Mahoning County Drainage Criteria and Storm Water Manual

Revised 2016

EXECUTIVE SUMMARY

Due to Ohio Environmental Protection Agency Stormwater regulatory requirements (Municipal Separate Strom Sewer System (MS4) - Phase II) and recurring significant flooding events within Mahoning County, the County Engineer's office is developing this manual as a tool to guide drainage designs, erosion/sedimentation control, post-construction runoff controls and Stormwater management for development and construction within Mahoning County.

The objectives of this manual are to provide engineering guidance to:

- Local communities and personnel responsible for implementing Stormwater management practices, programs, policies and operation/maintenance activities within Mahoning County.
- Engineers responsible for design of Stormwater conveyance structures, Stormwater management plans, drainage systems, and infrastructure in support of development.
- Individuals associated with Stormwater management at varying levels that may find the manual useful as a technical reference to illustrate Stormwater engineering design principals and techniques.

The intent of this drainage manual is to minimize impacts to:

- Human health and public safety
- Existing drainage infrastructure
- Flooding events and property damage
- Stream channel degradation

The County Engineer will provide updates and revisions to this manual periodically based on reviews of actual manual concepts implemented in the field and manual user suggestions and feedback on improving manual content and applicability. The County Engineer reserves the right to review drainage designs and construction plans submitted as a result of using this guidance manual. The County Engineer shall not be held liable as a result of information presented in this guidance manual. The manual has been developed primarily as a "tool" to guide developers, engineers, builders and contractors through the county's drainage design process and procedures. The County Engineer does not consider this as an all inclusive comprehensive design document or manual.

This manual has been prepared in cooperation with:

URS Corporation
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Suite 600
Cleveland, Ohio 44115

URS

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REFERENCES

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SECTION 1 INTRODUCTION

1.0 INTRODUCTION

1.1Purpose and Manual Organization

The primary purpose of this manual is to provide detailed and supporting information with examples which will allow developers, designers, contractors, builders and planners the tools necessary to address the subdivision regulations and OEPA permit requirements for both construction site runoff (erosion and sediment control) and post-construction Stormwater management within Mahoning County. The manual has been divided into the following technical sections:

- Introduction **(Section 1)**
- Drainage Design and Engineering **(Section 2)**
- Storm Drainage Systems **(Section 3)**
- Post-Construction Stormwater Management Requirements **(Section 4)**
- Stormwater Pollution Prevention Plans and Erosion/Sedimentation Control Requirements **(Section 5)**
- Floodplain Regulations **(Section 6)**
- Enforcement **(Section 7)**
- Appendices

Each section is subdivided to provide supporting details and example calculations to present a step by step process for implementing the drainage criteria in this manual. Application of concepts, methods, and engineering practices addressed in this manual should contribute toward effective and economic solutions for:

- Stormwater management
- Sound planning, engineering and design of drainage and Stormwater infrastructure systems
- Permit and promote development while decreasing downstream flooding
- Urban erosion/sedimentation control
- Reducing negative impacts to receiving watercourses
- Local drainage and flooding issues

Alternate engineering design methods, other than those identified in this manual, may be used with approval of the County Engineer. Complete supporting documentation, including calculations, shall be required at the request of the County Engineer for approval of these alternative methods.

1.2Using the Manual

The Manual has been developed with the ability to distribute sections independently or as a complete document. The primary objective of the manual is to provide a consistent approach to drainage design and Stormwater management within unincorporated Mahoning County. The following provides recommendations on the use of this manual for drainage design, construction projects, Stormwater management and compliance within Mahoning County.

- Review current pre-developed site conditions

- Consider incorporation of natural site conditions, contouring and set backs which are practical.
- Review and select appropriate drainage methodology presented in manual. Refer to examples provided in manual as guidance during design.
- Drainage methodology selected shall include review and incorporation of both quantity and quality runoff controls, temporary erosion and sediment controls and post-construction control best management practices.
- Completed subdivision and construction plans (Drainage designs with supporting calculations as requested, erosion and sedimentation control drawings along with Stormwater pollution prevention control plans) shall be submitted to the County Engineer for review.
- Obtain necessary project permits, pay associated fees and provide copies of approved permits to County Engineer.
- Complete Notice of Intent and submit to OEPA.
- Provide County Engineer with approved copy of NOI.
- Determine requirements to complete a Stormwater pollution prevention plan.

Project planners, developers and engineers should address both on-site, off-site runoff and downstream potential impact issues, local requirements and known flooding areas when developing project site plans for addressing project drainage and runoff.

1.3Drainage Policy

The Mahoning County Engineer shall ensure that sound engineering practices, concepts, and methods are incorporated into planning and design of drainage infrastructure and conveyance systems within Mahoning County. Emphasis shall be placed on protecting and managing the following:

- Public safety
- Historic flooding areas
- Protecting stream channels and property
- Current drainage infrastructure

The following elements, as defined by the Mahoning County's Subdivision regulations, are the basis for Mahoning County's drainage criteria.

Minor Drainage Systems - Collects and conveys Stormwater runoff from all storms up to and including the ten year storm. The runoff resulting from a ten year storm becomes the basis for system designs and runoff controls. Minor drainage systems consist of, but are not limited to storm sewer systems- curb inlets, catch basins, manholes, curb and gutter systems, ditches, yard drains, open channels and other surface conveyance systems.

Major Drainage Systems - Collects and conveys Stormwater run-off from less frequently recurring storms. The purpose is to manage Stormwater run-off which exceeds capacity of the minor drainage systems in a manner that eliminates or minimizes risk to health and human safety. For the purposes of this manual, the 100 year storm event will serve as the design storm of record for the major drainage systems.

Stormwater Storage Facilities - Intent is to ensure Stormwater run-off is properly conveyed, detained, or managed as the run-off moves through public or privately managed systems. Elements include, but are not limited to: detention/retention, outlet controls, quantity volume controls, simultaneous peak release rates, and minimization of downstream quantity and erosive impacts.

