Stormwater Manual

City of Mason, Ohio

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City of Mason, Ohio

Stormwater Manual

Contents

Section 1 - Introduction

This manual provides engineering design and construction standards for stormwater management, including requirements of the Ohio Environmental Protection Agency (EPA) permit No. OHQ000002: Authorization for Municipal Separate Storm Sewer Systems (MS4) to discharge stormwater 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 stormwater design guidelines, including specifics on hydrology, hydraulics, erosion and sediment control, comprehensive storm water management and construction materials and methods.

1.1 Stormwater Policy Goals

There are many goals in stormwater management. The most important of these is to protect life and property of the residents and businesses of Mason from damage due to stormwater runoff and to establish standards that achieve a level of erosion control and stormwater 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 stormwater management plan submittals and project reviews.
- Assuring that stormwater controls are incorporated into site planning and design at the earliest possible stage and that all stormwater management practices are properly designed, constructed and maintained.
- Ensuring consistency in review of stormwater permit applications and land alteration plans by the Engineering Department staff.
- Improving the ability of contractors to properly and consistently install stormwater facilities, with a high level of workmanship, according to the approved stormwater management plan.
- Meeting community needs for minimizing the impacts of new and modified development on existing stormwater management facilities, and on upstream and downstream properties.
- Meeting community needs for protecting local water resources by encouraging the construction of stormwater 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 Ordinance, Part 11, 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 stormwater 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 stormwater 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 stormwater 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 should be prepared in a tabular format similar to that illustrated in **Forms 1 and 2** (included in **Appendix A** of this manual). Note that this analysis must demonstrate that the storm sewer system will be adequately sized to convey the 10-yr storm runoff without surcharge and the 25-yr storm runoff without overtopping any catch basin, manhole, etc. In addition, the tables must show that a minimum Manning's "n" value of 0.015 was used.

d) A Time of Concentration Worksheet (**Form 3**, Appendix A of this manual) must 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 of this manual) provides the general format that should be followed and includes the minimum information that must be provided. 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 of this manual) and curve number determination worksheet (**Form 6,** Appendix A**,** must 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

To provide consistency within this manual as well as throughout this manual, the symbols and abbreviations listed in **Table 1** will be used. These symbols were selected because of their wide use in hydrologic publications.

Table 1
Symbols & Abbreviations

Symbol	*Definition*	*Units*
A	Drainage area	acres, sq. mi.
BDF	Basin development factor	%
C	Runoff coefficient	-
C_f	Frequency factor	-
CN	SCS-runoff curve number	-
C_t, C_p	Physiographic coefficients	-
d	Time interval	hours
ΔH	Elevation difference	Ft
I	Runoff intensity	in./hr
IA, IA%	Impervious area, percentage of impervious area	acres, %
I_a	Initial Abstraction	In
K	Frequency factor for a particular return period and skew	-
L	Length	Ft
L_T	Lag Time	hours
l	Length of mainstream to furthest divide	Ft
L_{ca}	Length along main channel to a point opposite the watershed	miles
M	Rank of a flood within a long record	-
n	Manning’s roughness coefficient	-
N	Number of years of flood record	years
P	Accumulated rainfall/ Precipitation depth	In
Q	Rate of runoff	cfs
q	storm runoff during a time interval	In
R	Hydraulic radius	Ft
RC	Regression constant	-
RQ	Equivalent rural peak runoff rate	cfs
S or Y	Ground slope	ft/ft or %
S_t	Potential maximum retention storage	In
SCS	Soil Conservation Service	-
S_L	Main channel slope	ft/mile
SL	Standard deviation of the logarithms of the peak annual floods	-
ST	Basin storage factor	%
T_B	Time base of the unit hydrograph	hours
t_c or T_c	Time of concentration	hours
T_t	Travel time or Lag time	hours
T_r	Snyders duration of excess rainfall	hours

Symbol	*Definition*	*Units*
UQ	Urban peak runoff rate	cfs
V	Velocity	ft/s
X	Logarithm of the annual peak	-
WQv	Water quality volume	Acre-ft

1.4 Definitions

The definitions listed in **Table 2** shall be used with regard to this manual and to stormwater management in the City of Mason.

Table 2
Definitions

Term	*Definition*
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 water quantity control.
Best Management Practices (BMPs)	Is the schedule of activities, prohibitions of practices, maintenance procedures, and other management practices (both structural and non-structural) to prevent or reduce the pollution of water resources and wetlands. BMP's also include treatment requirements, operating procedures, and practices to control facility and/or construction site runoff, spillage, or leaks: sludge or waste disposal; or drainage from raw material storage.
Building Official	The Building Official of the City of Mason, Ohio.
Building Inspector	Person designated by the representing the City of Mason, also referred to as the inspector for purposes of this manual.
City	The City of Mason and it's authorized agents.
Concentrated	Surface runoff that converges and flows primarily through water.

Term	*Definition*
Stormwater Runoff	conveyance features such as swales, gullies, waterways, channels or storm sewers and which exceeds the maximum specified 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. An illustration of critical depth is the depth at which water flows over a weir when no other backwater forces are involved. For a given discharge and prismatic crosssection geometry, there is only one critical depth.
Denuded Areas	Land surface on which the vegetation or other soil stabilization features have been removed, destroyed or covered and which may result in or contribute to erosion and sedimentation.
Developed Land Use	The land use according to the proposed development or the proposed land use according to the current City of Mason Zoning Map.
Developer	Person or company performing construction work of any kind in the project area.
Earth-disturbing Activity	Grading, excavating, filling, or other alteration of the earth's surface where natural or man-made ground cover is destroyed and which may result in or contribute to erosion and sediment pollution.
Erosion	The process by which the land surface is worn away by the action of water, wind, ice or gravity.
Erosion and Sediment Control Practices	Conservation measures, used to control sediment pollution including structural practices, vegetative practices and management techniques, which minimize the removal of soil from the land surface and prevent soil transport from a disturbed area by means of wind, water, ice gravity or any combination of those forces.
Erosion and Sediment Control Plan	A written description and site plan of pertinent information concerning erosion control measures.
Existing Land Use	The land use according to the most recent aerial photography available from the City of Mason or as determined from a property survey.
Final Stabilization	When all soil disturbing activities at the site have been completed and a uniform perennial vegetative cover with a density of at least

Term	*Definition*
	80% coverage for the area has been established or equivalent stabilization measures, such as the use of mulches or geotextiles, have been employed
Freeboard	Freeboard is an additional depth regarded as a safety factor, above the peak design water elevation.
Free Outlets:	Free outlets are those outlets whose tailwater is equal to or lower than critical depth. For culverts and storm drains having free outlets, lowering of the tailwater has no effect on the discharge or the backwater profile upstream of the tailwater.
Grading	Any earth disturbing activity including excavation, stripping, cutting, filling, stockpiling, or any combination thereof.
Grubbing	Removing, clearing, or scalping material such as sod, trees, roots, or stumps.
Hydraulic Roughness	A composite of the physical characteristics, which influence the flow of water across the earth's surface, whether natural or channelized, or the flow of water in a closed conduit or open channel. It affects both the time response of a watershed, and the flow rate in a drainage channel and in a closed conduit, and the channel storage characteristics. Usually expressed as Manning's "n" value.
Hydrologic Unit Code	A cataloging system developed by the United States Geological Survey (USGS) and the Natural Resource Conservation Services (NRCS) to identify watersheds in the United States.
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	Invert refers to the bowline of the culvert (inside bottom).
Lag Time (T_t)	The time from the centroid of the excess rainfall to the peak of the runoff hydrograph.
Maintenance	Activities by personnel to keep a system operational.
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.

Term	*Definition*
Natural Waterway /Watercourse	Waterways that are a part of the natural topography. Engineered or constructed channels are not natural waterways.
Interception	The storage of rainfall on foliage, detritus and other intercepting surfaces during a rainfall event.
ODOT	The Ohio Department of Transportation
Operator	The person or persons who, either individually or collectively, meet the following two criteria: (1) have operational control over the facility specifications (including the ability to make field modifications in specifications); and (2) have the day-to-day operational control over those activities at the facility necessary to insure compliance with pollution prevention or erosion and sediment control requirements and any permit conditions.
Partially submerged outlets	Those outlets whose tailwater is higher than critical depth and lower than the height of the culvert. Submerged outlets are those outlets having a tailwater elevation higher than the crown of the culvert.
Peak Discharge	The maximum rate of flow of runoff passing a given point during or after a rainfall event. Also known as peak flow.
Phasing	The clearing a parcel of land in distinct sections, with the stabilization of each section before the clearing of the next
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.
Qualified Inspection Personnel	A person knowledgeable in the principles and practices of erosion and sediment controls, who possess the skills to assess all conditions at the construction site that could impact storm water quality and to assess the effectiveness of any sediment and erosion control measure selected to control the quality of stormwater discharges from the construction activities
Rainwater and Land Development	Ohio's standards for storm water management, land development, and urban stream protection. The most current edition of these standards shall be used with this regulation
Sediment	Solid material, both mineral and organic, that is in suspension, is being transported, or has been moved from its site of origin by wind, water, gravity, or ice, and has come to rest on the earth's surface.

