a greater peak discharge than would occur if the entire drainage area were considered. In these cases, the design engineer should make adjustments to the drainage area by disregarding those areas where flow time is too slow to add to the peak discharge. Sometimes it is necessary to estimate several different times of concentration to determine the design flow that is critical for a particular application.
- When designing a drainage system, the overall flow path is not necessarily perpendicular to the contours shown on available mapping. Often the land will be graded and swales will intercept the natural contour and conduct the water to streets, which can reduce the time of concentration. Care should be taken in selecting overland flow paths in excess of 50 feet in urban areas.

b) Rainfall Intensity.

The rainfall intensity (I) is the average rainfall rate (in/hr) for a duration equal to the time of concentration for selecting a return period. Once the design engineer selects a particular return period and calculates a time of concentration for the drainage area, the rainfall intensity can be determined from the following equation using the variables listed in **Table 6**:

$$I = B / (T_c + N)^E$$

Where:

T_c = Time of concentration (minutes)

**Table 6: Rainfall Intensity for
Warren County, Ohio**

	B	N	E
2-yr	120.5086	22.75	1.0188
5-yr	112.0629	20.00	0.9640
10-yr	134.7132	20.50	0.9735
25-yr	171.7156	21.50	0.9891
50-yr	180.7870	20.50	0.9756
100-yr	202.6106	20.75	0.9718

- c) **Runoff Coefficient.** The runoff coefficient (C) is the variable of the rational method least susceptible to precise determination and requires judgment and understanding on the part of the designer. While engineering judgment will always be required in the selection of the runoff coefficients, a typical coefficient represents the integrated effects of many drainage basin parameters. **Table 7** considers only the effects of land use and average land slope. Runoff coefficients for developments with multiple types of ground cover should be calculated using a weighted average.

Table 7: Typical Runoff Coefficients

DESCRIPTION OF AREA	RUNOFF COEFFICIENT
Business	
Downtown	0.90
Neighborhood	0.65
Residential	
Single Family	0.60
Multi-Units, Detached	0.75
Multi-Units, Attached	0.70
Apartment	0.75
Industrial	
Light	0.80
Heavy	0.90
Parks, Cemeteries	0.30
Bare Earth	0.55
Playgrounds	0.45
Railroads	0.50
Schools & Churches	0.55
Unimproved	0.30
Forested Areas	0.25
Pavement, Roofs	0.95
Lawns	
Flat, < 2% slope	0.30
Average, 2 to 7% slope	0.35
Steep, > 7% slope	0.40

2.6

SCS Unit Hydrograph

1. **Background:** The techniques developed by the U.S. Soil Conservation Service for calculating rates of runoff require the same basic data as the Rational Method: drainage area, a runoff factor, time of concentration, and rainfall. The SCS approach, however, is more sophisticated in that it considers also the time distribution of the rainfall, the initial rainfall losses due to interception and depression storage, and an infiltration rate that decreases during the course of a storm. With the SCS method, the direct runoff can be calculated for any storm, either real or fabricated, by subtracting infiltration and other losses from the rainfall to obtain the precipitation excess. Details of the methodology can be found in the SCS "[National Engineering Handbook, Section 4.](#)"

2. Hydrographs: Two types of hydrographs are used in the SCS procedure, unit hydrographs and dimensionless hydrographs. A unit hydrograph represents the time distribution of flow resulting from one inch of direct runoff occurring over the watershed in a specified time. A dimensionless hydrograph represents the composite of many unit hydrographs. The following discussion outlines the equations and basic concepts used in the SCS method.
3. Drainage Area. The drainage area of a watershed is determined from topographic maps and field surveys. Large drainage areas should be divided into sub-drainage areas to account for major land use changes, obtain analysis results at different points within the drainage area, or locate storm water drainage facilities and assess their effects on water quality and flood flows. Prior to calculations, the engineer should conduct a field inspection for the existing drainage system for alterations to the natural drainage divides.
4. Rainfall. The SCS method is based on a 24-hour storm event that has a Type II time distribution. The Type II storm distribution is a “typical” time distribution, which the SCS has prepared from rainfall records for Ohio.
5. Rainfall-Runoff Equation. A relationship between accumulated rainfall and accumulated runoff was derived by SCS from experimental plots for numerous soils and vegetative cover conditions. Data for land-treatment measures were also included. The equation was developed mainly for small watersheds for which only daily rainfall and watershed data are ordinarily available. It was developed from recorded storm data that included total amount of rainfall in a calendar day, but not its distribution with respect to time. The SCS runoff equation is, therefore, a method of estimating direct runoff from a 24-hour or 1-day rainfall. The equation is:

$$Q = \frac{(P - I_a)^2}{(P - I_a) + S}$$

Where:

Q = accumulated direct runoff, inches.

P = accumulated rainfall (potential maximum runoff), inches.

I_a = initial abstraction including surface storage, interception, and infiltration prior to runoff, inches.

S = potential maximum retention, inches.

The relationship between I_a and S was developed from experimental watershed data. It removes the necessity for estimating I_a for common usage. The empirical relationship used in the SCS runoff equation is:

$$I_a = 0.2S$$

Substituting 0.2S for I_a in the runoff relationship equation creates:

$$Q = \frac{(P - 0.2S)^2}{(P + 0.8S)}$$

S is related to CN by:

$$S = \left(\frac{1000}{CN} \right) - 10$$

6. **Runoff Factor.** In hydrograph applications, runoff is often referred to as rainfall excess or effective rainfall—all defined as the amount by which rainfall exceeds the capability of the land to infiltrate or otherwise retain the rainwater. The principal physical watershed characteristics affecting the relationship between rainfall and runoff are land use, soil types, land slope, and antecedent moisture conditions. Descriptions of these characteristics are as follows:
 - a) Land use is the watershed cover, and includes both agricultural and non-agricultural uses. The City of Mason is primarily non-agricultural so agricultural watershed cover will not be used. If the existing land use conditions happen to be agricultural use, substitute open space or meadow, using the same soil groups.
 - b) Soil properties influence the relationship between rainfall and runoff by affecting the rate of infiltration. The SCS has divided soils into four hydrologic soil groups, based on infiltration rates. These are Soil Groups A, B, C, and D. The design engineer should consider the effects of development on the natural hydraulic soil group. Heavy equipment often compacts the soil during construction. Also, grading will mix the surface and substrate soils, so appropriate changes should be made in the soil group selected that will account for these effects.
 - c) Runoff curve numbers vary with the antecedent soil moisture conditions, defined as the amount of rainfall occurring in a selected period preceding a given storm. In general, the greater the antecedent rainfall, the more direct runoff there is from a given storm. A five-day period is used as the minimum for estimating antecedent moisture conditions. Antecedent soil moisture conditions also vary during a storm; heavy rain falling on a dry soil can change the soil moisture condition from dry to average to wet during the storm period. For design purposes, a Type 2 antecedent moisture condition should be used.
7. **Curve Numbers:** **Table 9** gives runoff factors suitable for watersheds in the City of Mason. Curve numbers should be selected only after a field inspection of the watershed and a review of the zoning and soils maps.
8. **Time of Concentration:** Travel time (T_t) is the time it takes water to travel from one location to another in a watershed. T_t is a component of time of concentration (T_c), which is the time for runoff to travel from the hydraulically most distant point of the watershed to a point of interest within the watershed. T_c is computed by summing all the travel

times for consecutive components of the drainage conveyance system. The methods of determining the T_c for this method are the same as the Rational Method Procedure. As noted previously, any developed or urban sheet flow path in excess of 50 feet should be considered suspect and additional information will need to be provided that will support the unusual circumstances. The Time of Concentration (T_c) or Travel Time (T_t) Worksheet (Form 3, Appendix A) may be used to calculate times of concentration for the watershed under study. This form is provided at the end of this Hydrology subsection. For larger watersheds and less frequent storm events, the majority of the runoff may not flow through the storm sewer system. The flow path may be through streets, lawns and ditches, rather than the storm sewer system. In these cases, the designer must identify the appropriate flow path for these larger storm events.