The three elements are explained in detail with supporting example calculations in *Section 2.0 Drainage Design and Engineering* of this manual. Criteria and requirements set forth in this manual are intended to be used as tools in combination with sound hydraulic/hydrologic engineering practices for both public and private projects. The County Engineer requires that all designs, permits, supporting drawings, state and local Stormwater runoff requirements be reviewed and stamped by a professional engineer registered in the State of Ohio.

1.4Planning

Locating permanent post-construction runoff controls and associated level of maintenance practices with regards to these controls are examples to be considered during initial project planning. The Mahoning County Engineer recommends that at a minimum, the following shall be considered and incorporated prior to submitting project construction plans:

- Has the project design incorporated naturally occurring site features such as stream buffers, natural site contours, green space where applicable, set backs, natural drainage features, etc.?
- Has the project design accounted for both off-site runoff and protection of streams and adjacent properties?
- Will the project drainage design minimize operation and maintenance activities from coming into contact with site Stormwater runoff?
- Has the project incorporated local Stormwater Best Management Practices (BMP's)?

1.5Limitations

The manual establishes uniform design criteria for Stormwater design and management practices within Mahoning County. The manual does not replace the need for sound engineering judgment nor does it preclude the use of information that may subsequently become available. The manual, as mentioned in Section 1.1 is not intended to be a comprehensive document. The objective is to provide a guidance manual which establishes uniform criteria for consistency in design of drainage and Stormwater runoff controls.

The Mahoning County Engineer, in its review of submitted project plans, reserves the right to return and/or request additional supporting documentation as necessary to assure the above project elements have been addressed to the maximum extent practicable. The Mahoning County Engineer recognizes that this manual is not all inclusive or comprehensive and will require updates periodically.

Anything not composed entirely of Stormwater is considered an illicit discharge. The Mahoning County Engineer shall prohibit all non-Stormwater discharges except those shown in Table 1.1:

TABLE 1-1: Allowable County, Non-Stormwater Discharges

Allowed Non-Stormwater Discharges			
Water line flushing	Uncontaminated pumped groundwater	Natural Springs	Flows from **riparian** habitats and **wetlands**
Landscape Irrigation	Discharges from portable water sources	Water from crawl space pumps	Dechlorinated swimming pool discharges
Diverted stream flows	Foundation drains	Footing drains	Street wash water
Rising groundwater	Air conditioning condensate	Lawn Watering	Discharges from flows from fire fighting activities
Uncontaminated ground water infiltration	Irrigation water	Individual residential car washing	

*Source: OEPA General **Stormwater** Permit- March 2003*

By completing and submitting construction plans and Notice of Intent (NOI), you agree to comply with the requirements of the Construction General Permit (CGP) and Mahoning County's drainage manual regulations and to limit the discharge of Stormwater runoff from the project site to the Maximum Extent Practicable.

1.6Manual Updating

The County Engineer will review regulatory requirements, best management practices, design criteria, and other supporting materials to provide necessary updates to the manual as required or necessary. The County Engineer will take under advisement, any design requirement suggestions or other manual revisions which will not be in conflict with the intent and purpose of this manual. Suggestions may be submitted at any time. Incorporation of submitted suggestions will be at the discretion of the County Engineer. Revisions to this manual will be made by addenda. All proposed revisions will undergo a public comment period prior to being added to this manual.

1.7Contact Information

Submit **all** manual suggestions and comments to:

Mahoning County Engineers Office
c/o Mr. Tim Burkert, P.E. Phone: (330) 799-1581
Design & Construction Engineer Fax: (330) 799-4600
940 Bears Den Road
Youngstown, Ohio 44511-1299
E-Mail – **tburkert@mahoningcountyoh.gov**

1.8Design and Construction Criteria

The following criteria will be used for the design and construction of all Stormwater conveyance, drainage and storage facilities:

- Design and installation of all Stormwater conveyance systems, storm sewers, Stormwater post-construction controls and detention/retention (Public and Private) shall comply with all applicable federal, state and local laws. Special attention shall be given to Mahoning County Erosion and Sedimentation control requirements addressed in Section 4 of this manual.
- In no case shall a structure be located within the impoundment area of any Stormwater (retention) storage facility or over any Stormwater drainage or sewer line.
- Roadway "Sags" and parking areas which also serve as temporary impoundments of runoff shall not exceed an impounded depth of 10 inches.
- Maintenance of all detention/retention facilities will be the responsibility of the property owner(s).
- Project downstream impacts shall not be allowed. Project Stormwater runoff shall be managed and maintained on site.

1.9Compliance with State and Federal Regulations

Addressing only the requirements associated with the Construction General Permit does not relieve the applicant of responsibility for obtaining all subsequent permits and/or approvals from the Ohio Environmental Protection Agency (OEPA), the United States Army Corp of Engineers (USACE) or any other federal, state and/or county agencies. Should the requirements vary, the more restrictive requirements will govern. Additional permits may include, but are not limited to those listed below. The Mahoning County Engineer shall require proof of compliance with these state and federal regulations be submitted with the project construction plan packet *(Packet for the purposes of this manual means- Site drainage plan sheets, Stormwater pollution prevention plans and erosion/sedimentation control plans)* prior to plan approval.

1. OEPA - <u>Authorization of Stormwater Discharges Associated with Construction Activity</u> - Proof of compliance will consist of an OEPA approved Notice of Intent (NOI) including NPDES project permit number.
2. OEPA - <u>Municipal Separate Storm Sewer System</u> - Phase II permit - Mahoning County's Stormwater Management Plan
3. All proposed development sites must be checked for the existence of wetlands by a qualified professional. If no wetlands are on the site, a letter from the qualified professional stating so shall be included with the submittal of the project construction plan packet. If wetlands are found to be on the site one or all of the following may be required based on the determined extent of the impact:

    a. <u>Jurisdictional Determination</u> - Proof of compliance shall be a copy of the Jurisdictional Determination from the USACE, confirming the findings of a qualified professionals survey and report.
    b. <u>Section 404 of Clean Water Act</u> - Proof of compliance shall be a copy of the USACE Individual Permit Application. Should an individual permit be required, public notification and meetings will be held. Should an

individual permit not be required, proof of compliance shall be a copy of the USACE Nationwide Permit including a site plan indicating proposed fill areas in proximity to waters of the U.S.