Term	*Definition*
Sediment Basin	Settling pond meeting or exceeding the design specifications of a temporary sediment basin as defined in water management and sediment control for urbanizing areas.
Sediment Control	The limiting of sediment transport by controlling erosion, filtering sediment from water, or detaining sediment-lade water allowing sediment to settle out.
Settling Pond	Runoff detention structure such as sediment basin or sediment trap, which detain sediment-laden runoff allowing sediment to settle out.
Sheet Flow	Overland water runoff in a thin uniform layer.
Slope	The face of an embankment or cut section; any ground whose surface makes an angle with the plane of the horizon. Slopes are expressed in a percentage based upon vertical difference in feet per 100 feet of horizontal distance or as a ratio of horizontal distance to vertical distance, for example 3:1 means three feet horizontal direction to one foot in elevation change.
Specific Energy	Specific energy (sometimes called 'specific head') is defined as the sum of the depth and velocity head of the f low.
Steep and Mild Slope	A steep slope culvert operation is where the computed critical depth is greater than the computed uniform depth. A mild slope culvert operation is where critical depth is less than uniform depth.
Storm Drains	Underground pipe systems designed to intercept and convey to an adequate outlet stormwater 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.
Stormwater Control Facility	Practices used to control accelerated stormwater runoff from development areas.
Stormwater Conveyance System	All storm sewers, channels, streams, ponds, lakes, etc., used for conveying Concentrated stormwater runoff or storing stormwater runoff.
Stormwater Runoff	Excess rainfall available after interception, depression storage, infiltration, and evapo-transpiration has been satisfied.

Term	*Definition*
Subdivision Subdivision (Continued)	The division or redivision of a lot, tract or parcel of land by any means into two or more lots, tracts, parcels or other divisions of land including changes in existing lot lines for the purpose, whether immediate or future, for lease, transfer of ownership or building or lot development. The name given to an area of land divided into lots including streets, walkways, easements, etc.
Submerged	Submerged inlets are those inlets having a headwater greater than 1 .5D.
Submerged Outlets	Partially submerged outlets are those outlets whose tailwater is higher than critical depth.
Surface Water of the State	All streams, lakes, reservoirs, marshes, wetlands, or other waterways situated wholly or partly within the boundaries of the state, except those private waters which do not combine or affect a junction with surface water. Waters defined as sewerage systems, treatment works or disposal systems in Section 6111.01 of the Ohio Revised Code are not included
Tailwater	Standing or running water, and specifically its elevation, outside the downstream or outlet end of a culvert or storm drain system.
Time of Concentration (T_c)	The time required for water to flow from the most hydraulically remote point of the basin to the location being analyzed. This is the maximum time for water to travel through the watershed, which is not always the maximum distance from the outlet to any point in the watershed.
Total Maximum Daily Load (TMDL)	The sum of the existing and or projected point source, nonpoint source, and background loads for a pollutant to a specified watershed, water body, or water body segment. A TMDL sets and allocates the maximum amount of a pollutant that may be introduced into the water and still ensures attainment and maintenance of water quality standards.
Uniform Flow	Uniform flow is flow in a prismatic channel of constant cross section having a constant discharge, velocity and depth of flow throughout the reach. In uniform flow it is assumed that the depth of flow is the same at every section of the channel.
Watershed	The drainage area contributing stormwater 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.

For all hydrologic analysis, the following factors shall be considered in the evaluation:

1. Drainage basin characteristics: size, shape, slope, land use, geology, soil type, surface infiltration, and storage.

2. Stream channel characteristics: geometry and configuration, slope, vegetation, channel roughness coefficient, natural and artificial controls, channel modification, aggradation/degradation, soil characteristics and ice and debris.

3. Flood plain characteristics: geometry, velocity of floodwater, and depth of floodwater.

4. Meteorological characteristics: precipitation amounts, intensities, and time of precipitation (hyetograph).

5. All hydrologic analysis shall consider the flood history of the area and the effect of these historical floods on existing and proposed structures. The flood history shall include the historical floods and the flood history of any existing structures.

2.2 Approved Methods

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

1. <u>Rational Method</u>: Used for detention facilities (for areas less than 5 acres only) and storm sewer design.

2. <u>SCS Unit Hydrograph</u>: Includes TR-55 and TR-20 computer programs, HYDRO, and HEC-1 Computer Programs. Acceptable for most stormwater management applications where hydrograph generation is required.

3. <u>Alternative Method</u>: 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 stormwater 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 stormwater 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 stormwater practices where pollutants will accumulate.

Local Basin Detention Facility Summary

Developed Conditions Peak Discharge		*Pre-Developed Conditions Peak Discharge*
2-year Frequency	Must be less than	2-year Frequency
10-year Frequency	Must be less than	10-year Frequency
100-year Frequency	Must be less than	25-year Frequency

b) <u>Major Basins</u>: Basins that have greater than 5 acres of drainage or have significant downstream restrictions. **Forms 5 and 6** (in Appendix A) must be completed and included in the submittal for all 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) Determining 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) 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 stormwater practices where pollutants will accumulate.

vi) 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

Percent increase in runoff volume from a 1-year frequency, 24-hour storm		*Storm Frequency (Years)*
Equal or Greater Than (Percent)	*Less Than (Percent)*	
-	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 stormwater 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 is recommended for estimating the design storm’s peak runoff for areas up to 5 acres for storm sewer design only. This method, while first introduced in 1889, is still used in many engineering offices in the United States. Although it has been criticized because of its simplistic approach, no other drainage design method has seen such widespread use. 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, which limits its use to 5 acres, 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	
Recurrence Interval (years)	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. The duration of rainfall shall be set equal to the time of concentration and shall be used to estimate the design average rainfall intensity (I). 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**.

$$T_t = \frac{0.93(nL)^{0.6}}{I^{0.4} S^{0.3}}$$

Where:

T_t = travel time, minutes.
L = flow length, feet.
n = Manning's value from Table 3.
I = average rainfall intensity for a storm duration equal to T_c, in/hr.
S = average slope of the sheet flow area, ft/ft.

Table 5:Manning's Kinematic Values for Calculating T_c & T_t

Surface Description	*Manning's n-Value*
Fallow crop land (Winter, Spring)	0.050
Range, short grass, athletic fields	0.100
Cultivated Soils (Summer, Fall)	0.060
Grass, lawns, yards	0.240
Woods, brush, unmowed fields	0.400
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 minutes.

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:

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

Where:

V = average velocity, ft/sec.

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

n = Manning's roughness coefficient for open channel flow (0.015 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 can not 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:

- First, 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.

- Second, 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**:

$$\mathbf{I = B / (T_c + N)^E}$$

Where:

T_c = Time of concentration (minutes)

Table 6: Rainfall Intensity for Warren County, Ohio

	B	N	E
1-yr			
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 stormwater 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. A description 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. Soil groupings for any site in Mason can be found from the SCS TR-55 Exhibit A-1 and the Warren County Soil Atlas. 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. <u>Curve Numbers</u>: **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. <u>Time of Concentration</u>: 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 ***Time of Concentration*** Section of 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) should 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

Urban Runoff CN Values for the City of Mason					
Cover Description	*Average % Impervious*	*A*	*B*	*C*	*D*
Fully Developed Urban Areas with vegetation established					
Open Space (Lawns, Parks, Golf Courses, Cemeteries, etc) < 50% grass cover		68	79	86	89
Open Space – 50% to 75% grass cover		49	69	79	84
Open Space – > 75% grass cover		39	61	74	80
Impervious Areas: parking areas, roofs, driveways, sidewalks		98	98	98	98
Impervious Areas: Streets & 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
Disturbed Areas					
Newly Graded Areas, no vegetation established[1]		81	89	93	95
Existing Conditions					
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, driveways, surrounding lots		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:

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

Where:

T_L = basin 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

$$q_P = \frac{484AQ_V}{T_P}$$

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 stormwater 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 in/10-minutes) x (60-minutes/hour) = 5.04 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 stormwater 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. 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 stormwater easement size may be made by the City Engineer based upon individual site conditions. The exact location of the stormwater 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.

2. 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 on the form provided in **Form 1**, Appendix A, or similar format. Headloss computations must 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.

Design computations of storm drain pipe systems using the Rational Formula and Manning's Equation shall be submitted on the Storm Drain Flow Tabulation Form provided by **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 & Terra Cotta pipe,	n = 0.015
Plastic & HDPE pipe,	n = 0.015
Corrugated metal, spiral metal and Corrugated plastic pipe,	n = 0.025
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.

Headloss computations shall be submitted with the stormwater design calculations on **Form 2** (provided in Appendix A).

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.

One accepted method is the backwater analysis method, which provides a more accurate estimate of pipe flow by calculating individual head losses in pipe systems that are surcharged and/or have submerged outlets. These head losses are added to a known downstream water surface elevation to provide a design water surface elevation for a given flow at the desired upstream location.

Total head losses may be determined as follows:

Total head loss = frictional loss + manhole loss + velocity head loss + junction loss

Frictional loss is computed from Manning's Equation expressed in the following form:

$$S_f = \frac{(nV)^2}{2.22R^{4/3}}$$

Where:

S_f = head loss per lineal foot of pipe due to friction
n = Manning's 'n'
V = Flow velocity in ft/sec = Q/A
R = Hydraulic radius, ft. A/P_w

The remaining components of total head loss shall be computed using standard equations, or estimated using graphical solutions.

3. 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 stormwater 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.

4. Non-Gravity Stormwater Systems. Stormwater facilities shall be designed to convey stormwater runoff by gravity flow unless approved by the City Engineer. Stormwater control systems, which do not satisfy this goal, would include stormwater 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.