Table 9 Runoff Curve Numbers

<i>Urban Runoff CN Values for the City of Mason</i>					
<i>Cover Description</i>	<i>Average % Impervious</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>
Open Space - Less than 50% grass cover		68	79	86	89
Open Space - 50% to 75% grass cover		49	69	79	84
Open Space - More than 75% grass cover		39	61	74	80
Impervious Areas: parking areas, roofs, driveways, sidewalks, roads (excluding right of way)		98	98	98	98
Impervious Areas: Streets & Roads with open ditches (including right-of-way)		83	89	92	93
Urban Districts: Commercial and Business	85	89	92	94	95
Urban Districts: Industrial	72	81	88	91	93
Urban Districts: Residential – townhomes	65	80	85	90	95
Urban Districts: Residential – ¼ acre lots	38	65	78	83	88
Urban Districts: Residential – 1/3 acre lots	30	58	73	81	86
Urban Districts: Residential – ½ acre lots	25	55	70	80	85
Urban Districts: Residential – 1 acre lots	20	52	68	79	84
Urban Districts: Residential – 2 acre lots	12	47	66	77	82
Newly Graded Areas, no vegetation established ¹		81	89	93	95
Woods – no forest litter, heavy grazing		45	66	77	83
Woods – some forest litter, some grazing		36	60	73	79
Woods – forest litter covering soil, no grazing		30	55	70	77
Meadow – continuous grass, no grazing, generally mowed for hay		30	58	71	78
Grass and weed mixture – vacant land, old farm fields, unmowed meadow, pasture land		48	67	77	83
Farmsteads – buildings, lanes, surrounding lot		59	74	82	86

¹ – Use these CN values for the design of temporary sediment control measures during construction.

9. SCS Unit Hydrographs – The USDA Soil Conservation Service (SCS) has developed methods of calculating runoff for any storm, by subtracting infiltration and other losses from rainfall depth to obtain precipitation excess. Detailed methodologies for these methods can be found in the SCS National Engineering Handbook, Chapter 4 (NEH-4). The dimensionless hydrograph varies with size, shape, and slope of the drainage area. The most significant characteristics affecting the dimensionless hydrograph shape are the basin lag and the peak discharge for a given rainfall. Basin lag in this method is defined as the time from the center of mass of rainfall excess to the hydrograph peak. The following equation is used to determine basin lag time:

$$T_L = \frac{\left(L^{0.8}(S+1)^{0.7}\right)}{(1900\sqrt{Y})}$$

Where:

T_L = lag time, hrs

L = length of the main channel to the farthest divide, ft

Y = average slope of the watershed, %

$S = (1000/CN) - 10$

CN = SCS curve number

T_L can be estimated by $T_L = 0.6 * T_C$

The following equations should be used in conjunction with Table 7 to determine the shape of the unit hydrograph.

$$T_p = (D/2) + T_L$$

Where:

T_p = time to peak, hrs

D = duration of excess unit rainfall, hrs

T_L = lag time of the watershed from previous equation, hrs

D can be estimated by $D = 0.133T_c$

$$Q_p = \frac{484AQ_v}{T_p}$$

Where:

A = watershed area, sq. mi.

Q_v = direct runoff

T_p = time to peak

Q_p = peak discharge, cfs

Unit hydrographs are applied to the incremental runoff values for the storm event through a process described as convolution that results in a design hydrograph. This process is described in detail in NEH-4.

10. Bulletin 71

- a) In 1992, the National Weather Service and the Illinois State Water Survey produced a publication called *Rainfall Frequency Atlas of the Midwest*, or Bulletin 71. This report updates the SCS TP-40 Rainfall Atlas by using a much longer, larger database of rainfall precipitation specifically for the Midwest States. This report found that the amount of rainfall, as well as the mean time distribution of rainfall events, was different from the TP-40 rainfall distribution and the SCS Unit hydrograph time distribution typically used in storm water design. The conclusion was that the SCS time distribution model was not suited for use in the Midwest because of our heavy rainstorms. In Southwest Ohio the rainfall (in inches) for a given recurrence interval is contained in **Table 10**.

Table 10: Rainfall (inches) for Given Recurrence Interval

Duration	2-mo	3-mo	6-mo	1-yr	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr
72-hr	1.45	1.70	2.22	2.78	3.43	4.22	4.83	5.70	6.47	7.29
48-hr	1.35	1.58	2.04	2.55	3.15	3.87	4.44	5.26	5.98	6.77
24-hr	1.28	1.49	1.89	2.33	2.86	3.49	3.99	4.70	5.32	6.04
18-hr	1.20	1.40	1.77	2.19	2.69	3.28	3.75	4.42	5.00	5.68
12-hr	1.12	1.30	1.64	2.03	2.49	3.04	3.47	4.09	4.63	5.25
6-hr	0.96	1.12	1.42	1.75	2.14	2.62	2.99	3.52	3.99	4.53
3-hr	0.82	0.95	1.21	1.49	1.83	2.23	2.55	3.01	3.40	3.87
2-hr	0.74	0.86	1.09	1.35	1.66	2.02	2.31	2.73	3.09	3.50
1-hr	0.61	0.70	0.89	1.10	1.34	1.64	1.88	2.21	2.50	2.84
30-min	0.47	0.55	0.70	0.86	1.06	1.29	1.48	1.74	1.97	2.23
15-min	0.35	0.40	0.51	0.63	0.77	0.94	1.08	1.27	1.44	1.63
10-min	0.27	0.31	0.40	0.49	0.60	0.73	0.84	0.99	1.12	1.27

- b) This is the family of rainfall curves used for both the Rational and SCS methodologies (or any other method that requires rainfall intensities). For example; a 10-minute, 10-year rainfall event will produce $(0.84 \text{ in}/10\text{-minutes}) \times (60\text{-minutes}/\text{hour}) = 5.04 \text{ in/hr}$.
- c) Bulletin 71 also examines the rainfall distribution for storm events. Rainfall distributions were grouped according to where the heaviest rainfall occurs in a storm; the first quarter, second quarter, third or fourth quarters. The median time distribution for Midwest heavy rainstorms for small basins (<10 sq. mi.) is contained in **Table 11**.
- d) Storms with durations of 6 hours or less should use the First-Quartile distribution. Storm durations of 6.1 to 12 hours, 12.1 to 24 hours, and greater than 24 hours should use the Second-, Third-, and Fourth-Quartile distributions, respectively.

Table 11: Median Time Distribution of Heavy Storm Rainfall at a Point

Cumulative storm rainfall (percent) for given storm type

Cumulative storm time, %	First-Quartile	Second-Quartile	Third-Quartile	Fourth-Quartile
0	0	0	0	0
5	16	3	3	2
10	33	8	6	5
15	43	12	9	8
20	52	16	12	10
25	60	22	15	13
30	66	29	19	16
35	71	39	23	19
40	75	51	27	22
45	79	62	32	25
50	82	70	38	28
55	84	76	45	32
60	86	81	57	35
65	88	85	70	39
70	90	88	79	45
75	92	91	85	51
80	94	93	89	59
85	96	95	92	72
90	97	97	95	84
95	98	98	97	92
100	100	100	100	100

Section 3 - Hydraulics

This section provides policies and technical procedures for analyzing the majority of storm water facilities required for land alteration projects. All storm water management practices shall be designed to convey storm water to allow for the maximum removal of pollutants and reduction in flow velocities. However, the engineer shall be responsible for more detailed analyses if necessitated by specific site characteristics, by Ohio EPA's Construction Permit or as required by the City Engineer.

3.1 Storm Sewer Systems

Open drainage systems shall be preferred on all new development sites to convey storm water where feasible. Storm sewer systems shall be allowed only when the site cannot be developed at densities allowed under the City zoning or where the use of an open drainage system affects public health or safety, all as determined by the City Engineer. The following criteria shall be used to design storm sewer systems when necessary:

1. Pipe System Description: Storm drain piping systems are networks of storm pipes, catch basins, manholes, inlets and outfalls designed and constructed to collect and transport surface water runoff. The hydraulic analysis of flow within storm drain piping systems typically involves analysis of flow caused by the gravity flow as well as hydraulic analysis of systems under pressure flow conditions.
2. Easements: The minimum easement width for any storm sewer system is 15 feet for pipes less than 36-inch diameter and 20 feet for pipes 36 inches and greater. More stringent requirements for storm water easement size may be made by the City Engineer based upon individual site conditions. The exact location of the storm water easement as well as the governing covenants and restrictions must be included in the construction drawings and on the record plat and shall be worded as indicated in the City of Mason, Subdivision Regulations.
3. Sewer Design Criteria: The design engineer must provide a comprehensive drainage boundary map at a scale of 1 inch=100 ft or less, showing each watershed subarea that drains to a catch basin or inlet, the flow path, time of concentration, C value, storm inlet type, pipe size, slope, etc. Calculations for the storm sewer system must be legible and provided either on Form 1, Appendix A, or in a similar format. Headloss computations may be submitted on the form provided in Form 2, Appendix A, or similar format.