4. Should a Section 404 Permit or Jurisdictional Determination not be necessary, the site owner shall submit a letter certifying that a qualified professional has surveyed the site and no waters of the United States were identified.

5. OEPA-Isolated Wetland Permit - Proof of compliance will consist of a copy of the OEPA's Isolated Permit Application, public notice or project approval or a letter from the site owner certifying that a qualified professional has surveyed the site and no waters of the state were identified.

6. Section 401 of Clean Water Act - Proof of compliance will consist of a copy of the OEPA's Water Quality Certification Application, public notice, project approval or a letter from the site owner certifying that a qualified professional has surveyed the site and no waters of the United States were identified.

7. Ohio Dam Safety Law - Proof of compliance will consist of a copy of the ODNR's - Division of Water permit application or a copy of the project approval letter for ODNR.

8. Federal Emergency Management Agency (FEMA) - Proof of compliance will consist of a copy of the project site showing all 100 year flood elevation limits. Should the project have been granted a waiver, copies of the approved Letter of Map Revision (LOMR) shall be submitted.

9. Notice of Intent (NOI)/ Notice of Termination (NOT) - Copies of the approved NOI shall accompany the construction plans. NOT's shall be applied for in a timely manner and a copy forwarded to the Mahoning County Engineer's office as documentation of project close out.

The permitting process may require extensive coordination, including project start time receipt of permit approval, construction sequencing and seasonal limitations. The Mahoning County Engineer recommends attention be given to "up-front" planning and consideration of alternatives before moving forward with potential time consuming permitting procedures and project design. The Mahoning County Engineer acknowledges that there will be times when multiple permits will be required, necessary and unavoidable. The following table is a summary of current permits being used on projects within Mahoning County:

The table is intended to be a summary of permits, submittals and project related issues:

TABLE 1-2: Permit Summary Table

Submittal Type	Requirement Drivers	Agency	Comments
Site **Drainage** Plan	Mahoning County Project Requirement	Mahoning County Engineers Office	Required as part of project package
Project **Erosion** and **Sedimentation** Control Plan	Mahoning County Erosion and Sediment Control Rules Construction General Permit- Land disturbance of 1 **acre** or greater E/S plan required.	Mahoning SWCD Ohio Environmental Protection Agency (OEPA)- Surface Water Division	Mahoning County Engineers Office requires that the **Erosion /Sedimentation** plan be submitted in conjunction w/ the **SWP3** plan.
Stormwater Pollution Prevention Plan (**SWP3**) + Post-Construction **Best Management Practices** • **BMP** Maintenance Plan. • **Notice of Intent** (**NOI**) • **Notice of Termination** (**NOT**)	Large Construction Projects- 5 **acres** or greater. Small Construction Projects- 1 to 5 **Acres**.	Mahoning County Engineers Office Mahoning SWCD Ohio Environmental Protection Agency (OEPA)- Surface Water Division	Mahoning County Engineers Office requires that the **SWP3** plan be submitted in conjunction w/ the E/S plan.
401/404 Nationwide General Permit: • 401-Water Quality Certification. • 404 – Nationwide General Permit Note: Associated with activities in and around waters of US.	Maintenance Activity- 200 feet maximum. Bank **Stabilization** – 500 feet maximum. **Drainage Ditch** Reshaping- 500 feet maximum (Waters of US). **Stormwater Management** Facilities- 300 feet maximum streambed loss due to discharge (**Intermittent streams** only, not allowed for **perennial streams**). Include maintenance plan	U.S Army Corp. of Engineers (USACE) Ohio Environmental Protection Agency-Division of Surface Water	USACE- 45 Day permit turn around period upon receipt of complete permit package. 30 days to review and provide notification of missing submittal components (Pre-Construction Notification (PCN)). Mahoning County **Engineer**- Recommends that these types of activities/permits be minimized and alternatives considered prior to implementing this process.
Floodplain Activities: • Letter of Map Revision-(LOMR) • Conditional Letter of Map Revision – (CLOMR) • Mahoning County Flooding regulations	Associated with structures within Floodplain/floodway. Requirement condition is no back water effect and no more than 1-foot of rise of water final surface elevation	Mahoning County Planning Commission Federal Emergency Management Agency (FEMA), USACE	FEMA- 45 Day permit application review period upon receipt of required information. Mahoning County **Engineer**- Recommends that any activities associated with structures within floodplain of floodway be minimized or implemented should no other alternatives be practical.

1.10Definitions and Acronyms

For the purpose of these regulations certain rules or word usage apply to the text as follows:

A) Words used in the present tense include the future tense, and the singular includes the plural, unless the context clearly indicates the contrary.

B) The term "shall" is always mandatory and not discretionary; the word "may" is permissive. The term "should" is permissive, but indicates strong suggestion.

C) The word or term not interpreted or defined by this Section shall be construed according to the rules of grammar and common usage so as to give these regulations their most reasonable application.

MANUAL DEFINITIONS:

ACRE: A measurement of area equaling 43,560 square feet.

BEST MANAGEMENT PRACTICES (**BMP's**): Structural or nonstructural facilities or activities that control soil erosion and/or Stormwater runoff at a development site. This includes treatment requirements, operating and maintenance procedures, and other practices to control site runoff, leaks, or waste disposal.

CHANNEL: A natural bed that conveys water; a ditch excavated for the flow of water.