DESIGN SUMMARY CHART
Minimum pipe size – 12-inch diameter
Pipe Material – under pavement/roadway-concrete, Outside pavement/roadway - 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
Overflow Route – show > 50-year flow path
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 stormwater; settle or filter particulates pollutants; and release the controlled stormwater 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 stormwater released shall not adversely affect the downstream property owners for the 1-, 2-, 5, 10-, 25, 50-, and 100-year storm events. 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 stormwater 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. Stormwater management facilities shall be designed to the following general guidelines:

A) Stormwater management systems shall be designed for the ultimate use of the watershed, including off-site drainage. Development areas developed for subdivisions shall provide a stormwater management system 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) Stormwater 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) Stormwater management facilities shall be designed with specific regard to 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 stormwater flows, all development areas shall be designed and constructed in compliance with these regulations.

G) 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 stormwater practices where pollutants will accumulate.

All basins must include the following design criteria:

a) <u>Dam Permit</u> – Required by The Ohio Department of Natural Resources for dam construction if;

1) Embankment is greater than 10 feet in height, or

2) Maximum capacity of the dam is greater than 15 acre-feet

b) <u>Other permits</u> – additional permits may be required when constructing a detention/retention basin. The developer is responsible for obtaining all necessary state and local permits.

c) <u>Embankment Construction</u> – 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) <u>Freeboard</u> – the maximum water surface elevation shall be at least 1.0 feet below the top of the basin.

e) <u>Impervious Runoff</u> - 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 stormwater 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 so that trash and clogging is not a problem. 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 1/3rd 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 and should include a concrete low-flow channel to aid in maintenance. The minimum slope in a dry basin should be 1.0 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 stormwater 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.

Example

If the percent increase in runoff between pre- and post-development is 45%, the basin must control the developed conditions 5-year storm back to the pre-developed 1-year storm. The 10-, 25-, 50-, and 100-year developed conditions storms must also be controlled to pre-developed conditions flows.

3. Outlet Structure and Routing Design

All stormwater 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/sec^2)
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:

$$Q = C_D L H^{1.5}$$

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 stormwater 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.

Each year on or before June 30, 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 stormwater 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 which encompass the entire delineated 25-year flood area;
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. <u>Collector Swales</u>

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 shall be required by the City Engineer as deemed necessary to either control erosion and/or eliminate wetness within open stormwater conveyance channels.

To prevent chronic wetness in the invert of open channels, subsurface tiles shall be installed a minimum of 18 inches in depth (from the tile invert), with a No. 8 gravel or equivalent size washed stone as a granular envelope, as follows:

Minor drainage collector swales in rear yards and between homes shall possess a maximum channel length of 400 lineal feet, unless subsurface tile or swale invert treatment in the form of concrete paving is also provided. 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 (such as a 2 ft. by 2 ft. trench filled with No. 8 washed gravel wrapped in fabric) if channel slope is between 0.3% and 0.5%, and/or length is greater than 400 feet; subsurface drainage tile if channel slope is between 0.5% 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/ft3.
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 ft. 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^3)
d = normal flow depth (ft)
S = channel gradient (ft/ft)

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

e) Choose a more resistant lining
f) Use concrete, gabions, or other more rigid lining either as full lining or composite
g) Decrease channel slope in combination with drop structures
h) 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:lV 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 (1.0) foot or 1.5 D_{50} (which ever 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 D_{50} size of stone (in inches) for riprap placed in a channel with average velocity 'v' and depth 'D'.

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

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 then 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).

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

The equation shown above for calculation D_{50} is based on a safety factor of 1.2 and a stone weight of 165 Lbs/ft^3. For situations other than a uniform straight channel, the D_{50} size determined from the above equation should be multiplied by a Stability Correction Factor as calculated in the below equation.

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

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 topwidth ($R_C/T > 30$); 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/ft^3 the D_{50} 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/ft^3 has a specific gravity of about 2.65).

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

Where:

S_G = specific gravity of stone, Lbs/ft^3
C_{SG} = specific gravity correction factor

The riprap layer thickness shall be a minimum of D_{100}, and the D_{85} /D_{15} 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 D_{100}, the following reductions in D_{50} stone size are allowed:

- for blanket thickness equal to 1.5 D_{100}, the D_{50} size can be reduced 25 percent.

- for blanket thickness equal to 2.0 D_{100}, the D_{50} 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 (D_{50} in feet):

$$n = 0.0395(\mathrm{D}_{50})^{1/6}$$

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:

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

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. <u>Outlet Control</u>

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 stormwater 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

4.1 Key Section Highlights

1. A Storm Water Pollution Prevenetion Plan (SWP3) is required for all non-single-family residential land disturbing activities of any size.

2. A SWP3 is required for all land disturbing activities that result in the disturbance of less than one acre of total land area and which are part of a larger common plan of development or sale, including single family residential developments that are a part of planned residential developments.

3. Each SWP3 shall include as a minimum one or more separate plan sheets that clearly portray the methods and means whereby erosion and sediment control measures are implemented. These plan sheets shall be included in the Construction Documents for each project and shall be implemented by the Construction Contractor.

4. No amount of surface area of erodible earth material shall be exposed at one time by clearing and grubbing, excavation, borrow or fill without prior approval by the City Stormwater Engineer.

4.2 Purpose and Background

1. This section is intended to establish technically feasible and economically reasonable storm water management standards to achieve a level of erosion and sediment controls that will minimize damage to property and degradation of water resources and wetlands, and will promote and maintain the health, safety and welfare of the citizens of the City of Mason. The section includes 1) goals and policies, 2) practice standards, and 3) specifications, and plan submittal information.

2. Construction activities require, as a part of land development, the removal of natural ground cover, creating the potential for erosion to occur. The goal of this policy is to establish a minimum set of criteria and standards that developers and contractors must implement to ensure that receiving streams and water bodies are protected from sediment loads resulting from construction site runoff.

3. This document includes a description of temporary and permanent sediment control measures that should be considered by developers when designing a Storm Water Pollution Prevention Plan (SWP3) for each project. These control measures include, but are not limited to, the use of straw bales, dikes, slope protection, sediment pits, basins and dams, coarse aggregate, mulches, grasses, filter fabrics, ditch linings, and other erosion control devices and methods.

4. 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) Excavations below finished grade for drain fields, tanks, vaults, tunnels, equipment, basements, swimming pools, cellars or footings of buildings or structures for which a building permit shall have been issued by the City, unless the excavation is part of the work within a project area which required such a permit

    c) Tilling of the soil for fire protection purposes

    d) Special projects with the express written approval of the City Engineer.

    e) Any un-subdivided parcel less than one acre in size.

5. Neither submission of an SWP3 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.

6. 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.

4.3 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, erosion and sediment discharge from construction sites using, but not limited to, applicable methods and standards established by these regulations. The goals of such erosion and sediment control measures are to:

a) Minimize the extent and duration of disturbed soil exposure;

b) Protect off-site and downstream locations, drainage systems, and natural watercourses from erosion and sedimentation;

c) Limit exit velocities from the site to non-erosive or natural values;

d) Implement a thorough ongoing inspection, maintenance and follow-up program.

Control of sediment from construction sites may be accomplished through utilization of a variety of erosion and sediment control practices. The complexity of the erosion and sediment control plan will vary depending upon individual site conditions. For example, a small commercial or industrial site may not require installation of erosion control practices to the extent that a multi-section residential subdivision development would.

The goal of implementing the erosion control plan is to limit the dislodging of soil particles and, as a result, the quantity of sediment leaving the construction site. This may partially be accomplished through installation of control measures that trap sediment prior to leaving the site. Sediment trapping practices typically remove only a small portion of the total suspended solids, and must be used in combination with practices such as temporary and permanent seeding, flow diversions, and stream bank protection, as examples, which minimize the dislodging of soil particles.

Prevention of sediment leaving the site is a general performance goal that may be used as a guide to the use of erosion and sediment 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 erosion and sediment control 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 erosion control plan which addresses each form of erosion and sedimentation.

4.4 Requirements

It is the intent of the City that all land alterations be considered for erosion and sediment reduction measures. Land alteration falls into one of three categories with differing requirements as follows:

1. Land alterations that disturb 5 or more acres.

2. Land alterations that disturb 1 to 5 acres, and all non-single-family residential land disturbing activities.

3. Land alterations which disturb less than 1 acre – all single-family residential land disturbing activity less than one acre shall employ, at a minimum, perimeter type erosion and sediment control practices. The City Engineer or their representative requires gravel access drives at construction sites.

4.5 Storm Water Pollution Prevention Plans (SWP3)

A Storm Water Pollution Prevention Plan (SWP3) is required for all non-single-family residential land disturbing activities of any size. In addition, an SWP3 will be required for all land disturbing activities that result in the disturbance of less than one acre of total land area and which are part of a larger common plan of development or sale.

As part of the SWP3 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 erosion and sediment control related information developed for and/or submitted to state or federal authorities shall be submitted to the City of Mason Stormwater Engineer as part of the SWP3.

The SWP3 must contain a description of the controls appropriate for each construction operation and the contractor/developer must implement such controls. The SWP3 must clearly describe for each major construction activity the appropriate control measures; the general sequence during the construction process under which measures will be implemented; and the contractor responsible for implementation (e.g., contractor A will clear land and install perimeter controls and contractor B will maintain perimeter controls until final stabilization). The SWP3 shall indentify all subcontractors engaged in activities that could impact storm water runoff. The SWP3 shall contain signatures from all of the identified subcontractors indicating that they have been informed and understand their roles and responsibilities in complying with the SWP3

The SWP3 shall include a description of and detailed drawings for, all structural practices that shall store runoff, allowing sediments to settle and or divert flows away from exposed soils or otherwise limit runoff from exposed areas. Structural practices shall be used to control erosion and trap sediment from a site remaining disturbed for more than fourteen (14) days. Sediment in the runoff water shall be trapped by such practices including, among others: sediment settling ponds, silt fences, storm drain inlet protection, and earth diversion dikes or channels which direct runoff to a sediment settling pond. All sediment control practices must be capable of ponding runoff in order to be considered functional. Earth diversion dikes or channels alone are not considered a sediment control practice unless used in conjunction with a sediment settling pond. Sediment control structures shall be functional throughout the course of earth disturbing activity. Sediment basins and perimeter sediment barriers shall be implemented prior to grading and within seven (7) days from the start of grubbing. They shall continue to function until the up slope development area is re-stabilized. As construction progresses and the topography is altered, appropriate controls must be constructed or existing controls altered to address the changing drainage patterns.