Manning's Equation shall be considered acceptable for calculating storm drain pipe sizes under non-submerged conditions. The storm drain system must be capable of passing the 10-year storm event with free water surface elevations below the crown of the pipe. Additionally, the engineer must check the hydraulic grade line of the system to assure that the 25-year storm can pass through the system without exceeding the elevation of the catch basin inlets. In no event shall the storm sewer pipe be less than 12 inches in diameter.

Storm sewer pipe material shall be concrete if under pavement or roadways, and may be concrete, HDPE, or SDR35 PVC if not under pavement.

Pipe cover shall be 12" between the top of the pipe and the pavement subgrade if under pavement, and shall be 24" between the top of the pipe and the ground surface in unpaved areas.

Storm manholes shall be placed at a maximum interval of 400 feet.

Storm sewers shall be designed to provide a minimum 10 feet horizontal clearance from other utilities and an 18-inch vertical clearance from other utilities.

Design computations of storm drain pipe systems using the Rational Formula and Manning's Equation may be submitted on the Storm Drain Flow Tabulation Form provided (Form 1, Appendix A) or by suitable computer program output listing that provides similar information. Manning's "n" values for all proposed storm drain materials shall be 0.015. For existing materials, Manning's "n" values shall be as follows:

Concrete pipe,	n = 0.013
Plastic & HDPE pipe,	n = 0.009
Corrugated metal pipe,	n = 0.019
Corrugated plastic pipe,	n = 0.024
Ductile Iron pipe,	n = 0.015

The minimum storm drain flow velocity (assuming full pipe flow) shall be 2.5 feet-per-second (fps). The minimum slope for storm drains equal to or larger than 48 inches in diameter shall be 0.0025 feet/foot. The maximum full-flow design velocity of any storm sewer pipe shall be less than 12 fps.

For hydraulic analysis of existing or proposed storm drains with submerged outfalls, a more sophisticated design/analysis methodology than Manning's Equation will be required. Various computer modeling programs are available for analysis of storm drains under these conditions. These models must be approved by the City Engineer.

4. Storm Drain Inlet Design. Storm drain inlets shall be spaced so that no more than 3.0 acres of pervious or 1.0 acres of impervious area drains to the inlet. The design methodology used to compute the flow capacity of storm drain inlet grates shall utilize orifice and weir flow equations outlined by these standards, with consideration given to grated open areas, and flow dimensions provided by the casting manufacturer. The grate casting shall provide sufficient grated open area to convey the 10-year storm event. The maximum depth that storm water may pond above the inlet grate must not threaten surrounding permanent structures or public facilities. Emergency overflow points shall be provided for inlets placed in a sump condition.

Roll curb and gutter inlet grates, as a general rule, shall be placed at a maximum interval of 300 feet, provided a minimum 10-year design storm flow capacity has also been achieved. Conformance with additional requirements for design and placement of storm drain inlets within public streets and roads, as set forth in the City of Mason Subdivision Regulations, will be required.

Inlets in roadway gutter lines must be spaced to prevent flow from entering public road intersections. In addition, inlets can be spaced intermediately in residential street gutter lines to allow one lane of traffic to remain open. The design storm for these conditions is the 10-year storm event. Further information on other gutter design calculations can be found in Federal Highway Administration, “Drainage of Highway Pavements”, FHWA-TS-84-202, Hydraulic Engineering Circular No. 12.

5. Storm Outfall Design: Storm sewer system outfalls must not be subject to frequent floods or backwaters. Standard headwalls and/or headwalls with wingwalls including rock channel protection and aprons as erosion control shall be constructed for all outfalls. Suitable energy dissipation shall be provided as necessary to prevent erosion.
6. Non-Gravity Storm Water Systems: Storm water facilities shall be designed to convey storm water runoff by gravity flow unless approved by the City Engineer. Storm water control systems, which do not satisfy this goal, would include storm water pumping systems and mechanical sluice gates as examples.

Design options that do not rely upon gravity flow may be approved by the City Engineer. At a minimum, the engineer must submit documentation of the unfeasibility and/or undue hardship required to install available gravity flow design options. This documentation must include the following additional information:

- a) Identification of a lifetime maintenance schedule for the non-gravity flow system.
- b) Covenants attached to the property deed, which place sole responsibility for maintenance of the non-gravity flow system with the current property owner of record.

Pumping systems, where approved, shall be designed using the hydraulic methods that apply to storm drain pump systems, set forth within standard engineering texts. Non-gravity flow systems shall be designed such that should the system fail, damage to adjoining properties and facilities will be limited to the site only.

<i>DESIGN SUMMARY CHART</i>
Minimum pipe size – 12-inch diameter
Pipe Material – under pavement -concrete, Outside pavement - Concrete/HDPE/SDR35
Pipe Slope – minimum 2.5 fps, Maximum <12 fps
Minimum Cover – under pavement 12 inches below subgrade, open space 24 inches
Manhole Spacing – 400 feet maximum
Inlet Spacing – 300 feet maximum, also check drainage area to inlet
Design Storm – 10-year for pipe sizing, 25-year hydraulic grade line
Utility Crossing separation – minimum 10 feet horizontal, 18-inches vertical
Drainage Area to Catch Basin – 1 acre impervious or 3 acres pervious
Submerged Outlets – design using methods other than Manning’s Equation
Outlet Protection – required and must be designed

3.2 Detention/Retention Design

1. General Requirements

Ohio EPA's Construction Permit and the design methods and criteria outlined within this section shall be used as a minimum in the design and evaluation of detention/retention systems within the City of Mason. This includes Extended Detention/Retention facilities that detain storm water; settle or filter particulates pollutants; and release the controlled storm water to a water resource. All designs must be supplemented with a detention/retention design summary report. Form 4 provides a sample detention/retention design summary report. Detention/retention shall be required on all new development.

The release point flow, velocity, and storage volume of any detention/retention basin shall be designed such that the storm water released shall not adversely affect the downstream property owners for the 1-, 2-, 5, 10-, 25, 50-, and 100-year storm events. Additionally, to protect against stream erosion or hydromodification, the post-developed peak flows from the 1-year and 2-year 24 hour storms should be released at a flow rate equal to 45% of the pre-developed 2-year peak flow.

The engineer must assure that there is adequate capacity in the downstream storm sewer system, ditch, culvert, stream, etc. to accept the basins discharge from all of the storm events. It may be necessary for the engineer to provide a detailed hydraulic analysis of the downstream storm water system to assure that there is adequate capacity in the downstream system. "Adequate capacity" includes engineering analysis to confirm that downstream structures will not be adversely impacted, velocities do not increase to erosive speeds, and proposed uses of off-site properties are not impacted. If the downstream system is not adequate to accept the proposed peak discharges, the allowable detention/retention basin discharge must be reduced or the developer must upgrade the downstream system.

2. Design Criteria.

Design of any type of detention/retention basin must include hydrograph routing through the basin to size the proposed outlet structure. Refer to the Hydrology section of this policy to determine the methodology acceptable to the City. Storm water management facilities shall be designed to the following general guidelines:

- A) Storm water management systems shall be designed for the ultimate use of the watershed, including off-site drainage. Areas developed for subdivisions shall provide a storm water management for the ultimate development of all the subdivided lots.
- B) A detention/retention facility in a single-family residential development must be located on an individual lot owned and maintained by a Home Owners Association (HOA) or Lake Maintenance Association (LMA) or within an easement area dedicated to the HOA or LMA for recreational use and maintenance responsibility. The facility can be built as part of the subdivision green space area owned and maintained by the HOA provided access to the basin

is granted to each property owner in the subdivision. The basin lot or easement area and its access points must be clearly marked with signage stating that it is open to all residents of the HOA or LMA. The HOA or LMA must include every homeowner in the subdivision.

- C) Storm water management facilities shall be designed so that they will continue to function with minimal maintenance. The facilities shall be designed and maintained in a manner that improves water quality such that unwanted vegetation, stagnation, and mosquito colonies are prevented and the water quality remains habitable for aquatic species. In order to achieve this, the plan should include but is not limited to aquatic habitat design features, vegetation control measures, rip-rap around the basin above and below the normal pool elevations and mechanical aerators.
- D) Storm water management facilities shall be designed with specific considerations for safety.
- E) The design criteria shall be applied to each watershed within the development area. Post-development drainage crossing pre-development drainage divides is generally discouraged. However, if this is impractical, all pre- and post-development runoff rates and volumes shall be calculated using their respective predevelopment drainage divides and submitted to the City Engineer for review.
- F) To protect property from flood damage and channel erosion, and to protect water resources from degradation resulting from accelerated storm water flows, all development areas shall be designed and constructed in compliance with these regulations.
- G) Release rates from the storm water management facilities shall be designed to minimize erosion of downstream conveyance swales and stream channels.
- H) An additional volume equal to 20% of the Water Quality Volume (WQV) shall be incorporated into the design for sediment storage. This volume shall be incorporated into the sections of storm water practices where pollutants will accumulate.