CHANNEL PROTECTION AND WATER QUALITY VOLUME ($CPWQ_V$): Volume of Stormwater runoff that must be captured and treated before discharge from the developed site after construction is complete. $CPWQ_V$ is based on the expected runoff generated by the mean storm precipitation volume from post-construction site conditions at which rapidly diminishing returns in the number of runoff events captured begins to occur.

CRITICAL STORM: That storm which is calculated using the post-construction percentage increase in volume of runoff from a proposed development. The critical storm is used to calculate the maximum allowable Stormwater discharge rate from a developed site.

DETENTION STRUCTURE: A permanent Stormwater management facility for the temporary storage of runoff, and is designed so as not to create a permanent pool of water.

DEVELOPMENT AREA: A lot or contiguous lots owned by one person or persons, or operated as one development unit, and used or being developed for commercial, industrial, residential, institutional, or other non-farm construction or alternative that changes runoff characteristics, upon which soil-disturbing activities occur.

DEVELOPMENT DRAINAGE AREA: A combination of each hydraulically unique drainage areas with individual outlet points on the development area.

DISTURBED AREA: An area of land subject to erosion due to the removal of vegetative cover and/or soil disturbing activities

DITCH: An open channel, either dug or natural, for the purpose of drainage or irrigation with intermittent flow.

DRAINAGE: The removal of excess surface water or groundwater from land by surface or subsurface drains.

DRAINAGE IMPROVEMENT: As defined in Ohio Revised Code (ORC). 6131.01 (C), and/or conservation works of improvement, ORC. 1511 and 1515.

DUMPING: Grading, pushing, piling, throwing, unloading, or placing

ENGINEER: A Professional Engineer registered in the State of Ohio.

EROSION: The process by which the land surface is worn away by the action of wind, water, ice, gravity, or any combination of those forces.

EROSION AND SEDIMENT CONTROL: The control of soil material, both mineral and organic, to minimize the removal of soil material from the land surface and to prevent its transport out of a disturbed area by means of wind, water, ice, gravity, or any combination of those forces.

FINAL STABILIZATION: All soil disturbing activities at the site have been completed and a uniform perennial vegetative cover with a density of at least 80% cover for the area has been established or equivalent stabilization measures, such as the use of mulches, geotextiles, have been employed.

GRASSED WATERWAY: A broad or shallow natural watercourse or constructed channel, covered with erosion-resistant grasses or similar vegetative cover, used to convey surface water.

HYDRIC SOILS: Soils that are saturated, flooded, or ponded for a long enough time period during the growing season that anaerobic conditions develop in the upper part of the soil. Soils that are considered “wetland” soils.

HYDROGRAPH:Time distribution of runoff from a watershed.

HYDROPHYTIC VEGETATION: Plants that are found in wetland areas. These plants have been classified by their frequency of occurrence in wetlands.

IMPERVIOUS: Not allowing infiltration which means any paved, hardened or structural surface regardless of its composition including (but not limited to) buildings, roads, driveways, parking lots, loading/unloading spaces, decks, patios, and swimming pools.

INTERMITENT STREAM: Stream which conveys flow periodically throughout the year. No permanent or consistent flow of water.

LANDSCAPE ARCHITECT: A Professional Landscape Architect registered in the State of Ohio.

LARGER COMMON PLAN OF DEVELOPMENT: A contiguous area where multiple separate and distinct construction activities may be taking place at different times on different schedules under one plan.

LOT: A tract of land occupied or intended to be occupied by a use, building, or group of buildings and their accessory uses and buildings as a unit, together with such open spaces and driveways as are provided and required. A lot may contain more than one contiguous lot.

MAXIMUM EXTENT PRACTICABLE: The level of pollutant reduction that site owners of small municipal separate storm sewer systems regulated under 50 C.F.R. Parts 9, 122, 123, and 124, referred to as NPDES Stormwater Phase II, must meet.

MULTI-FAMILY DEVELOPMENT: Apartments, condominiums, townhouses, duplexes, or other similar buildings housing more than one family.

NPDES: National Pollutant Discharge Elimination System. A regulatory program in the Federal Clean Water Act that prohibits the discharge of pollutants into surface water of the United States without a permit.

Notice of Intent (**NOI**): Notice of Intent obtained from the Ohio EPA under the NPDES Phase 2 Program.

Notice of Termination (**NOT**): Notice of Termination obtained from the Ohio EPA under NPDES Phase 2 Program.

OHIO EPA: Ohio Environmental Protection Agency.

ODNR-**DSWC**: Ohio Department of Natural Resources, Division of Soil and Water Conservation.

PERENNIAL STREAM:A stream that maintains water in its channel throughout the year.

PERSON: Any individual, corporation, firm, trust, commission, board, public or private partnership, joint venture, agency, unincorporated association, municipal corporation, county or state agency, the federal government, other legal entity, or an agent of combination thereof.

PHASING: Clearing/grubbing/excavating a parcel of land in distinct sections, with the stabilization of each section occurring before clearing the next.

RAINWATER AND LAND DEVELOPMENT MANUAL: Ohio's standards for Stormwater management, land development, and urban watercourse protection. The most current edition of these standards shall be used with this regulation.

RETENTION STRUCTURE: A permanent Stormwater management facility that provides for the storage of runoff by means of a permanent pool of water.

RIPARIAN: Contiguous tract of land in contact with a stream and within the same watershed as the stream.

RUNOFF: The portion of rainfall, melted snow, or irrigation water that flows across the ground surface and is eventually returned to water resources, watercourses, or wetlands.

SEDIMENT: Soils or other surface materials that are or have been transported or deposited by the action of wind, water, ice, gravity, or any combination of those forces, as a product of erosion.

SEDIMENTATION: The deposition of settling of sediment.

SEDIMENT BASIN: A barrier or other suitable retention structure built across an area of water flow to intercept runoff and allow transported sediment to settle and be retained, prior to discharge into water of the State.