Each SWP3 shall include as a minimum one or more separate plan sheets that clearly portray the methods and means whereby erosion and sediment control measures are implemented. These plan sheets shall be included in the Construction Documents for each project and shall be implemented by the Construction Contractor. The SWP3 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 (Note: This information is intended to be similar to that required under Ohio Administrative Code 1501:15-1-01):

Site Description

1. A general project description including the nature and purpose of the earth-disturbing activity;

2. Total Area of Site and the area of the site that is expected to be disturbed (i.e., grubbing, clearing, excavation, filling or grading, including off site borrow areas);

3. An estimate of the impervious area and percent of imperviousness created by the soil disturbing activity;

4. A description of prior land uses at the site;

5. An implementation schedule which describes the sequence of major soil-disturbing operations (i.e. grubbing, excavating, grading, utilities and infrastructure installation) and the implementation of erosion and sediment controls to be employed during each operation of the sequence;

6. The location and name of the immediate receiving stream or surface water(s) and the first subsequent receiving water(s);

7. The aerial (plan view extent and description of wetlands or other special aquatic sites at or near the site which will be disturbed or which will receive discharges from disturbed areas of the project;

8. For subdivided developments where the SWP3 does not call for a centralized sediment control capable of controlling multiple individual lots, a detail drawing of a typical lot showing standard individual lot erosion and sediment control practices;

Vicinity Sketch/Map

1. A vicinity sketch locating the development area and all pertinent surrounding features, including water resources;

2. Location of all existing and planned buildings, structures, utilities, storm and sanitary sewers and waterlines in the project area;

3. Location of any building or structure, on land of adjacent property owners, within 100 feet of the project area;

4. Detailed plans of all existing surface water locations including springs, wetlands, streams, lakes, water wells, etc. and proposed storm water provisions, retaining walls, vegetative practices;

5. Location of designated stone construction entrances where vehicles will ingress and egress the construction site;

6. Areas designated for the storage or disposal of solid, sanitary and toxic waste, including dumpster areas, areas designated for cement truck washout, and vehicle fueling;

7. The location of sensitive areas receiving runoff from the development area;

8. Location of detention/retention basins or steep excavations and other protective devices to be constructed in connection with, or as a part of the proposed work;

9. Location of fences around sediment basins/ponds, include the sediment settling volume and contributing drainage area;

10. The existing and proposed topography in one (1') foot increments;

11. The location and description of existing and proposed drainage patterns and facilities, including any allied drainage facilities beyond the development area;

12. The limits of earth-disturbing activity;

13. The types of soils within or affected by the development area and the location of all highly erodible or unstable soils;

14. Permanent and temporary erosion and sediment control practices to be employed on the development area including:

    a) Their location; and

    b) Erosion Control structure size, detail drawings, maintenance requirements, and design calculations.

15. Stormwater provisions, including:

    a) A general description of the stormwater management strategy proposed to meet the requirements of rule 1501:15-01-05 of the Administrative Code;

    b) The location and design calculations for all permanent stormwater conveyance, detention, and retention structures;

    c) The person or entity responsible for continued maintenance of the stormwater control structure;

d) Description of routine maintenance requirements and maintenance schedule for the upkeep, monitoring, cleaning, and replacement of sediment control measures; and

e) Permanent access and access easements required to perform inspection and maintenance of stormwater control structures and stormwater conveyance systems.

16. The schedule, phasing, and coordination of construction operations and erosion and sediment control practices.

4.6 General Standards

In order to control sediment pollution of water resources the owner or person responsible for the development area shall use conservation planning and practices to develop any SWP3. The following general principles and practice standards apply to the development of the SWP3 and are effective in minimizing erosion and sedimentation and shall be included where applicable.

These standards are general guidelines and shall not limit the right of the City to impose additional, more stringent requirements, nor shall the standards limit the right of the City to waive individual requirements.

4.7 Construction Requirements

1. The SWP3 must make use of practices that preserve the existing natural condition to the maximum extent practicable. Stripping of vegetation, re-grading or other development shall be done in such a way that will minimize erosion. Whenever feasible, natural vegetation shall be retained, protected and supplemented. Such practices may include preserving riparian areas, preserving existing vegetation and vegetative buffer strips, phasing of construction operations in order to minimize the amount of disturbed land at any one time, and designation of tree preservation areas or other protective clearing or grubbing practices.

2. The SWP3 shall limit the surface area of erodible earth material exposed by clearing and grubbing, excavation, borrow, and fill operations and provide immediate permanent or temporary control measures to prevent contamination of adjacent streams or other water courses, lakes, ponds, or other areas of water impoundment.

3. The SWP3 shall construct and install temporary erosion control measures prior to earth disturbing activities. Temporary devices that cannot be installed at the beginning of the project (i.e., inlet protection devices) must have temporary sediment control devices placed such that minimal sediment will escape the site

any time during the construction process. Additional temporary control measures beyond those identified in the SWP3 will be implemented by the developer/contractor as directed by the City's Stormwater Engineer to correct conditions that develop during construction that were not foreseen during the design stage; that are needed prior to installation off permanent control features; or that are needed temporarily to control erosion that develops during normal construction practices.

4. The SWP3 shall incorporate all permanent erosion control features into the project at the earliest possible time. Except where future construction operations will damage slopes, the developer/contractor shall perform the permanent seeding and mulching and other exposed slope protection work in stages, as soon as substantial areas of exposed slopes can be made available.

5. The amount of surface area of erodible earth material exposed at one time by clearing and grubbing, excavation, borrow or fill shall shall be kept to a practical minimum. The Stormwater Engineer may increase or decrease the allowable amount of surface area of disturbed earth to be exposed at one time as determined by their analysis of project conditions. Factors such as the amount of exposed erodible soil adjacent to the project limits, waste and borrow sites, farm land, soil erodibility, slope, cut or fill height, exposed area contributing to a watercourse and weather will be considered in this determination.

6. The SWP3 must make use of erosion controls that are capable of providing cover over disturbed soils. A description of control practices designed to re-stabilize disturbed areas after grading or construction shall be included in the SWP3. The SWP3 must provide specifications for stabilization of all disturbed areas of the site and provide guidance as to which method of stabilization will be employed for any time of the year. Such practices may include: temporary seeding, permanent seeding, mulching, matting, sod stabilization, vegetative buffer strips, phasing of construction operations, the use of construction entrances and the use of alternative ground cover

4.8 Topsoiling

1. The application of at least a minimum depth of topsoil may be required for those critical areas, such as within open channels and fill slopes, where glacial till material is left on the surface after final grading. Unweathered glaciated till is that material located approximately 30 inches to 40 inches below the soil surface, and can be found at the ground surface in highly eroded areas. The subgrade shall be raked and all rubbish, sticks, roots, and stones larger than 2-inch shall be removed. Subgrade surfaces shall be raked or otherwise loosened immediately prior to being covered with topsoil.

2. Topsoil shall be evenly spread to a minimum depth of four (4) inches. All areas to be utilized for soil stockpiles shall be clearly identified on the approved

erosion control plan. The topsoil stockpile shall be located so as not to interfere with site work, and shall be provided with adequate temporary erosion control measures according to those guidelines specified herein, and shown on the approved erosion control plan. Surface roughening must be completed to allow proper bonding of topsoil to the soil material below.

4.9 Temporary Vegetation/Stabilization

1. Disturbed soils shall be stabilized with temporary vegetation or mulching to protect exposed critical areas during development as specified in Table-1.

Table 1: Temporary Stabilization

Area requiring temporary stabilization	*Time frame to apply erosion control*
Any disturbed area within 50 feet of a stream and not at final grade.	Within two (2) days of the most recent disturbance if the area will remain idle for more than twenty-one (21) days.
For all construction activities, any disturbed area, including soil stockpiles that will be dormant for more than twenty-one (21) days but less than one (1) year, and not within 50 feet of a stream.	Within seven (7) days of the most recent disturbance within the area.
Disturbed areas that will be idle over winter.	Prior to November 1.
Note: Where vegetative stabilization techniques may cause structural instability or are otherwise unobtainable, alternative stabilization techniques must be employed. These techniques may include mulching or erosion matting.	

2. Temporary seeding areas shall be fertilized at ½ the normal plan or specification rate of application as specified in ODOT Item 659. All areas of temporary seeding shall be seeded with annual ryegrass sown at the rate of 2 pounds per 1,000 square feet and mulched in accordance with ODOT Item 659. The seed bed shall be thoroughly watered and/or mowed in accordance with the requirements of ODOT Item 659.

4.10 Permanent Vegetation

1. The permanent final vegetation and structural erosion control and drainage measures shall be installed in the development as specified in Table-2.

Table 2: Permanent Stabilization

Area requiring permanent stabilization	*Time frame to apply erosion control*
Any area that will lie dormant for one (1) year or more.	Within seven (7) days of the most recent disturbance.
Any area within 50 feet of a stream and at final grade.	Within two (2) days of reaching final grade.
Any area at final grade.	Within seven (7) days of reaching final grade within that area.