All basins must include the following design criteria:

- a) Dam Permit – If required by the latest regulations available from The Ohio Department of Natural Resources.
- b) Other permits – additional permits may be required when constructing a detention/retention basin. The developer is responsible for obtaining all necessary state and local permits.
- c) Embankment Construction – vegetated areas 3 feet above normal water depth of wet detention basins shall have an earthen embankment constructed with side slopes no steeper than 3 (horizontal) to 1 (vertical). The embankment shall be constructed of a compacted (98% Std. Proctor) clean clay core with at least 6 inches of topsoil on any area that will support vegetation. Side slopes from 3 feet above normal water depth to 3 feet below normal water depth shall be 6:1 (6

horizontal to 1 vertical) or flatter. Sod or rock/riprap shall be used for all side slopes of the detention basin.

- d) Freeboard – the maximum water surface elevation shall be at least 1.0 feet below the top of the basin.
- e) Impervious Runoff - all impervious area on the site shall be routed through the detention/retention facility.
- f) Retention Basins – the minimum normal depth of a retention basin, calculated at the deepest point in the basin, shall be eight (8) feet.
- g) Boundary - for basins in single-family residential developments the boundary lines for the basin lot or easement area must extend to the maximum flood limits. Access shall be provided for maintenance purposes and property owner access around the entire basin by extending the easement or boundary of the basin lot. The City Engineer may make more stringent requirements for storm water easement size and additional covenants based upon individual site conditions.
- h) Lot Access - the basin lot or easement area must have a minimum width of twenty (20) feet lot frontage along a dedicated right-of-way for equipment access. A maintenance vehicle access way having a minimum width of 10 feet shall be provided. The access way shall be located around the perimeter of each facility, have a cross slope no steeper than 10 to 1 and be stabilized with suitable materials adequate to prevent excessive rutting by the maintenance vehicles.
- i) Overflow – the detention basin shall be designed so that an overflow structure and path exists with the capacity of the 100-year storm. A safe overland flow path for the 100-year storm must be shown on the construction drawings.
- j) Outlet Structures – basin outlet structures should be designed to limit clogging. Overly small or narrow openings should be avoided or protected by grates and trash racks.
- k) Outlet Structures for Extended Detention Facilities – The outlet shall be designed to not release more than the first half of the water quality volume in less than $\frac{1}{3}$ rd of the drain time. A valve shall be provided to drain any permanent pool volume for removal of accumulated sediments. The outlet shall be designed to minimize clogging, vandalism, maintenance, and promote the capture of floatable pollutants.
- l) Basin Bottoms – dry basins should be sloped to drain, the minimum slope in a dry basin should be 2.0 percent.
- m) Infiltration Prevention - to prevent the permanent pool from partially or completely infiltrating into the ground, retention basins shall only be allowed under the following conditions:
 - 1) Where existing soils are categorized as hydrologic soil group C (HSG-C) or hydrologic soil group D (HSG-D) and gravelly sands or fractured bedrock are not present, or
 - 2) Where a liner is installed to sustain the permanent pool of water.

- n) Aeration - mechanical aeration or fountains shall be provided for each retention basin. Aeration must be of sufficient number and/or size to provide water circulation for the entire basin.
- o) Modification - No modifications to the facility shall be made unless approved by the City Engineer e.g., reducing the size of the facility, adding fill, trees, etc.
- p) Location - Public street rights-of-way will not be acceptable areas for construction of detention/retention facilities.

Local Basins are defined as detention/retention facilities that have a total developed watershed area of less than 5.0 acres and do not have significant downstream restrictions.

Major Basins are detention/retention facilities that have a total developed watershed area greater than 5.0 acres or have significant downstream restrictions. The City Engineer shall make the final decision on whether the downstream area has significant restrictions. The minimum hydraulic performance levels and accepted design methodologies for local and major basins shall conform to the criteria identified in the Hydrology section of this document.

All off-site flows must be taken into account. The engineer can design a conveyance system that will safely pass the off-site flows through the development. This conveyance system design must use the 100-year developed conditions storm event and must follow the open channel section requirements of this policy. However, the allowable release rate from the site must include the pre-developed discharges from both on-site and off-site watersheds. Alternately, the design engineer may wish to pass off-site flows through the detention/retention basin. This design must provide the off-site flows an adequate conveyance system to the basin. The basin design must incorporate the pre-developed conditions flows for both on-site and off-site watersheds in calculating the allowable release rates. When designing this system, the engineer shall assure that the basin and conveyance system will safely accept the off-site flows under current conditions as well as fully developed conditions in the watershed.

If the basin is used as storm water quality control, off-site flows shall be diverted around storm water quality control facilities or, if this is not possible, the storm water quality control facility shall be sized to treat the off-site flow. Comprehensive Storm Water Management Plans will not be approved until it is demonstrated to the satisfaction of the City Engineer that off-site runoff will be adequately conveyed through the development site in a manner that does not exacerbate upstream or downstream flooding and erosion.

3. Outlet Structure and Routing Design

All storm water basins must be designed using hydrograph routing through the basin. All hydrograph routing calculations must be included in the detention/retention design summary report. Stage-Storage and Stage-Discharge graphs and backup calculations must be presented in a clear and concise manner. Drowned effects of orifices and weirs must be taken into account in the outlet structure. The principal outlet pipe must be designed taking into account inlet/outlet control and tailwater effects. Outlet protection is required and must be designed using the highest flow velocity of the 1- through 100-year peak discharges. Outlet protection design as described under the outlet protection section of this chapter shall be the minimum required for outlet structures of detention basins.

4. Outlet Hydraulics

The outlet hydraulics of a detention/retention basin typically consists of two types of flow, orifice and weir flow. The basic equation for determination of orifice flow is as follows:

$$Q = C_D A \sqrt{2gH}$$

Where:

Q = peak discharge rate, cfs

C_D = coefficient of discharge, dimensionless

A = cross sectional area of orifice, square feet

g = acceleration due to gravity (32.2 ft/sec²)

H = head on the orifice, feet.

The value of H is determined by different methods depending upon the location of the water surface as follows:

- Free Discharge: H is the difference in elevation between upstream water surface and center of flow of the orifice.
- Submerged Orifice: H is the difference in elevation between upstream and downstream water surfaces.

The value of the coefficient of discharge C_D is a function of the size and shape of the orifice, the head on the orifice, the sharpness of the orifice's edge, the roughness of the inner Surface, and the degree to which the contraction of flow is suppressed (Reference King's Handbook of Hydraulics). A nominal value of 0.60 may be used for the standard types of orifices and head ranges used for outlet control structures, however, sound engineering judgment must be used in the practical application of this value.

Weir structures may be sharp-crested, rounded, or broad-crested. The means by which a weir functions can change depending upon the depth of head above the weir. A broad-crested weir may become a sharp-crested weir at higher heads, depending upon its physical configuration.

The general equation for weir flow is as follows:

$$Q = C_D LH^{1.5}$$

Where:

Q = peak discharge rate, cfs

C_D = coefficient of discharge, dimensionless

L = length of the weir, feet

H = head on the weir, the difference in elevation between the weir crest and the water surface measured upstream of the crest a short distance, feet.

Values of C_D for sharp-crested, rectangular weirs can range from about 3.3 to 4.9. This coefficient is dependent upon the head on the weir, the height of the weir crest above the streambed, and the degree of submergence. Values of C_D can be selected from tables in King's Handbook of Hydraulics or other suitable references. Sound engineering judgment must be used in the interpretation of C_D values for various design conditions.

5. Maintenance

It is essential that detention/retention facilities are properly maintained in order to assure its performance; therefore, the developer shall prepare a facility maintenance plan as part of the construction drawing and storm water design calculations. A draft maintenance plan shall be submitted to the City Engineer for approval at the time of the site construction plan approval process and implemented during construction. The final maintenance plan must be approved prior to platting the first section of the subdivision.

Maintenance plans shall include: a method and frequency for inspection of all permanent structures; debris/clogging control through appropriate removal and disposal; vegetation control (e.g., mowing, harvesting, wetland plants); erosion repair; non-routine maintenance (e.g., grading and sediment removal to eliminate ponding); the rejuvenation or replacement of filters and appropriate soils; mosquito monitoring and abatement, encompassing inspections for conditions conducive to mosquito breeding; routine maintenance (e.g., vegetation control, debris, and sediment removal) and conditions where the use of insecticides may be warranted.