SEDIMENT POLLUTION: Degradation of waters of the state by sediment as a result of failure to apply management or conservation practices to abate wind or water soil erosion, specifically in conjunction with soil-disturbing activities on land used or being developed for commercial, institutional, industrial, residential, or other non-farm purposes.

SETBACK: A designated transition area around water resources or wetlands that is left in a natural, usually vegetated, state to protect the water resources or wetlands from runoff pollution. Construction activities in this area are restricted or prohibited as required in this regulation.

SOIL AND WATER CONSERVATION DISTRICT: An entity organized under Chapter 1515 of the Ohio Revised Code; referring either to the Soil and Water Conservation District, Board, or its designated employee(s), hereinafter referred to as the Mahoning SWCD.

SOIL DISTURBING ACTIVITY: Clearing, grubbing, grading, excavating, filling, or other alteration of the earth's surface where natural or human made ground cover is destroyed and which may result in, or contribute to erosion and sediment pollution. This may also include construction of non-farm buildings, structures, utilities, roadways, parking areas, and septic systems that will involve soil disturbance or altering of the existing ground cover.

STABILIZATION: The use of Best Management Practices, such as seeding and mulching, that reduce or prevent soil erosion by water, wind, ice, gravity, or a combination of those forces.

STORM FREQUENCY: The average period of time within which a storm of a given duration and intensity can be expected to be equaled or exceeded.

STORMWATER: Stormwater runoff, snowmelt, surface runoff, and drainage

STORMWATER MANAGEMENT: Runoff water safely conveyed or temporarily stored and released at an allowable rate to minimize erosion and flooding.

SUBSOIL: That portion of the soil below the topsoil or plow layer, typically beginning 6-12" below the surface, but can also extend to 48" or deeper in the case of prime farmland soils, down to bedrock parent material.

SWP3: Stormwater Pollution Prevention Plan as defined and required by the Ohio EPA

TEMPORARY SOIL STABILIZATION: Establishment of temporary vegetation, mulching, geotextiles, sod, preservation of existing vegetation and other techniques capable of quickly establishing cover over disturbed areas to provide erosion control between construction operations.

TOPSOIL: The upper layer of soil that is usually darker in color and richer in organic matter and nutrients than the subsoil.

USDA-NRCS: United States Department of Agriculture, Natural Resources Conservation Service.

WATERCOURSE: A definite channel with defined bed and banks within which concentrated water flows, either continuously or intermittently, (e.g., brooks, **channels**, creeks, rivers, or streams.

WATER RESOURCE: Any public or private body of water including lakes and ponds, as well as streams, gullies, ditches, swales, or ravines that have banks, a defined bed, and a definite direction of course, either continuously or intermittently flowing.

WATERSHED: The total drainage area contributing runoff to a single point.

WETLAND: Those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support and contain a predominance of hydric soils, and that under normal circumstances do support a prevalence of hydrophytic vegetation typically adapted for life in saturated soil conditions, including swamps, marshes, bogs, and similar areas (40 CFR 232, as amended).

SECTION 2 DRAINAGE DESIGN AND ENGINEERING

2.0 DRAINAGE DESIGN AND ENGINEERING

2.1Hydrologic Design Policies

A design storm is the defined precipitation pattern used in hydraulic system design. The design storm is not an actual storm of record. Rather, it is a fabricated storm compiled from average characteristics of previous storm events and therefore is used to predict future storm events.

There are various hydrologic techniques to estimate the design storm. These include, but are not limited to, the Rational Method, the S.C.S. Graphical Peak Discharge Method, and the S.C.S. Unit Hydrograph Method. Each of these methods has limitations and their results vary from peak discharge only to hydrograph generation.

The following sections describe in detail the methodology and resources to calculate the design storm for the desired application:

2.2Rational Method

The rational method is a formula for estimation of peak flow rates for small, **drainage** areas. Its formula is a ratio between **runoff** and rainfall rates. *It shall be used primarily when designing the storm system (minor) in urban or rural areas.* It shall not be used for the overland system (major) when the drainage area is greater than 20 **acres**.

Rational Formula:

$Q = CIA$

Where: Q = rate of runoff (cfs)
C = runoff coefficient
I = rainfall intensity (in/hr)
A = drainage area (acres)

- The **runoff** coefficient, C, is a dimensionless decimal value that estimates the percentage of rainfall that becomes runoff. It incorporates most of the hydrological abstractions, soil types, antecedent conditions, etc. Values of typical C coefficients are listed in Table 2-1.

  Where small **watersheds** have various land use or ground covers, a Weighted "C" value shall be used. The following example illustrates how a Weighted "C" value is calculated:

Example

Area	Land Use	"C"	"CA"
5	Roof	0.95	4.75
15	Lawn	0.35	5.25
20	Summation		10.0

Weighted "C" (Cw) = CA/Area = 10/20 = 0.50

- The rational method assumes that the rainfall intensity, I, is uniform over the entire watershed during the entire storm duration. The maximum runoff rate occurs when the rainfall lasts as long, or longer, than the time of concentration.

- The time of concentration, Tc, is the time required for the runoff from the most remote part of the watershed to reach the point under design. The Tc for small watersheds (overland travel distance is less than 1,000 feet) can be determined using Figure 2-1. Once the Tc is calculated, the rainfall intensity can determined using Table 2-2.

Note: Peak runoff rates as determined using the rational method cannot be added together to determine a resultant peak discharge rate from two or more separate watersheds. These are not cumulative runoff values.