2. The developer/contractor is responsible for all activities required to develop a vegetative cover including, seeding, sodding, mulching, and watering. At a minimum, the owner shall provide mulch at a rate of 70 to 90 lbs./1,000 square feet; 20-10-10 fertilizer at a rate of 10 lbs./1,000 square feet; and seed at a rate of 5 lbs./1,000 square feet. The seed mixture should be 10% Kentucky Bluegrass, 70% Tall Fescue, and 20% Perennial Ryegrass and applied uniformly with a cyclone seeder or hydroseeder. Seed containing noxious weeds will not be accepted and the maximum amount of weed seed shall be 2.0% with 0.0% desirable.

4.11 Mulching and Erosion Control Blankets

1. Application of mulching material immediately after temporary and permanent seeding will be required. Seed mixtures may be applied as part of a hydroseeder slurry containing wood fiber on slopes less than 4 (horizontal) to 1 (vertical), and less than 300 feet in length, or with straw mulch. Straw mulch and seeding is required to be placed the first 2 feet behind curbs.

2. Straw mulching shall be at a rate of 1 ½ to 2 tons per acre, and shall be anchored utilizing nylon 1-inch square mesh netting installed according to manufacturer's recommendations, or a liquid binder. Binding of straw mulch may be accomplished as follows:

    a. Any liquid asphalt or asphalt emulsion material that is thin enough to be adequately blown from spray equipment, applied at a rate of 0.10 gallon per square yard. Synthetic binders may be used as recommended by the manufacturer.

3. Installation of erosion control blankets according to manufacturer's specifications will be required within the flowline of all drainage swales, on all retention/detention pond banks and on all fill slopes of 4 (horizontal) to 1 (vertical) or steeper.

4.12 Sodding

Establishment of permanent vegetation by sodding will not generally be required by the City, except on basin side slopes. In those areas where the immediate establishment of permanent turf is deemed necessary, sodding will be an acceptable means of providing vegetative cover for erosion control. When placed within the flowlines of defined drainage ways, staking of sod to prevent undermining will be required. Sod in good condition must be placed on a roughened surface and kept watered for a minimum of two weeks. The preparation of areas to be sodded and the placement of sod shall conform to ODOT item 660.

4.13 Dumping and Unstable Water Banks.

1. No soil, rock, debris, or any other material shall be dumped or placed into a water resource or into such proximity that it may readily slough, slip, or erode into a water resource unless such dumping or placing is authorized by the City Stormwater Engineer, and, when applicable, the U.S. Army Corps of Engineers, for such purposes as, but not limited to, constructing bridges, culverts, and erosion control structures.

2. Unstable soils prone to slipping or landsliding shall not be graded, excavated, filled, or have loads imposed upon them unless the work is done in accordance with a qualified professional engineer's recommendations to correct, eliminate, or adequately address the problems.

4.14 Cut and Fill Slopes

Cut and fill slopes shall be designed and constructed in a manner which will minimize erosion. Consideration shall be given to the length and steepness of the slope, soil type, upslope drainage area, groundwater conditions, and slope stabilization. The angle of vegetated cut and fill slopes shall not exceed 3 (horizontal) to 1 (vertical) unless a detailed slope stability plan is provided. Slope protection shall be provided by use of temporary and permanent diversion dikes, vegetative cover, and slope drains. Concentrated stormwater flow shall not be allowed to flow down cut or fill slopes without proper slope stabilization.

4.15 Stabilization of Channels & Outlets

All constructed channels and outlets associated with a development must be constructed so that they remain stable during all phases of the construction activities. All channel lining must be designed for construction and final conditions. Grass channel shall be limited to a maximum two percent slope under bare earth conditions. Natural channels should be left undisturbed whenever possible. If the minimum slope cannot be maintained then temporary ditch checks shall be constructed consisting of straw or hay bales or coarse aggregate to minimize erosion. Temporary ditch lining shall meet the requirements of ODOT Item 667, 668, or 670.

4.16 Outlet Channel Protection

Concentrated stormwater runoff leaving a development site shall be discharged to an open channel, storm sewer pipe inlet or culvert that is capable of receiving this discharge. Runoff velocities shall be controlled during all storm events, up to the 100-year return interval storm, so that the peak runoff velocity during and after the completion of the land alteration approximates existing conditions.

4.17 Waste, Debris, and Pollution Elimination

Appropriate measures shall be taken to minimize or eliminate wastes and unused building materials and all pollutants from being carried from the site by runoff. Proper storage, handling and use of all potentially polluting substances shall be employed.

4.18 Disposition of Temporary Practices

All temporary erosion and sediment control practices shall be disposed of within thirty days after final site stabilization is achieved or after the temporary practices are no longer needed, unless otherwise directed by the City. Trapped sediment shall be permanently stabilized to prevent further erosion.

4.19 Technical Design Criteria

This section provides details for specific sediment control measures implemented in an SWP3. Individual control measures can be modified upon the request and review of the City's Stormwater Engineer based on special site characteristics and conditions.

4.20 Access Drives and Job Site Silt Control

1. During construction, traffic can carry a significant amount of soil and debris onto paved public roads. This represents a sediment problem as well as safety hazards and public nuisance. The main construction entrance of the project shall be constructed with coarse aggregate to help minimize and prevent soil transport onto public roads. Soil and debris should be swept and/or shoveled from roadways and unprotected areas on a daily basis and not placed in the storm sewer system.

2. The purpose of required installation of coarse aggregate construction access drives is to keep sediment out of the natural and engineered stormwater conveyance systems and reduced the transport of silt and other debris onto the public right-of-way.

3. During the early construction stages of residential and commercial job sites (prior to street paving), 2 to 3 inch or larger stone placed onto a properly compacted or otherwise prepared subgrade, at a minimum depth of six (6) inches with a minimum size of 20' x 50' width and length must be placed at all ingress and egress points used by vehicles to enter and leave the perimeters of a subdivision or commercial site. The stone drives must be sufficiently graded to

facilitate surface drainage and periodically top-dressed as conditions demand or as directed by the City.

4. Provisions for proper dust control may be required as deemed necessary by the City's Stormwater Engineer.

4.21 Storm Sewer Inlet Protection

1. All storm sewer inlets which accept water runoff from the development area shall be protected so that sediment-laden water will not enter the storm sewer system without first being filtered or otherwise treated to remove sediment, unless the storm sewer system drains to a settling facility. Temporary inlet filters and filter dikes shall consist of straw or hay bales or filter fabric fence. Filter fabric for sediment fences shall meet the requirements of ODOT 712.09 Type C. Storm drain inlet protective measures should be constructed in a manner that will: facilitate cleanout and disposal of trapped sediment, minimize interference with construction activities, and prevent inconvenience or damage to adjacent properties from ponding waters.

2. Sediment barriers shall be provided around all functional storm sewer inlets, during that period prior to permanent stabilization of the disturbed upstream drainage area. Inlet barriers must not be removed until such time as the entire upstream drainage area of that inlet has been properly stabilized.

4.22 Temporary Sediment Traps/Basins

1. Concentrated stormwater runoff from disturbed areas flowing at rates that exceed the design capacity of sediment barriers**,** stormwater runoff from drainage areas that exceed the design capacity of sediment barriers and/or stormwater runoff from 10-acres of disturbed land shall pass through a sediment-settling facility. The sediment-settling pond shall provide both a sediment storage zone and a dewatering zone. The volume of the dewatering zone shall be at least 67 cubic yards of storage per acre of total contributing drainage area and have a minimum of 48-hour drain time for sediment basins serving a drainage area over 5 acres.

1. The volume of the sediment storage zone shall be calculated by one of the following methods:

    a. The volume of the sediment storage zone shall be 1000 cubic feet per disturbed acre within the watershed of the basin.

    b. The volume of the sediment storage zone shall be the volume necessary to store the sediment as calculated with a generally accepted erosion prediction model.

2. When determining the total contributing drainage area, off-site areas and areas which remain undisturbed by construction activity must be included unless runoff from these areas is diverted away from the sediment settling pond and is not comingled with sediment-laden runoff. The depth of the dewatering zone must be less than or equal to five (5) feet. The configuration between the inlets and the outlet of the basin must provide at least two units of length for each one unit of width (> 2:1 length: wide ratio), however a length to width ratio of 4:1 is recommended. Sediment must be removed from the sediment-settling pond when the design capacity has been reduced by 40 percent. This limit is typically reached when sediment occupies one-half of the basin depth. When designing sediment settling ponds, the applicant must consider public safety, especially as it relates to children, as a design factor for the sediment basin and alternative sediment controls must be used where site limitations would preclude a safe design. The use of a combination of sediment and erosion control measures in order to achieve maximum pollutant removal is encouraged.

1. The facility's storage capacity shall be sixty-seven cubic yards per acre of drainage area. Temporary sediment basins shall be constructed by methods described in ODOT Item 203 Excavation and Embankment or Item 601 Rock Channel Protection, Type C without filter. Sand or filter fabric may be required. The purpose for installation of temporary sediment traps/basins is to detain sediment-laden runoff from small disturbed areas for a length of time sufficient to allow the majority of sediment to settle out.
2. Temporary sediment traps, along with the other pertinent controls, shall be installed as shown on the approved erosion control plan prior to the initiation of any land disturbing activities. Sediment traps and basins shall be inspected routinely and after each rain event and shall be cleaned of sediment deposits and repaired as necessary to maintain their operating efficiency.
3. The ability of the contractor to install on-site soil stabilization and sedimentation practices such as temporary and permanent seeding, sediment barriers, and flow diversion in a timely manner may be used to determine the need for installation of sediment basins. Effective use of these other available erosion and sediment control practices within a defined construction sequence may be considered by the designer when evaluating potential site applications for sediment basins.