Every homeowner in the subdivision shall be equally financially responsible to provide maintenance in accordance with the approved maintenance plan

When the detention/retention facility is built a sign shall be placed near the facility identifying maintenance responsibility of this facility. When the facility is transferred from the developer/builder to HOA the sign shall be replaced accordingly.

Before the basin is transferred to the HOA for maintenance responsibilities an inspection report shall be furnished to the City Engineer. A licensed professional engineer certifying that the detention/retention facility has full storage capacity, all inlet and outlet structures are fully functional, and the facility is maintained in accordance with the approved

construction and maintenance plans must perform this inspection. Approved maintenance plans and all maintenance records shall be transferred to the homeowners association (HOA) when the property and other documents are transferred to HOA.

The owner of the detention/retention facility shall provide to the City a certification that the facility appears to be maintained in accordance with the approved plan. A compliance certification shall be completed by a company or person trained in the maintenance of detention/retention facilities.

If the storm water management facilities fail to function as designed or if the above maintenance requirements have not been adhered to the City has the right to enter onto the property and take any corrective action necessary to assure the system functions properly. Costs associated with such work shall be assessed back to the developer through the performance or maintenance bond or each property owner in the subdivision or to the HOA.

3.3 Open Channel Design

1. General Requirements

Open channels are a natural or man-made conveyance for water in which:

- a) the water surface is exposed to the atmosphere, and
- b) the gravity force component in the direction of motion is the driving force.

The principles of open channel flow hydraulics are applicable to all drainage facilities including culverts.

Stream channels are usually natural channels with their size and shape determined by natural forces, usually compound in cross section with a main channel for conveying low flows and a floodplain to transport flood flows, and usually shaped geomorphologically by the long term history of sediment load and water discharge which they experience.

Artificial channels include roadside channels, irrigation channels and drainage ditches which are man-made channels with regular geometric cross sections, and unlined, or lined with artificial or natural material to protect against erosion.

While the principles of open channel flow are the same regardless of the channel type, stream channels and artificial channels (primarily roadside channels) will be treated separately in this chapter as needed.

Hydraulic and hydrologic computations must be performed to determine the maximum inundated area resulting from the 25-year design storm event runoff. No habitable structures may be located within this area.

For areas that drain more than 15 acres:

- a) Easements must be dedicated as described below.
- b) Additional hydraulic and hydrologic calculations must be performed to determine the maximum inundated area resulting from the 100-year design storm event runoff.
- c) A 100-year flood line must be delineated in addition to the 25-year easement restriction.

The lowest location of any proposed habitable structures where water may enter must be located a minimum of 18 inches above this delineated 100-year flood elevation.

2. Collector Swales

Surface water collector swales within the rear yard and side yard areas of residential subdivisions and on all non-residential parcels draining more than fifteen (15) acres shall be constructed within a drainage easement possessing a minimum width of twenty (20) feet. For residential properties the drainage swales should be generally constructed approximately in the middle of the easement.

Open Ditches: Open ditches, those which do not have grass bottoms or are not accessible to vehicular traffic within the ditch, shall be placed within a drainage easement of a minimum width of ten (10) feet from the top of one bank of the channel.

Properties located within the regulatory floodway or floodway fringe area shall provide floodway/floodway fringe boundary delineation's on the site plan. A citation of the regulatory source for these boundary delineations and minimum lowest enclosed floor elevations of permanent structures shall be provided on the site plan. No earthmoving activities including cut, fill, re-grading, etc. shall be permitted in the floodway or floodway fringe without a floodplain permit from the City of Mason. Additional information regarding alternatives within regulatory floodway hazard areas may be found in the Floodplain Management Section of the City of Mason Zoning Code.

Except for roadside ditches, the side-slope of grass lined channels shall be no steeper than 3 (horizontal) to 1 (vertical). When the bottom width of trapezoidal grass-lined channels exceeds fifteen (15) feet, rock rip-rap or paved low flow channels shall be provided to convey low flows and to prevent meandering. For grass lined channels, intended to convey continuous trickle flows such as for retention pond outlets, an enclosed storm drain, subsurface tile with gravel envelope, rock rip-rap, or paved low flow channel will be required.

The side-slope of rock riprap lined open conveyance channels shall be no steeper than 1 (horizontal) to 1 (vertical), unless otherwise approved by the City Engineer. Concrete-lined channels may be required by the City Engineer as deemed necessary to either control erosion and/or eliminate wetness within open storm water conveyance channels.

Minor drainage collector swales in rear yards and between homes shall possess a maximum channel length of 400 lineal feet, unless otherwise authorized by the City Engineer. The required channel slope and invert treatment for minor drainage collector swales shall be as follows: grass lined swale if slope is 1% or greater and length is less than 400 feet; concrete paved channel or other acceptable treatment if channel slope is between 0.3% and 1.0%, and/or length is greater than 400 feet. The minimum channel slope shall be 0.3%.

For relatively large open channels and perennial streams, minimum channel slopes and the provision of subsurface drainage shall be approved on a case-by-case basis by the City Engineer.

Privately owned open channels, including man-made ditches, swales, and natural streams, shall be repaired and/or reconstructed such that all woody vegetation has been cleared, and the channel banks are properly stabilized to prevent present and future erosion.

3. Channel Lining Design Requirements

The peak discharge from the 10-year design storm event shall be used to design channel linings for all channels. The final design of open channels should be consistent with permissible shear stress (T_p) for the selected channel lining. Reference should be made to the publication FHWA-RD-89-110, HEC-15, for a more detailed description of this analysis.

The process of channel lining design is as follows:

- a) Select a lining and determine the permissible shear stress in lbs/ft^2 .
- b) Choose an initial Manning's 'n' value based on engineering reference books, such as 'Open-Channel Hydraulics' by V. T. Chow.
- c) Calculate normal flow depth (D), in feet at design discharge using Manning's Equation.
- d) Compute maximum shear stress (T_d), in lbs/ft^2 , at normal depth as:

$$T_d = 62.4DS$$

Where:

T_d = maximum shear stress (lbs/ft^2)

d = normal flow depth (ft)

S = channel slope (ft/ft)

If $T_d < T_p$ then the channel lining is acceptable. Otherwise consider the following options.

- a) Choose a more resistant lining
- b) Use concrete, gabions, or other more rigid lining either as full lining or composite
- c) Decrease channel slope in combination with drop structures
- d) increase channel width and/or flatten side slopes

For channel designs incorporating a riprap lining, the following procedures shall be used. Riprap shall not be placed on a side slope steeper than 1H:1V unless otherwise approved by the City Engineer. The toe of the riprap shall be extended below the channel or ditch bed a minimum distance of one foot or 1.5 D₅₀ (whichever is greater) except where alternate methods are approved or where the ditch or channel bottom is also covered with riprap. Filter fabric or a filter course of gravel should be placed under the stone for larger drainage channels.

For normal channel design, riprap can be sized using a method developed by the Federal Highway Administration and slightly modified for use here. The following equation gives the D₅₀ size of stone (in inches) for riprap placed in a channel with average velocity 'v' and depth 'D'.

$$D_{50} = 0.0136v^3 / D^{0.5} K^{1.5}$$

K is the side slope correction factor and can be found from the following equation and shall be used for all side slope placement on slopes steeper than 4H:1V. For other placement K is equal to one (1.0). θ is equal to the bank angle with the horizontal (e.g. a 1V:3H slope has a θ value of 18.43 degrees).

$$K = \sqrt{1 - (\sin^2 \theta / 0.396)}$$

The equation shown above for calculation D₅₀ is based on a safety factor of 1.2 and a stone weight of 165 Lbs/ft³. For situations other than a uniform straight channel, the D₅₀ size determined from the above equation should be multiplied by a Stability Correction Factor as calculated in the below equation.

$$C_{SF} = (SF/1.2)^{1.5}$$

Where:

SF = stability factor

C_{SF} = stability correction factor

Values for SF are found in the table below.