TABLE 2-1: Runoff Coefficients

Recommended Runoff Coefficients

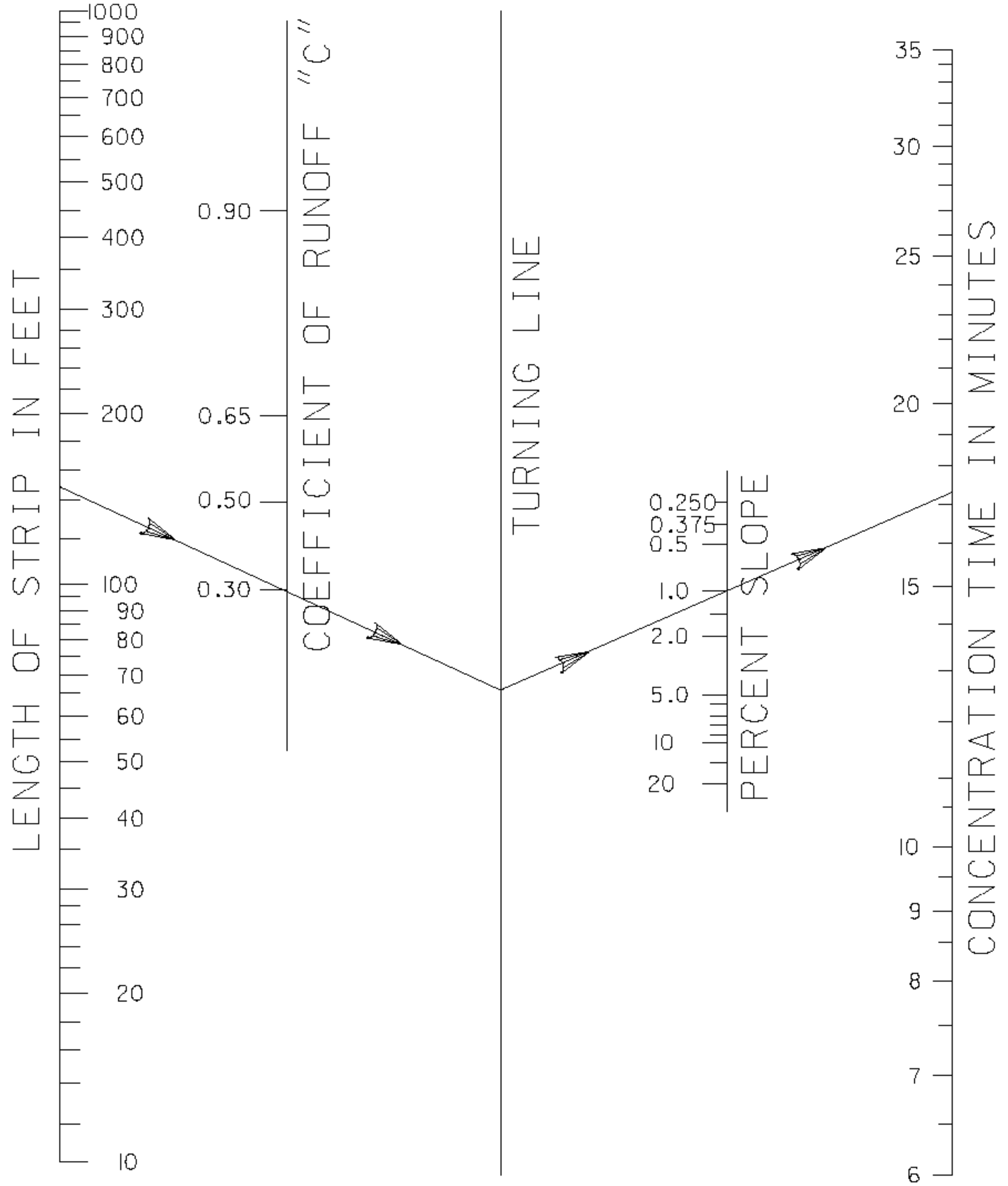
Description of Area	Runoff Coefficients
Business	
Downtown	0.95
Neighborhood	0.70
Residential (**lot** size)	
12,000 – 25,000 FT^2	0.50
25,000 – And Over	0.40
Apartment	0.70
Industrial	
Light	0.80
Heavy	0.90
Other	
Parks, cemeteries	0.25
Playgrounds	0.35
Railroad yard	0.35
Undeveloped	0.30
Shopping centers	0.90

It often is desirable to develop a composite **runoff** based on the percentage of different types of surface in the **drainage** area. This procedure often is applied to typical "sample" blocks as a guide to selection of reasonable values of the coefficient for an entire area. Coefficients with respect to surface type currently in use are:

Character of Surface	Runoff Coefficients
	Post-Developed
Pavement	
Asphalt and Concrete	0.95
Brick	0.85
Roofs	0.95
Lawns	0.35

The coefficients in these two tabulations are applicable for storms of 5-to 10-yr frequencies. Less frequent, higher intensity storms will require the use of higher coefficients because infiltration and other losses have a proportionally smaller effect on **runoff**. The coefficients are based on the assumption that the design storm does not occur when the ground surface is frozen.

FIGURE 2-1: Overland Flow Chart



Source: Ohio Department Of Transportation-Location and Design Manual- Vol-2 Figure 1101-1 (revised July, 1999)