4.23 Fabric Fence Barriers

1. The purpose of fabric fencing is to intercept and retain sediment from disturbed areas of limited size and preventing this sediment from leaving the construction site. Sheet flow runoff from denuded areas shall be intercepted by silt fence or diversions to protect adjacent properties, water resources, and wetlands from sediment transported via sheet flow Fabric fences may also be used to decrease the velocity of sheet flows and moderate velocity channel flows.

2. . Where intended to provide sediment control, silt fence shall be placed on a level contour and shall be capable of temporarily ponding runoff.

3. The relationship between the maximum drainage areas to silt fence for a particular slope range is shown in Table 3 below. Storm water diversion practices shall be used to keep runoff away from disturbed areas and steep slopes. Such devices, which include swales, dikes or berms, may receive storm water runoff from areas up to 10 acres. Placing silt fence in parallel does not extend the permissible drainage area to the silt fence..

Table 3: Maximum Drainage Area to Silt Fence

Maximum Drainage Area (acres) to linear feet of silt fence	*Range of Slope for a drainage area (%)*
0.5	**< 2%**
0.25	**≥ 2% but < 20%**
0.125	**≥ 20% but < 50%**

4. Synthetic filter fabric barriers shall be provided with wooden or reinforcement bar stakes at a maximum spacing of six (6) feet for reinforced barriers and four (4) feet for non-reinforced barriers. The City may require the use of fence backed (reinforced) silt fencing.

5. Sediment barriers shall be inspected after each rainfall, and at least daily during periods of prolonged rainfall. Barriers that become decomposed or inoperable prior to the end of their effective use shall be promptly replaced.

6. Sediment deposits shall be removed upon reaching approximately one-half of the height of the barrier at its lowest point or if it causes a silt fence to bulge. Sediment should be deposited at a controlled fill area. During clean-out operations, the fence must not be undermined.

4.24 Diversions

1. Diversion terraces are temporary or permanent channels constructed with a ridge along their downstream side, placed across the slope, in order to reduce the slope length and intercept and divert stormwater runoff to a stabilized outlet.

2. Diversion terraces shall be installed where sheet flow must be diverted from disturbed areas so that permanent vegetation may be established, or where slope lengths must be reduced in order to prevent sheet, rill, and gully erosion.

3. Stabilization of all disturbed areas upstream of the diversion dike must be completed concurrently with installation of the diversion dike and flow channel.

4. The flow velocity of open channels may be determined utilizing Manning's equation. Permissible velocities are given in the table below. Alternately, the designer can provide calculations to prove that the channel has been designed to be non-eroding.

Table 4.1: Channel Velocities

Permissible Velocities for Diversions		
Soil Texture	*Bare Channel (fps)*	*Fair Vegetative Cover (fps)*
Sand, silt, sandy loam, silty loam	1.5	2.5
Silty clay loam, silty clay loam	2.0	3.5
Clay	2.5	4.5

5. Diversion channels shall be provided with adequate outlets that convey concentrated flow without erosion. This outlet may be provided as a properly stabilized developed stormwater conveyance channel, storm sewer pipe, or culvert.

6. The diversion channel, dike, stabilized upstream areas, and outlet channel shall be inspected after every rainfall. Sediment deposits shall be removed, damaged and eroded areas repaired, and reseeding accomplished within either twenty-four (24) hours, or as soon as the soil dries sufficiently to allow work to proceed.

4.25 Rock Riprap/Rock Channel Protection

1. The installation of rock riprap provides a permanent, erosion-resistant ground cover through use of large, loose, angular stone. Note that approved commercial products may be used in place of rock riprap where applicable.

2. Rock riprap shall be required by the City as a means of protecting the soil surface from the erosive forces of concentrated stormwater runoff, as a sediment filtering device, and as a means of stabilizing eroding stream banks and slopes with seepage problems and/or non-cohesive soils. Some examples of where rock riprap may be utilized would include at storm sewer outlets, at culvert ends, on channel banks and/or bottoms, within roadside ditches, as temporary sediment barriers, as rock chute structures, and for slope stabilization.

3. Placement of the rock riprap must follow immediately after installation of the filter fabric layer, and a dense, well-graded mass of stone with minimal voids

must be produced. Riprap shall be placed to its full thickness in one operation, avoiding the segregation of the various stone sizes.

4. Crushed, discarded concrete shall be an acceptable alternative to rock riprap provided it is well graded, a density adjustment is made, and it meets all other requirements of this policy. The minimum thickness of the riprap layer shall be no less than 6 inches. Temporary rock check dams will be accepted as sediment barriers within minor drainage channels that drain to abutting off-site properties and/or drainage facilities, in minor swales and ditch lines that have been rough graded, around activated storm sewer inlets, and at the outlet ends of storm sewer pipes.

5. Rock riprap installations shall be inspected after every rainfall to determine if high flows have caused undermining, or if stones have been dislodged. Needed repairs shall be accomplished within twenty-four (24) hours, or as soon as the soil dries sufficiently to allow work to proceed.

4.26 Temporary Stream Crossings

1. Due to the potential for significant erosion and sediment suspension, construction activities in and around streams shall be kept to a minimum. Streams including bed and banks shall be restabilized immediately after in-channel work is completed, interrupted, or stopped. To the extent practicable, construction vehicles shall be kept out of streams. Where in-channel work is necessary, precautions shall be taken to restabilize the work area during construction to minimize erosion. If a live (wet) steam must be crossed by construction vehicles during construction, a temporary stream crossing shall be provided.

2. The purpose of temporary stream crossings is to provide a means for construction traffic to cross-flowing streams without damage to the channel or banks, and to keep sediment generated by construction traffic out of the stream.

3. Multiple culvert installations shall be approved on a case basis, provided the minimum pipe diameter proposed is eighteen (18) inches, and sufficient space is provided between culverts to allow for soil compaction.

4. Culverts shall have a slope greater than or equal to the stream bed being crossed, and extend the full width of the crossing, including side slopes.

5. Temporary stream crossings shall be inspected after every rainfall, and at least weekly for assessment of damages due to stormwater flows or construction equipment. Necessary repairs shall be accomplished within twenty-four (24) hours, or as soon as the soil dries sufficiently to allow work to proceed.

4.27 Non-Sediment Pollutant Controls

1. No solid or liquid waste, including building materials, shall be discharged in storm water runoff. The applicant must implement site Best Management Practices (BMPs) to prevent toxic materials, hazardous materials or other debris from entering water resources or wetlands. These practices shall include but are not limited to the following:

    a. Waste Materials: A covered Dumpster shall be made available for the proper disposal of garbage, plaster, drywall, grout, gypsum, and other water materials.

    b. Concrete Truck Wash Out: The washing of concrete material into a street, catch basin, or other public facility or natural resource id prohibited. A designated area for concrete washout shall be made available.

    c. Fuel/Liquid Tank Storage: All fuel/liquid tanks and drums shall be stored in a marked storage area. A dike shall be constructed around this storage area with a minimum capacity equal to 110% of the volume of all containers in the storage area.

    d. Toxic or Hazardous Waste Disposal: Any toxic or hazardous waste shall be disposed of properly.

    e. Contaminated Soils Disposal and Runoff: Contaminated soils from redevelopment sites shall be disposed of properly. Runoff from contaminated soils shall not be discharged from the site. Proper permits shall be obtained for development projects on solid waste landfill sites or redevelopment sites

4.28 Internal Inspections

2. All controls on the site shall be inspected at least once every seven calendar days and within 24 hours after any storm event greater than one-half inch of rain per 24 hour period. The inspection frequency may be reduced to at least once every month if the entire site is temporarily stabilized or runoff is unlikely due to weather conditions (e.g. site is covered with snow, ice or the ground is frozen). A waiver of inspection requirements is available until one month before thawing conditions are expected to result in a discharge if prior written approval has been attained from the City Engineer and all of the following conditions are met:

    f. The project is located in an area where frozen conditions are anticipated to continue for extended periods of time (i.e. more than one month).

g. Land disturbance activities have been suspended and temporary stabilization id achieved.

h. The beginning date and end dates of the waiver period are documented in the SWP3.

3. The contractor/developer shall assign qualified inspection personnel to conduct these inspections to ensure that the control practices are functional and to evaluate whether additional control measures are required. Qualified inspection personnel are individuals with knowledge and experience in the installation and maintenance of sediment and erosion controls.

4. These inspections shall meet the following requirements:

   a. Disturbed areas and areas used for storage of materials that are exposed to precipitation shall be inspected for evidence of or potential for pollutants entering the drainage system.

   b. Erosion and sediment control measures identified in the SWP3 shall be observed to ensure that they are operating correctly. The applicant shall utilize the provided inspection form **Form 7** or an alternate form acceptable to the City Engineer. The inspection form shall include:

      i. The inspection date.

      ii. Names, titles and qualifications of personnel making the inspection.

      iii. Weather information for the period since last inspection, including a best estimate of the beginning of each storm event, duration of each storm event and approximate amount of rainfall for each storm event in inches, and whether any discharges occurred.

      iv. Whether information and a description of any discharge occurring at the time of inspection.

      v. Locations of:

         1. Discharge of sediment or other pollutants from site.

         2. BMPs that need to be maintained.

         3. BMPs that failed to operate as designed or proved inadequate for a particular location.

         4. Where additional BMPs are needed that did not exist at the time of inspection.

vi. Corrective action required including any necessary changes to the SWP3 and implementation dates.

c. Discharge locations shall be inspected to determine whether erosion and sediment control measures are effective in preventing significant impacts to the receiving water resource or wetland.

d. Locations where vehicle enter or exit the site shall be inspected for evidence of off-site vehicle tracking.

e. The contractor/developer shall maintain for three years following stabilization the results of these inspections, the dates of inspections, major observations relating to the implementation of the SWP3, a certification as to whether the facility is in compliance with the SWP3, and information on any incidents of non-compliance determined by these inspections

4.29 Maintenance

1. The SWP3 shall be designated to minimize maintenance requirements. All control practices shall be maintained and repaired as needed to ensure continued performance of their intended function until final stabilization. All sediment control practices must be maintained in a functional condition until all up slope areas they control reach final stabilization. The applicant shall provide a description of maintenance procedures needed to ensure the continued performance of control practices and shall ensure a responsible party and adequate funding to conduct the maintenance, all as determined by the City Engineer.