Condition	Stability Factor
Uniform flow: straight or mildly curving reach (curve radius/channel top width (R _c /T > 30); little impact from wave action and floating debris; little uncertainty in design parameters.	1.0 - 1.2

Gradually varied flow; moderate bend curvature ($30 > R_C/T > 10$); moderate impact from waves or debris; moderate uncertainty in design parameters.	1.3 - 1.6
Approaching rapidly varied flow; sharp bend curvature ($10 > R_C/T$); significant impact from waves or debris, high flow turbulence; significant uncertainty in design parameters.	1.6 – 2.0

If the rock density is significantly different from 165 lbs/ft³ the D₅₀ size should be multiplied by a specific gravity correction factor (C_{SG}). S_G is the specific gravity of the stone (stone weighing 165 lbs/ft³ has a specific gravity of about 2.65).

$$C_{SG} = [1.65/(S_G - 1)]^{1.5}$$

Where:

S_G = specific gravity of stone, lbs/ft³

C_{SG} = specific gravity correction factor

The riprap layer thickness shall be a minimum of D₁₀₀, and the D₈₅ /D₁₅ value shall be less than 4.6. Stone shall be angular in shape. Riprap shall be placed so as not to be flanked by the flow. The end of the protected section should be keyed into the bank to prevent scouring failure. For riprap blanket thickness greater than D₁₀₀, the following reductions in D₅₀ stone size are allowed:

- for blanket thickness equal to 1.5 D₁₀₀, the D₅₀ size can be reduced 25 percent.
- for blanket thickness equal to 2.0 D₁₀₀, the D₅₀ size can be reduced 40 percent.

Channel design must account for riprap thickness in channel excavation. Channel roughness for riprap lined channels can be evaluated from (D₅₀ in feet):

$$n = 0.0395(D_{50})^{1/6}$$

4. Design of Open Channels Using Manning's Equation

Manning's Equation may be used to size proposed open channels where backwater effects created by obstructions within the channel or elevated tailwater are not of concern.

Manning's Equation may be solved directly from its standard form as follows:

$$Q = \frac{1.49}{n} AR^{2/3} S^{1/2}$$

Where:

Q = Flow Rate, (ft³/s)
v = Velocity, (ft/s)
A = Flow Area, (ft²)
n = Manning's Roughness Coefficient
R = Hydraulic Radius, (ft)
S = Channel Slope, (ft/ft)

The above equation shall be iterated as necessary with various values of channel geometry to obtain the desired values of flow quantity, velocity, and depth. Engineering reference books, such as 'Open-Channel Hydraulics' by V. T. Chow may be used as a guide for Manning's 'n' values.

3.4 Culverts/Bridges

1. General Requirements

The design methods and criteria outlined or referred to within this section shall be used in the design and evaluation of culvert systems within the jurisdiction of this Policy. Computer models such as Federal Highway Administration's HY-8 may be used to perform culvert/bridge design computations. The design of culverts can be quite complex, therefore, only introductory material is presented herein. The designer is referred to Federal Highway Administration publication Hydraulic Design Series No.5 (HDS-5), 'Hydraulic Design of Highway Culverts', Report No. FHWA-IP-85-15, for a complete review of acceptable design. Methods contained in HDS-5 shall be used for the design of culverts.

Culverts shall be designed to pass the 100-year frequency event. An easement must be recorded for the peak discharge from the 100-year flow areas on all contiguous property. The design engineer must always calculate the inlet/outlet control and tailwater effects in the design. An easement must be shown on the construction drawings and recorded on all affected properties for the 100-year storm event flow areas. The 100-year storm event must be checked to determine the flooded area so that a building restriction line can be shown on a record plat. The lowest elevation where water may enter any adjacent structures must be 18 inches higher and outside this delineation.

Open culverts which pose a threat of damage to property or a hindrance of public services due to backwater and/or road overflow shall be analyzed utilizing the direct-step backwater method or reservoir flood routing techniques for determination of the depth of flow over the culvert/roadway during the peak discharge from the 100-year design storm event, backwater elevations, downstream flow velocities and resulting channel scour impacts. Any culvert or bridge that is located in a FEMA floodplain must be analyzed using methodologies acceptable to FEMA and the City of Mason.

2. Inlet Control

Inlet control for culverts may occur in two ways:

Unsubmerged: Where the headwater depth is not sufficient to submerge the top of the culvert and the culvert inlet slope is supercritical. Under these conditions, the culvert inlet acts like a weir.

Submerged: The headwater submerges the top of the culvert but the pipe does not flow full. Under these conditions the culvert inlet acts like an orifice.

The nomographs provided by Hydraulic Design Series No. 5, Report No. FHWA- IP-85-15 may be used to determine culvert flow under inlet control conditions for common culvert materials.

3. Outlet Control

Outlet control will govern in the design of open culverts when the headwater is sufficiently deep, the culvert slope sufficiently flat, and the culvert sufficiently long.

Outlet control flow conditions can be calculated based on energy balance, however, the nomographs presented in HDS-5 should be used to determine the headwater elevations for outlet control.

The Bernoulli equation may be used to solve culvert flow if it is necessary to use another method other than the HDS-5 nomographs. The equation can be expressed in a simplified form by the following equation:

$$HW_o'' = T_w' + H_L$$

Where:

HW_o = Headwater depth above the outlet invert (ft)

T_w = Tailwater depth above the outlet invert (ft)

H_L = The sum of all the energy losses including: entrance loss, friction loss, exit loss, and losses for grates, bends, obstructions, etc.

This equation is used to calculate the culvert capacity directly when the culvert is flowing under full flow conditions. Backwater calculations, beginning at the downstream tailwater elevation, may be required under certain conditions. The downstream water surface elevation is based on the critical depth or tailwater elevation whichever is greater. Simplifications, modifications and nomographic solutions to this procedure are available in HDS-5.

Selection of the inlet type is an important part of culvert design, particularly culverts with inlet control. Hydraulic efficiency and cost can be significantly affected by inlet conditions. The inlet coefficient K_e , is a measure of the hydraulic efficiency of the inlet,

with lower values indicating greater efficiency. All methods described in this chapter, directly or indirectly, use inlet coefficients.

4. Outlet Protection

Energy dissipaters shall be employed whenever the velocity of flows leaving a storm water management facility exceeds the erosive velocity of the downstream channel system. The procedure presented in this section is taken from USDA, SCS (1975). Two sets of curves, one for minimum and one for maximum tailwater conditions, are used to determine the apron size and the median riprap diameter, D_{50} . If tailwater conditions are known, or if both minimum and maximum conditions may occur, the apron should be designed to meet criteria for both. Although the design curves are based on round pipes flowing full, they can be used for partially full pipes and box culverts.

Section 4 – Erosion and Sediment Control

Erosion and Sediment Controls shall be provided during construction to reduce the runoff of sediment and pollution of receiving streams. At a minimum, the requirements of the current Ohio EPA Construction general permit should be met, including the requirement for development of a Storm Water Pollution Prevention Plan (SWP3) for each site. The current permit requirements and supporting information can be found on the following Ohio EPA website:

https://www.epa.ohio.gov/dsw/permits/GP_ConstructionSiteStormWater

Sediment and erosion controls should be designed to meet the recommendations provided in the current version of the Ohio Rainwater and Land Development Manual. The current version of the manual can be found here: https://epa.ohio.gov/dsw/storm/technical_guidance.

Section 5 – Storm Water Management

5.1 Key Section Highlights

1. Every subdivision and land development shall be provided with a Storm water Management System which is adequate to serve the area and meets the requirements of this chapter and the Ohio EPA Construction Storm water General Permit.
2. Developers are required to design improvements that reduce water quality impacts to receiving water resources that may be caused by new development or re-development activities.
3. Storm water management systems shall be designed for the ultimate use of the land.
4. Developers are required to complete an Inspection and Maintenance Agreement for all storm water management practices under this regulation. The Inspection and Maintenance Agreement shall be a standalone document between the City of Mason and the Developer. Once a Storm Water Management Plan has been approved and constructed it shall be the responsibility of the Developer to provide all owners of constructed controls a copy of the

Inspection and Maintenance Agreement. The owner shall maintain the facility as designed and constructed to ensure its proper operation to meet the intent and requirements of this chapter at all times.