TABLE 2-2: Rainfall Intensity for Mahoning County

Time of Concentration (min)	2 Yr. (in/hr)	5 Yr. (in/hr)	10 Yr. (in/hr)	25 Yr. (in/hr)	50 Yr. (in/hr)	100 Yr. (in/hr)
5	4.51	5.45	6.19	7.11	7.80	8.50
6	4.31	5.21	5.91	6.77	7.42	8.08
7	4.11	4.97	5.63	6.44	7.05	7.66
8	3.92	4.72	5.34	6.10	6.67	7.24
9	3.72	4.48	5.06	5.77	6.30	6.82
10	3.52	4.24	4.78	5.43	5.92	6.40
11	3.39	4.09	4.61	5.24	5.71	6.18
12	3.26	3.93	4.44	5.05	5.51	5.96
13	3.13	3.78	4.26	4.85	5.30	5.73
14	3.00	3.62	4.09	4.66	5.10	5.51
15	2.87	3.47	3.92	4.47	4.89	5.29
16	2.81	3.40	3.84	4.38	4.80	5.19
17	2.74	3.32	3.76	4.30	4.70	5.09
18	2.68	3.25	3.68	4.21	4.61	5.00
19	2.62	3.18	3.60	4.12	4.52	4.90
20	2.55	3.11	3.52	4.03	4.42	4.80
21	2.49	3.03	3.44	3.95	4.33	4.70
22	2.43	2.96	3.36	3.86	4.24	4.60
23	2.36	2.89	3.28	3.77	4.14	4.51
24	2.30	2.82	3.20	3.68	4.05	4.41
25	2.24	2.74	3.12	3.60	3.96	4.31
26	2.17	2.67	3.04	3.51	3.86	4.21
27	2.11	2.60	2.96	3.42	3.77	4.11
28	2.05	2.53	2.88	3.33	3.68	4.02
29	1.98	2.45	2.80	3.25	3.58	3.92
30	1.92	2.38	2.72	3.16	3.49	3.82
35	1.80	2.23	2.56	2.98	3.29	3.61
40	1.67	2.08	2.39	2.79	3.09	3.40
45	1.55	1.94	2.23	2.61	2.90	3.19
50	1.43	1.79	2.06	2.42	2.70	2.98
55	1.30	1.64	1.90	2.24	2.50	2.77
60	1.18	1.49	1.73	2.05	2.30	2.56
70	1.10	1.39	1.61	1.91	2.14	2.38
80	1.01	1.28	1.49	1.77	1.98	2.21
90	0.93	1.18	1.37	1.63	1.83	2.03
100	0.85	1.08	1.25	1.48	1.67	1.85
110	0.76	0.97	1.13	1.34	1.51	1.68
120	0.68	0.87	1.01	1.20	1.35	1.50

Intensities determined from the Precipitation Frequency Data Server (PFDS) created and maintained by the Hydrometerological Design Studies Center, DOC/NOAA/National Weather Service. Values are averages of a range of data as determined across Mahoning County.
http://hdsc.nws.noaa.gov/hdsc/pfds/orb/oh_pfds.html

2.3 Simplified S.C.S. Graphical Peak Discharge Method

2.3.1 Methodology

Peak Discharge Method is applicable for estimating peak flows from storms of 24 hours in duration, the drainage area consists of homogenous soil types and land-surface cover, and drainage areas up to 20 square miles. *This method shall be used to design storm culverts*.

2.3.2 Equations and Concepts

Peak Discharge Equation:

$$Qp = quAQFp$$

Where: Qp = peak discharge (cfs)
qu = unit peak discharge (cfs/mi²/in.)
A = drainage area (mi²)
Q = rainfall (in.)
Fp = pond and swamp adjustment factor (Table 2-10)

The input requirements for this method are as follows:

- P = 24-hour design rainfall (See Table 2-3)
- Hydrological Soil Group
- CN = Curve Number (See Table 2-4)
- Tc = time of concentration, hours (See Figure 2-2)
- Rainfall Distribution Type (**Type II for Mahoning County**)
- **Storm Frequency**

TABLE 2-3: 24-Hour Cumulative Rainfall, P

Frequency	24-hour Rainfall (in.)
2-year	2.40
5-year	2.90
10-year	3.40
25-year	4.00
50-year	4.50
100-year	5.00

A. HYDROLOGIC SOIL GROUP CLASSIFICATION

SCS has developed a soil classification system that consists of four groups, identified as ***A***, ***B***, ***C***, and ***D***. Soils are classified into one of these categories based upon their ***minimum infiltration rate***. Soil characteristics associated with each Hydrologic Soil Group are generally described as follows:

Group A: Soils with low runoff potential due to high infiltration rates, even when thoroughly wetted. These soils consist primarily of deep, well to excessively drained sands and gravels with high water transmission rates (**0.30 in./hr.**). Group **A** soils include **sand, loamy sand,** or **sandy loam**.

Group B: Soils with moderately low runoff potential due to moderate infiltration rates when thoroughly wetted. These soils consist primarily of moderately deep to deep, and moderately well to well-drained soils. Group **B** soils have moderate water transmission rates (**0.15-0.30 in./hr.**) and include **silt loam or loam**.

Group C: Soils with moderately high runoff potential due to slow infiltration rates when thoroughly wetted. These soils typically have a layer near the surface that impedes the downward movement of water or soils. Group **C** soils have low water transmission rates (**0.05-0.15 in./hr.**) and include **sandy clay loam**.

Group D: Soils with high runoff potential due to very slow infiltration rates. These soils consist primarily of clays with high swelling potential, soils with permanently high water tables, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly **impervious** parent material. Group **D** soils have very low water transmission rates (**0-0.05 in./hr.**) and include **clay loam**, **silty clay loam**, **sandy clay**, **silty clay**, or **clay**.

Refer to the latest version of the Soil Survey of Mahoning County to determine Soil Type and corresponding Hydrologic Group within project area or visit the following GIS website for soil and other useful information:

http://gis.mahoningcountyoh.gov/

B. RUNOFF CURVE NUMBER, CN

The soil group classification, cover type and the hydrologic condition are used to determine the **runoff** curve number, ***CN***. The *CN* indicates the runoff potential of an area when the ground is not frozen. **Table 2-4** provides the *CN's* for various land use types and soil groups.

"Good Condition" shall be used for determining the runoff curve number for pre-development.

The user is referred to TR-55 for additional cover types and general assumptions and limitations.