   When inspections reveal the need for repair, replacement or installation of erosion and sediment control BMPs, the following procedures shall be followed:

   a. When practices require repair or maintenance. If an internal inspection reveals that a control practice is in need of repair or maintenance, with the exception of a sediment-settling pond, it must be repaired or maintained within three (3) days of the inspection. Sediment-settling ponds must be repaired or maintained within ten (10) days of the inspection.

   b. When practices fail to provide their intended function. If an internal inspection reveals that a control practice fails to provide their intended function as detailed in the SWP3 and that another, more appropriate control practice is required the SWP3 must be amended and the new control practice must be installed within ten (10) days of the inspection.

   c. When practices depicted on the SWP3 are not installed. If an internal inspection reveals that a control practice has not implemented in accordance with the schedule, the control practice must be implements within ten (10) days from the date of inspection. If the internal inspection reveals that the planned control practices is not needed, the record must contain a statement of explanation as to why the control practices is not needed.

Section 5 – Stormwater Management

5.1 Key Section Highlights

1. Every subdivision and land development shall be provided with a Stormwater Management System which is adequate to serve the area and meets the requirements of this chapter and other criteria of the City.

2. Developers are required to design improvements such that in a 100 year storm, the rate of stormwater runoff leaving the project area at strategic points is no more after development than if the project area had remained undeveloped. If necessary, detention/retention facilities shall be constructed to assure that this requirement is met.

3. 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.

4. Developers are required to incorporate storm water quality and quantity controls into the site planning and design at the earliest possible stage in the development process.

5. It is not the intent of this chapter to hinder innovative and creative solutions to drainage problems. However, in the interest of expediting the processing of plans and construction, use of standard procedures, forms, nomographs, charts and computer programs is necessary. Deviation from these standards will cause delay in the approval process.

6. Stormwater management systems shall be designed for the ultimate use of the land.

7. 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 a level of quantity and quality controls that will minimize damage to property and degradation of water resources and wetlands, and will promote and maintain the health, safety and welfare of the citizens of the City of Mason. The section includes 1) goals and policies, 2) practice standards, and 3) specifications, and plan submittal information.

2. Areas developed as a part of land development shall provide storm water management and 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 Stormwater 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. The rationale will also describe how the storm water management practices minimize impacts to the physical, chemical, and biological characteristics of on-site and downstream water resources and, if necessary, correct current degradation of water resources that is occurring or take measures to prevent predictable degradation of water resources.

4. 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.

5. 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.

6. 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 Stormwater 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 stormwater 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.

Stormwater Quality Control

1. Direct runoff to a BMP:

The site shall be designed to direct runoff to one or more of the following storm water management practices. These practices are listed in Table 2 of this regulation and shall be designed to meet the following general performance standards:

a. Extended conveyance facilities that slow the rate of storm water runoff; filter and biodegrade pollutants in storm water; promote infiltration and evapotranspiration of storm water; and discharge the controlled runoff to a water resource.

b. Extended detention facilities that detain storm water; settle or filter particulate pollutants; and release the controlled storm water to a water resource.

c. Infiltration facilities that retain storm water; promote settling, filtering, and biodegradation of pollutants; and infiltrate captured storm water into the ground. The City Engineer may require a soil engineering report to be prepared for the site to demonstrate that any proposed infiltration facilities meet these performance standards.

d. For sites less than five (5) acres, but greater than one (1) acre and not part of a common plan of development, where 5 or more acres are disturbed, the City Engineer may approve other BMPs if the applicant demonstrates to the City Engineer's satisfaction that these BMPs meet the objectives of this regulation as stated in the section on Alternative Post-Construction BMPs 5. b.

e. For sites 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, the City Engineer may approve other BMPs if the applicant demonstrates to the City Engineer's satisfaction that these BMPs meet the objectives of this regulation as stated in the section on Alternative Post-Construction BMPs 5. b., and has prior written approval from the Ohio EPA.

f. 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.*

2. SWMP Practices criteria:

Practices chosen must be sized to treat the water quality volume (WQv) and to ensure compliance with Ohio Water Quality Standards (OAC Chapter 3745-1).

a. The WQv shall be equal to the volume of runoff from a 0.75 inch rainfall event and shall be determined according to one of the following methods:

i. Through a site hydrologic study approved by the City Engineer that uses continuous hydrologic simulation; site-specific hydrologic parameters, including impervious area, soil infiltration characteristics, slope, and surface routing characteristics; proposed best management practices controlling the amount and/or timing of runoff from the site; and local long-term hourly records, or

ii. Using the following equation:

$$WQv = C*P*A/12$$

Where terms have the following meanings:

WQv = water quality volume in acre-feet
C = runoff coefficient appropriate for storms less than 1 in.
P = 0.75 inch precipitation depth
A = area draining into the storm water practice, in acres.

Runoff coefficients required by the Ohio Environmental Protection Agency (Ohio EPA) for use in determining the water quality volume can be determined using the list in Table 1 or using the following equation to calculate the runoff coefficient, if the applicant can demonstrate that appropriate controls are in place to limit the proposed impervious area of the development:

$C=0.858i^3 - 0.78i^2 + 0.774i + 0.04$, where:
i = fraction of the drainage area that is impervious

Table 1: Runoff Coefficients Based on the Type of Land Use

Land Use	*Runoff Coefficient*
Industrial & Commercial	0.8
High Density Residential (>8 dwellings/acre)	0.5
Medium Density Residential (4 to 8 dwellings/acre)	0.4
Low Density Residential (<4 dwellings/acre)	0.3
Open Space and Recreational Areas	0.2
Where land use will be mixed, the runoff coefficient should be calculated using a weighted average. For example, if 60% of the contributing drainage area to the storm water treatment structure is Low Density Residential, 30% is High Density Residential, and 10% is Open Space, the runoff coefficient is calculated as follows: (0.6)(0.3)+(0.3)(0.5)+(0.1)(0.2) = (0.35)	

b. An additional volume equal to 20% of the WQv shall be incorporated into the storm water practice for sediment storage. This volume shall be incorporated into the sections of storm water practices where pollutants will accumulate.

c. Storm water quality management practices shall be designed such that the drain time is long enough to provide treatment and protect against downstream bank erosion, but short enough to provide storage available for successive rainfall events as defined in Table 2.

Table 2: Draw Down Times for Storm Water Management Practices

Best Management Practice	*Drain Time of WQv*
Infiltration Facilities*	24 - 48 hours
Extended Conveyance Facilities (Vegetated Swales, Filter Strips)	
• Vegetated Filter Strip with Berm	24 hours
• Enhanced Water Quality Swale	24 hours
• Flow Through Design	**
Extended Detention Facilities	
• Extended Dry Detention Basins***	48 hours
• Wet Detention Basins +	24 hours
• Pocket Wetland^	24 hours
• Constructed Wetlands (above permanent pool)	24 hours
• Bioretention*	40 hours
• Sand and other Media Filtration	40 hours

* The WQv shall completely infiltrate within 48 hours so there is no standing or residual water pool.

** Sized to pass a hydrograph with a volume equal to the WQv, duration of 2 hours, peak rainfall intensity of 1 inch/hour at a depth of no more than 3 inches and have a minimum hydraulic residence time of 5 minutes. The use of this criterion is limited to sites where the total area disturbed is 5 acres or less. Prior approval from the City Engineer is necessary to use this practice. For sites 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 written approval is required from the Ohio EPA.

*** The use of a forebay and micropool is required on all extended dry detention basins. Each is to be sized at a minimum 10% of the WQv.

+Provide both a permanent pool and an extended detention volume above the permanent pool, each sized with at least 0.75*WQv.

^Pocket wetland must have a wet pool equal to the WQv, with 25% of the WQv in a pool and 75% in marshes. The EDV above the permanent pool must be equal to the WQv.

d. Each practice shall be designed to facilitate sediment removal, vegetation management, debris control, and other maintenance activities defined in the Inspection and Maintenance Agreement for the site.

3. Additional criteria applying to infiltration facilities:

   a. Infiltration facilities shall only be allowed if the soils of the facility fall within hydrologic soil groups A or B, if the seasonal high water table is at least three (3) feet below the final grade elevation, and any underlying bedrock is at least six feet below the final grade elevation.

   b. All runoff directed into an infiltration basin must first flow through a pretreatment practice such as a grass channel or filter strip to remove coarse sediments that could cause a loss of infiltration capacity.

   c. During construction, all runoff from disturbed areas of the site shall be diverted away from the proposed infiltration basin site. No construction equipment shall be allowed within the infiltration basin site to avoid soil compaction.