5.2 Purpose and Background

1. This section is intended to establish technically feasible and economically reasonable storm water management standards to achieve storm water controls that will minimize damage to property and degradation of water resources and wetlands.
2. Areas developed shall provide storm water quality controls for the development in an effort to reduce impacts to receiving water resources that may be caused by the new development or re-development activities.
3. A Comprehensive Storm Water Management Plan shall be developed describing how the quantity and quality of storm water will be managed after construction is complete for every discharge from the site and/or into a water resource. The Plan will illustrate the type, location, and dimensions of every structural and non-structural storm water management practice incorporated into the site design, and the rationale for their selection. The rationale must address how these storm water management practices will address flooding within the site as well as flooding that may be caused by the development upstream and downstream of the site. These regulations shall apply to earth-disturbing activities performed within the jurisdiction of the City of Mason, unless excluded as follows:
 - a. Activities regulated by, and in compliance with, the Ohio Agricultural Sediment Pollution Abatement Rules.
 - b. Special projects with the express written approval of the City Engineer.
4. Neither submission of a SWMP under the provisions herein nor compliance with the provisions of these regulations shall relieve any person from responsibility for damage to any person or property otherwise imposed by law. Other State and local permits may apply and are the responsibility of the Owner/Developer to obtain. In the event of conflict between the these requirements and pollution control laws, rules, or regulations of other Federal, State, or local agencies, the more restrictive laws, rules, or regulations shall apply.
5. If any clause, section, or provision of these regulations is declared invalid or unconstitutional by a court of competent jurisdiction, validity of the remainder shall not be affected thereby

5.3 Basic Policies and Procedures

All land alterations, regardless of extent or type, shall be accomplished in such a way as to control and limit, to the maximum extent practicable, water quantity and quality impacts from construction sites using, but not limited to, applicable methods and standards established by these regulations. The goals of such quantity and quality control measures are to:

- a) Control storm water runoff from the developed property and ensure that all storm water management practices are properly designed, constructed and maintained;
- b) Reduce water quality impacts to receiving water resources that may be caused by new or redeveloped activities;
- c) Control the volume, rate and quality of storm water runoff originating from the developed property so that surface water and ground water are protected and flooding and erosion potential are not increased
- d) Maximize use of storm water management practices that serve multiple purposes including, but not limited to, flood control, erosion control, fire protection, water quality protection, recreation, and habitat preservation;
- e) Implement a thorough ongoing inspection, maintenance and follow-up program.

Control of storm water quantity and quality from construction sites may be accomplished through utilization of a variety of storm water control practices. The complexity of the Storm Water Management Plan will vary depending upon individual site conditions.

Prevention of pollutants leaving the site and reduction of flooding are general performance goals that may be used as a guide to the use of storm water quantity and quality control practices; however, this guideline must be applied by the design engineer and developer with caution. Although the designer will be allowed to retain a certain degree of flexibility when deciding which practices should be used on the developing site, the City will reserve the right at any time to require additional practices as necessary to provide a comprehensive storm water management plan.

The City of Mason shall administer the requirements, shall be responsible for determination of compliance with the requirements, and shall issue notices and orders as may be necessary. The City of Mason may consult with the Warren County SWCD, private engineers, storm water districts, or other technical experts in reviewing the Comprehensive Storm Water Management Plan.

5.4 Requirements

It is the intent of the City that all land alterations be considered for comprehensive storm water management plan. The development of the Comprehensive Storm Water Management System requires providing two separate and distinct drainage systems, the minor system and the major system:

1. The minor drainage system is for collecting and transporting runoff from frequently occurring storms. It includes open channels, street curbs and gutters, and underground storm sewers, manholes, catch basins, and culverts. This system's purpose is to lessen or eliminate inconveniences and safety and health hazards associated with frequent storms. Except where indicated otherwise, design criteria and requirements of this chapter are directed to the minor drainage system.

2. The major drainage system is to insure that storm water runoff which exceeds the capacity of the minor drainage system has a route to follow to the retention basin. It shall be recognized that the major drainage system exists even when it is not planned and whether or not physical facilities are intelligently located in respect to it.

5.5 Storm Water Quality Control

All sites shall be designed to manage runoff as required by the current Ohio Construction General Permit issued by Ohio EPA. Storm water management practices shall be designed as described in the *ODNR Rainwater and Land Development Manual, current edition*. Additionally, Storm water quality management practices should take into consideration any applicable Total Maximum Daily Loads (TMDLs) as issued by Ohio EPA.

For the construction of new roads and roadway improvement projects by public entities (i.e. the state, counties, townships, cities, or villages), the City may approve BMPs not included in Table 2 of this regulation, but must show compliance with the current version of the Ohio Departments of Transportations *Location and Design Manual, current edition*.

Criteria for the Acceptance of Alternative post-construction BMPs: The applicant may request approval from the City Engineer for the use of alternative structural post-construction BMPs if the applicant shows to the satisfaction of the City Engineer that these BMPs are equivalent in pollutant removal and runoff flow/volume reduction effectiveness to those listed in the *ODNR Rainwater and Land Development Manual, current edition*. If the site is greater than five (5) acres, or less than five (5) acres but part of a larger common plan of development or sale, which will disturb five (5) or more acres, prior approval from the Ohio EPA is necessary.

5.6 Storm Water Management Plans

The Comprehensive Storm Water Management Plan shall contain an application, narrative report, construction site plan sheets, a long-term Inspection and Maintenance Agreement, and a site description along with the usual plan submissions required in Subdivision Rules and Regulations.

As part of the SWMP process, the developer shall be responsible for obtaining all applicable county, state, and federal permits or notices for land disturbing activities prior to commencement of land disturbing activities. All applicable county, state and federal standards shall be adhered to when conducting land disturbing activities. Copies of all applications, letters of intent, submittals, plans and other related information developed for and/or submitted to state or federal authorities shall be submitted to the City of Mason Engineer as part of the SWMP.

Each SWMP shall include as a minimum one or more separate plan sheets that clearly portray the methods and means whereby water quantity and quality control measures are implemented. These plan sheets shall be included in the Construction Documents for each practice and shall be implemented by the Construction Contractor. The SWMP documents shall be prepared under the supervision of, and certified by a Registered Professional Engineer, and shall include, as a minimum, the following site document information:

Site Description

1. A description of the nature and type of the construction activity (e.g. residential, shopping mall, highway, etc.);
2. Total area of the site and the area of the site that is expected to be disturbed (i.e. grubbing, clearing, excavation, filling or grading);
3. If available, a description of prior land uses at the site;
4. An estimate of the impervious area and percent of imperviousness created by the soil-disturbing activity at the beginning and at the conclusion of the project;
5. Existing data describing the soils throughout the site, including, if available, the soil series and association, hydrologic soil group, porosity, infiltration characteristics, depth to groundwater, depth to bedrock, and any impermeable layers;
6. If available, the quality of any known pollutant discharge from the site such as that which may result from previous contamination caused by prior land uses;
7. The location and name of the immediate water resource(s) and the first subsequent water resource(s);
8. The aerial (plan view) extent and description of water resources at or near the site that will be disturbed or will receive discharges from the project;
9. Describe the current condition of water resources including the vertical stability of stream channels and indications of channel incision that may be responsible for current or future sources of high sediment loading or loss of channel stability.

Site Map

1. Limits of soil-disturbing activity on the site;
2. Soils types for the entire site, including locations of unstable or highly erodible soils;
3. A contour plan showing the outline of all areas outside the project area that contributes runoff to it and a delineation of drainage watersheds expected before, during and after major grading activities as well as the size of each drainage watershed in acres;
4. Water resource locations including springs, wetlands, streams, lakes, water wells, and associated setbacks on or within 200 feet of the site, including the boundaries of wetlands or streams and first subsequent named receiving water(s) the applicant intends to fill or relocate for which the applicant is seeking approval from the Army Corps of Engineers and/or Ohio EPA;
5. Estimated runoff (Q) before and after development for terminal points along natural streams, proposed open channels, and other strategic points such as existing storm sewers or culverts;
6. The location of any in-stream activities including stream crossings;
7. Location of proposed detention/retention areas;

8. Location of proposed storm water quality BMPs; and
9. Any other information required by the City to clarify intent.

Improvement Plan

In addition to the subdivision requirements, the improvement plan for the project area shall contain, but is not limited to, the following information:

1. Contact Information: Company name and contact information as well as contact name, address, and phone number for the following:
 - a. The Professional Engineer who prepared the Comprehensive Storm Water Management Plan.
 - b. The site owner.
2. Ohio EPA NPDES Permit Number and other applicable state and federal permit numbers, if available, or status of various permitting requirements if final approvals have not been received.
3. Location, including complete site address and sub lot numbers if applicable.
4. The Site Plan sheet shall show the entire site on one plan sheet to allow a complete view of the site during plan review. If a smaller scale is used to accomplish this, separate sheets providing an enlarged view of areas on individual sheets should also be provided. The Site plan includes:
 - a. The location of each proposed post-construction storm water management practice.
 - b. The geographic coordinates of the site and each proposed post-construction practice.
 - c. Diameter, length, slope, type pipe and class of all storm sewers, culverts and subsurface drainage.
 - d. Invert elevations on profiles of all pipes at terminal points such as manholes inlets, catch basins and headwalls.
 - e. Top of grate elevations of manholes and grate flow lines of catch basins and inlets.
 - f. Type of catch basin, inlet and manhole (ODOT or City designation).
 - g. Headwall type (ODOT or City designation)
 - h. Actual existing and proposed cross sections of open channels showing width of bottom, depth of water, erosion control measures and limits, and side slopes at each point of design along with a profile indicating the longitudinal slope and bottom elevations at the terminal points of design.
 - i. High and low points indicating the direction of runoff flow along the profile of the roadway.