4. Additional criteria applying to extended conveyance facilities:

   a. Facilities shall be lined with fine turf-forming, flood tolerant grasses.

   b. Facilities designed according to the extended conveyance detention design drain time shall:

      i. Not be located in areas where the depth to bedrock and/or seasonal high water table is less than 3 feet below the final grade elevation.

      ii. Only be allowed where the underlying soil consists of hydrologic soil group (HSG) A or B, unless the underlying soil is replaced by at least a 2.5 foot deep layer of soil amendment with a permeability equivalent to a HSG A or B soil and an underdrain system is provided.

   c. Facilities designed according to the flow through design drain time shall:

      i. Only be allowed on sites where:

         1) The total area disturbed is 5 acres or less.

         2) The discharge rate from the BMP will have negligible hydrologic impacts to received waters as described in the section on Alternative Post-Construction BMPs 5. b. below.

         3) Prior written approval is given by the City Engineer; and

         4) For sites 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 written approval has been.

ii. Be designed to slow and filter runoff flowing through the turf grasses with a maximum depth of flow no greater than 3 inches.

iii. Be designed to have a minimum hydraulic residence time of 5 minutes.

d. Concentrated runoff shall be converted to sheet flow, or a diffuse flow using a plunge pool, flow diffuser or level spreader, before entering an extended conveyance facility designed according to the flow through drain time.

5. 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 Table 2. 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. To demonstrate the equivalency, the applicant must show:

a. The alternative BMP has a minimum total suspended solid (TSS) removal efficiency of 80 percent, using the Level II Technology Acceptance Reciprocity Partnership (TARP) testing protocol.

b. The water quality volume discharge rate from the selected BMP is reduced to prevent streambed erosion, unless there will be negligible hydrologic impact to the receiving surface water of the State. The discharge rate from the BMP will have negligible impacts if the applicant can demonstrate one of the following conditions:

i. The entire water quality volume is recharged to groundwater.

ii. The development will create less than one acre of impervious surface.

iii. The development project is a redevelopment project with an ultra-urban setting, such as a downtown area, or on a site where 100 percent of the project area is already impervious surface and the storm water discharge is directed into an existing storm sewer system.

iv. The storm water drainage system of the development discharges directly into a large river of fourth order or greater or to a lake, and where the development area is less than 5 percent of the water area upstream of the development site, unless a Total

Maximum Daily Load (TMDL) has identified water quality problems in the receiving surface water of the State.

5.5 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 Stormwater 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. 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 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; and

8. 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 Stormwater 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 stormwater 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. Inlet capacity computations; and
8. 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 Materials and Methods

Every subdivision and land development area shall be designed with a Stormwater Management System that is adequate to serve the area and meet the requirements described herein as well as additional City rules, ordinances, and regulations. This chapter is intended to establish minimum standards for the materials used for stormwater construction. The section includes material standards and specifications as well as construction methods. Other State and local construction standards may apply; in the case that multiple standards apply, the more conservative and stringent standard shall prevail.

6.1 Storm Sewer Pipe.

1. Slope and Pipe Size: The minimum storm sewer size shall be 12-inch diameter. The minimum and maximum storm sewer slopes shall conform to the following table:

Table 6.1: Storm Sewer Slopes and Velocities

Diameter (in.)	*n*	*Min. Slope*	*Min.V (ft/s)*	*Max. Slope*	*Max V (ft/s)*
12	0.015	0.40%	2.5	9.31%	12.0
15	0.015	0.30%	2.5	6.91%	12.0
18	0.015	0.24%	2.5	5.42%	12.0
21	0.015	0.19%	2.5	4.41%	12.0
24	0.015	0.16%	2.5	3.69%	12.0
27	0.015	0.14%	2.5	3.16%	12.0
30	0.015	0.12%	2.5	2.74%	12.0
33	0.015	0.10%	2.5	2.42%	12.0
36	0.015	0.09%	2.5	2.15%	12.0
42	0.015	0.08%	2.5	1.75%	12.0
48	0.015	0.06%	2.5	1.47%	12.0
54	0.015	0.05%	2.5	1.25%	12.0
60	0.015	0.05%	2.5	1.09%	12.0

2. Storm Sewer Pipe Materials. Storm sewers shall conform to ODOT and be fabricated from the following materials:

   a) Reinforced Concrete Circular Pipe – Pipe shall conform to ODOT Item 706, Class IV with rubber gaskets.

   b) Polyvinyl Chloride and HDPE Smooth Interior Pipe – Pipe shall conform to ODOT Item 707 and shall also comply with ASTM F 949 or AASHTO M 304. Pipe material may be used only in areas not under pavement and with the City Engineer's approval.

3. Pipe Cover. Minimum pipe cover shall be 12-inch overtop of the pipe to the sub grade for concrete pipe and 24-inch over top of pipe for polyvinyl chloride and HDPE pipe.

4. Pipe Bedding and Backfill. Pipe bedding material shall conform to ODOT 603, Class B bedding for concrete pipe, or as directed by the City Engineer. ODOT 603 applies to all storm sewers, except concrete box sections as noted in the specification. For all other piping materials, provide ODOT 603 Class B bedding at least 6 inches under the bottom of the pipe and 12 inches over the crown of the pipe. All bedding materials shall be ODOT 703 #9 course aggregate. All backfill material shall be densely compacted in accordance with ODOT 603, or as directed by the City Engineer.

5. Excavation, Laying, and Joining. Trench excavation for the purpose of installing storm sewer pipe, bedding, and backfill shall be performed in accordance with ODOT 603. Where required, furnish, install, and maintain sheeting and bracing required by Federal, State, and local safety requirements to support the sides of the excavation and prevent loss of ground which could endanger personnel, damage or delay the work, or endanger adjacent structures. If the City Engineer is of the opinion that at any point sufficient or proper supports have not been provided, the City may order additional supports placed at the expense of the developer. Compliance with such order shall not relieve the developer from their responsibility for the sufficiency of such supports.

   Storm sewer laying and joining shall be performed in compliance with ODOT Specification section 603. Storm sewer piping shall be inspected by the City before any backfill is placed. Any pipe found to be out of alignment, unduly settled, damaged, or improperly laid or joined in accordance with the ODOT requirements shall be taken up and re-laid or replaced.

6.2 Catch Basins and Manholes

Catch basins and manholes shall be constructed as shown in the City of Mason Construction Standard Drawings and shall conform to the following requirements:

1. The maximum allowable distance between manholes or catch basins is three hundred feet (300’). Alignment of storm sewers shall be as straight as possible to maintain good hydraulics. A manhole or catch basin shall be installed at all angle points and every change in pipe size or slope. Cast iron frame shall be Neenah R-1664, or approved equal, with “Storm” in large letters on the lid and shall be set on the cone with asphalt mastic.

2. The construction, reconstruction, or adjustment of new and existing manholes and catch basins shall be performed in accordance with ODOT specification item 604.

3. Precast reinforced concrete materials used in manholes and catch basins shall comply with the requirements of ODOT specification item 706.13.

4. Cast-in-place walls shall have a nominal thickness of 8-inches. Precast walls shall have a minimum thickness of 6-inches and be reinforced sufficiently to permit shipping and handling without damage.

5. Plastic steps shall be provided where the depth exceeds 48-inches.

6.3 Concrete Channels

Concrete channels shall be used in all detention basins and in all open ditch areas where there is a potential erosion problem, as directed by the City Engineer.

6.4 Curb & Gutter

Construction of new curb and gutter shall be performed in accordance with ODOT specification section 609 and the City's standard construction details and shall meet the following requirements:

1. Placement of curbs and/or combined curb and gutter may be either by the formed method or by curb machine. Precast concrete curb shall not be allowed unless approved by the City Engineer.

2. Expansion joints shall be constructed at right angles to the curb line at immovable structures and at point of curvature for short radius curves. In straight runs, expansion joints shall be placed not to exceed 100-feet spacing. Preformed expansion joint filler at 1-inch thick shall be constructed in such a manner that it will extend from the bottom to the top and for the full width of the curb and/or combined curb and gutter section. Dowel bars shall be used at all expansion joints.

3. Construction joints shall be constructed at right angles to the curb line at intervals not to exceed 10-feet. Contraction joints may be sawed, hand-formed, or made by ¼-inch thick division plated in the formwork. Depth of joint shall be minimum of 2-inch for combined curb and gutter, and a minimum of 1/3 the depth for other curbs.

4. Concrete shall be ODOT Class C with a compressive strength of 4,000 psi at 28 days.

5. Machine formed curb and/or curb and gutter shall be placed in accordance with ODOT specification 609.04 (c).

6. All curb areas must be proof rolled and inspected before curbs are laid. Curbs shall not be placed on frozen ground.

6.5 Headwalls

Headwalls shall be constructed as shown in the City of Mason Construction Standard Drawings and shall conform to the following requirements:

1. All headwall structures shall be constructed of cast-in-place concrete. Headwall structures shall be of the materials and constructed by the methods as described under ODOT specification 499 and 511. Reinforcing steel shall be constructed of the materials and placed/installed as specified under ODOT specification section 509.

2. Precast, masonry block, and brick headwalls shall not be allowed unless approved by the City Engineer.

6.6 Storm Culverts

Culverts greater than 36-inch in diameter shall be constructed of concrete and shall conform to the following requirements:

1. Reinforced concrete elliptical culverts shall conform to the ODOT specification 706.04.

2. Precast reinforced concrete box culverts shall conform to ODOT specification 706.05.

3. Precast reinforced concrete three-sided flat topped culverts shall conform to ODOT specification 706.051.

4. Precast reinforced concrete arch culverts shall conform to ODOT specification 706.052.