- j. Structural details and design data for detention/retention facilities.
- k. Details of construction for all structures not included in the City standard construction drawings, or other referenced standards.
- l. Location of any easements or other restrictions placed on the use of the property.
- m. Any other information required by the City Engineer to clarify intent or design features.

Drainage and Grading Plans

In addition to the improvement plan, a drainage plan shall be submitted. This plan may be the required improvement plan or a similar plan at a scale of one inch equals 100 feet or larger showing at least the following additional information:

- 1. Contours indicating the existing and final grading at vertical increments of no more than two feet.
- 2. Discharge (Q), coefficient of runoff (c) and drainage area (A) along with the outline of the drainage area for each inlet, catch basin, culvert and open channel point of design and other locations designated by the City Engineer. Drainage areas that lie partially outside the limits of the drainage and grading plan may be delineated on any contour map acceptable to the City Engineer;
- 3. Discharge (Q) before and after development at strategic points within and at extremities of the project area;
- 4. Delineation of the boundaries and contour elevation, along with the track, of the major drainage system through downstream areas to an adequate outlet even though the outlet may be outside the project area;
- 5. Delineation of the horizontal limits of ponding areas at low points (sags) in the street profile and low points outside the street right-of-way including, but not limited to, culvert headwater, natural stream water surfaces, and sump type inlets for storms with frequencies of twenty-five and 100 years;
- 6. High and low water horizontal limits and contour elevation of detention/retention/sedimentation facilities along with water surface and control weir elevations, outlet structures, etc.;
- 7. Areas outside of the project area susceptible to sediment deposits or to erosion caused by accelerated runoff;
- 8. Location of soils that may be limited for the proposed use;
- 9. All requirements of this chapter; and
- 10. Any other information required by the City Engineer to clarify intent, specified requirements, or design features

Supporting Data

All data and design information used for tile design of drainage facilities and for determining downstream flood information shall be submitted with the drainage and grading plan. To facilitate review and avoid confusion, legends, descriptions and structure numbering used on design forms

or other calculations shall be identical to those used on the improvement plans and the drainage and grading plan. This data shall include but are not limited to:

1. Weighted runoff coefficient calculations for each contributing area;
2. Pavement drainage computations;
3. Storm sewer computations;
4. Culvert design computations;
5. Open channel computations;
6. Detention/retention facilities computations;
7. Water quality BMP computations;
8. Inlet capacity computations; and
9. Any other information required by the City Engineer to clarify intent or design features.

Inspection and Maintenance Agreement

The Inspection and Maintenance Agreement required for storm water management practices under this regulation shall be a stand-alone document between the City of Mason and the applicant and shall contain the following information and provisions:

- a. The location of each storm water management practice, including those practices permitted to be located in, or within 50 feet of, water resources, and identification of the drainage area served by each storm water management practice.
- b. A schedule for regular maintenance for each aspect of the storm water management system and description of routine and non-routine maintenance tasks to ensure continued performance of the system as is detailed in the approved Comprehensive Storm Water Management Plan. This schedule may include additional standards, as required by the City Engineer, to ensure continued performance of storm water management practices permitted to be located in, or within 50 feet of, water resources.
- c. The location and documentation of all access and maintenance easements on the property.
- d. Identification of the landowner(s), organization, or municipality responsible for long-term maintenance, including repairs, of the storm water management practices.
- e. The landowner(s), organization, or municipality shall maintain storm water management practices in accordance with this regulation.
- f. The City of Mason has the authority to enter upon the property to conduct inspections as necessary to verify that the storm water management practices are being maintained and operated in accordance with this regulation.
- g. The City of Mason shall maintain public records of the results of site inspections, shall inform the landowner(s), organization, or municipality responsible for maintenance of the inspection results, and shall specifically indicate any corrective actions required to bring the storm water practices into proper working condition.
- h. If the City of Mason notifies the landowner(s), organization, or municipality responsible for maintenance of the maintenance problems that require correction, the specific

corrective actions shall be taken within a reasonable time frame as determined by the City of Mason.

- i. The City of Mason is authorized to enter upon the property and to perform the corrective actions identified in the inspection report if the landowner(s), organization, or municipality responsible for maintenance does not make the required corrections in the specified time period. The City of Mason shall be reimbursed by the landowner(s), organization, or municipality responsible for maintenance for all expenses incurred within 10 days of receipt of invoice from the City of Mason.
- j. The method of funding long-term maintenance and inspections of all storm water management practices.
- k. A release of the City of Mason from all damages, accidents, casualties, occurrences, or claims that might arise or be asserted against the City of Mason from the construction, presence, existence, or maintenance of the storm water management practices.

Alteration or termination of these stipulations is prohibited. The applicant must provide a draft of this Inspection and Maintenance Agreement as part of the Comprehensive Storm Water Management Plan submittal. Once a draft is approved, a recorded copy of the Agreement must be submitted to the City of Mason to receive final inspection approval of the site.

As-Built Plans

Amended improvement plans specifying the locations, dimensions, elevations, and capacities of all facilities as constructed shall be submitted to the City on construction completion of the project. These shall include all required design features except those waived by the City Engineer. All revisions to the approved plans shall be approved by the City prior to construction.

Section 6 – Construction Specifications

Construction and materials specifications and requirements should at a minimum meet ODOT requirements.

Appendix A

Forms for City of Mason Stormwater Manual

FORM 1- Storm Sewer Design Tabulation Form

[illegible]

FORM 2 – Storm Sewer Headloss Tabulation Sheet

[illegible]

FORM 3

Time of Concentration (T_c) or Travel Time (T_t) Worksheet for the City of Mason, OH

Project _____ By _____

Location _____ Date _____

Circle One: Present Developed _____

Circle One: T_c T_t through subarea _____

NOTES: Space for as many as two segments per flow type can be used for each worksheet. Include a map with watershed boundaries and flow path(s) with the report. Label segment ID on map.

Sheet Flow (Applicable to T_c only)

	Segment ID				
1. Surface Description	.....			
2. Manning's roughness coeff., n	.....			
3. Flow Length, L (total \leq 50 ft dev. conditions only)	..... ft				
4. Two-yr 24-hr rainfall, P_2	..... in				
5. Land slope, s	..... ft/ft				
6. Compute T_t	..... hr		+		=

Shallow Concentrated Flow

	Segment ID				
7. Surface description	.....			
8. Flow length, L	..... ft				
9. Watercourse slope, s	..... ft/ft				
10. Average velocity, V	..... ft/s				
11. Compute T_t , $T_t = L/(3600V)$	..... hr		+		=

Channel Flow

	Segment ID				
12. Cross sectional flow area	..... ft ²				
13. Wetted perimeter, P_w	..... ft				
14. Hydraulic radius	..... ft				
15. Channel slope, s	..... ft/ft				
16 Manning's roughness Coeff., n	.....			
17. $V = (1.49 r^{2/3} s^{1/2}) / n$	..... ft/s				
18 Flow length, L	..... ft				
19. Compute T_t	..... hr		+		=
20. Watershed or subarea T_c (ΣT_t from 6, 11, 19)	.....			

(Note: Inflow and outflow hydrographs must accompany this summary report.)

[illegible]

FORM 5 **SUMMARY OF DATA (SCS Method)**

Project Name:

Total Site Area (acres):

Drainage Area # (see note 1)	Drainage Area	CN*	Tc*	Tt*
	(Acres)		(Hours)	(Hours)

Note 1: The Drainage Area number should correlate to an area shown on the Drainage area map

Basin Information		Description of outlet structure:			
Frequency	Peak Inflow**	Peak Outflow**	Storage**		Elevation**
(yr)	(cfs)	(cfs)	(ft ³)	(ac-ft)	(ft)
1					
10					
25					
100					

Release Rates		
<i>Critical Storm* =</i>		
Storm Frequency	Pre-Developed Allowable Release Rates**	Post-Developed Release Rate**
(yr)	(cfs)	(cfs)
1		
10		
25		
100		

*Provide detailed calculations on these values were determined.

**Provide output data from software used in analysis with the pertinent values highlighted/identified

Note: Complete and submit the Tc/Tt worksheet, the Curve number determination form, and the Basin Summary Report with this form

FORM 6 **Curve Number Determination**

Project Name:

Drainage Area Description:

Drainage Area =

Acres

Soil Types:

% A
% B
% C
% D

Land Use:

Composite Runoff Curve Number:

	Land Use		Soil Type	CN	Soil Type %	Land Use %	CN*Soil %*Land %

Composite CN =