TABLE 2-4: Runoff Curve Numbers

Runoff Curve Numbers, CN (1)					
Runoff curve number for selected agricultural, suburban, and urban land use. (Antecedent moisture condition II, and $I_a – 0.2S$)					
LAND USE DESCRIPTION		**HYDROLOGIC SOIL GROUP**			
		A	B	C	D
Cultivated land[1] : without conservation treatment		72	81	88	91
: with conservation treatment		62	71	78	81
Pasture or range land: poor condition		68	79	86	89
: good condition		39	61	74	80
Meadow: good condition		30	58	71	78
Wood or forest land: thin stand, poor cover, no mulch		45	66	77	83
: Good cover[2]		25	55	70	77
Open spaces, lawns, parks, golf courses, cemeteries, etc.					
good condition: grass cover on 75% or more of the area		39	61	74	80
fair condition: grass cover on 50% to 75% of the area		49	69	79	84
Commercial and business areas (85% **impervious**)		89	92	94	95
Industrial districts (72% **impervious**)		81	88	91	93
Residential[3]					
Average **lot** size	Average % **Impervious**[4]				
1/8 **acre** or less	65	77	85	90	92
1/4 **acre**	38	61	75	83	87
1/3 **acre**	30	57	72	81	86
1/2 **acre**	25	54	70	80	85
1 **acre**	20	51	68	79	84
Paved parking **lots**, roofs, driveways, etc.[5]					
Streets and roads:					
paved with curbs and storm sewers[5]		98	98	98	98
gravel		76	85	89	91
Dirt		72	82	87	89

[1] For a more detailed description of agricultural land use curve numbers refer to National Engineering Handbook, Section 4, Hydrology, Chapter 9, Aug. 1972.
[2] Good cover is protected from grazing and litter and brush cover soil.
[3] Curve numbers are computed assuming the runoff from the house and driveway is directed towards the street with a minimum of roof water directed to lawns where additional infiltration could occur.
[4] The remaining pervious areas (lawn) are considered to be in good pasture condition for these curve numbers.
[5] In some warmer climates of the country a curve number of 95 may be used.

Where watersheds, or sub-watershed areas, have various ground covers and hydrologic groups, a Weighted "CN" value shall be used. The following example illustrates how a Weighted "CN" value is calculated:

Worksheet 2: Runoff curve number and runoff

Project: Heavenly Acres	By: WJR	Date: 10/1/85
Location: Dyer County, Tennessee	Checked: NM	Date: 10/3/85

Check one: ☐ Present ☒ Developed

1. Runoff curve number

Soil name and hydrologic group (appendix A)	Cover description (cover type, treatment, and hydrologic condition; percent impervious; unconnected/connected impervious area ratio)	CN [1/] Table 2-2	CN [1/] Figure 2-3	CN [1/] Figure 2-4	Area ☒ acres ☐ mi² ☐ %	Product of CN x area
Memphis, B	25% connected impervious 1/2 acre lots, good condition	70			75	5250
Loring, C	25% impervious with 50% unconnected 1/2 acre lots, good condition			78	100	7800
Loring, C	Open space, good condition	74			75	5550
				Totals ➡	250	18,600

[1/] Use only one CN source per line

CN (weighted) = $\frac{\text{total product}}{\text{total area}} = \frac{18{,}600}{250} = 74.4$; Use CN ➡ 74

2. Runoff

		Storm #1	Storm #2	Storm #3
Frequency	yr	25		
Rainfall, P (24-hour)	in	6.0		
Runoff, Q (Use P and CN with table 2-1, figure 2-1, or equations 2-3 and 2-4)	in	3.19		

Blank Worksheet 2, taken from TR-55, Second Edition, June 1986, is included in the Appendix.

C. TIME OF CONCENTRATION, Tc

The time of concentration is the sum of the time increments for each flow segment present in the *tc* flow path, such as ***overland*** or ***sheet flow***, ***shallow concentrated flow***, and ***channel flow***.

$$Tc = T_{\text{sheet flow}} + T_{\text{shallow concentrated flow}} + T_{\textbf{channel}\text{ flow}}$$

These flow types are influenced by surface roughness, **channel** shape, flow patterns, and slope, and are discussed below:

a. Overland (sheet) flow is shallow flow over plane surfaces. For the purposes of determining time of concentration, overland flow usually exists in the upper reaches of the hydraulic flow path.

The kinematic solution to Manning's equation is used to compute *tc* for overland sheet flow:

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

Where:
n = Manning's (See Table 2-5)
L = flow length in feet (<300 feet) See Note
P_2 = 2-year/24-hour rainfall (inches)
S = average land slope, ft/ft

NOTE: *Sheet flow can influence the peak discharge of small* ***watersheds*** *dramatically because the ratio of flow length to flow velocity is usually very high.* ***Surface roughness, soil types, and slope will dictate the distance before sheet flow transitions into shallow concentrated flow.*** *TR-55 stipulates that the maximum length of sheet flow is 300 feet. Many hydrologists and geologists will argue that, based on the definition of sheet flow that 100 to 150 feet is the maximum distance before the combination of quantity and velocity create shallow concentrated flow. In an urban application (usually a relatively small drainage area), the flow time associated with 300 feet of sheet flow will result in a disproportionately large segment of the total time of concentration for the watershed. This will result in a very slow overall tc and may not be representative of the drainage area as a whole.* ***As stated previously, the designer must be sure that the flow path chosen is not only representative of the drainage area, but also is the flow path for the significant portion of the total peak discharge****.*

TABLE 2-5: Surface Description – Mannings "n"

Surface Description '*n*' Value
Smooth Surfaces (Concrete, Asphalt, Gravel, or
Bare Soil 0.011
Fallow (No Residue) 0.05
Cultivated Soils:
Residue Cover < 20% 0.06
Residue Cover > 20% 0.17
Grass:
Short Grass Prairie. 0.15
Dense Grasses2 . . . . 0.24
Bermuda grass 0.41
Range (Natural) 0.13
Woods:3
Light Underbrush 0.40
Dense Underbrush 0.80

1 The 'n' values are composite of information compiled by Engman (1986).
2 Includes species such as weeping lovegrass, bluegrass, buffalo grass, blue grama grass, and native grass mixtures.
3 When selecting n, consider cover to a height of about 0.1 ft. This is the only part of the plant cover that will obstruct sheet flow.

From 210-VI-TR-55, Second Edition, June 1986

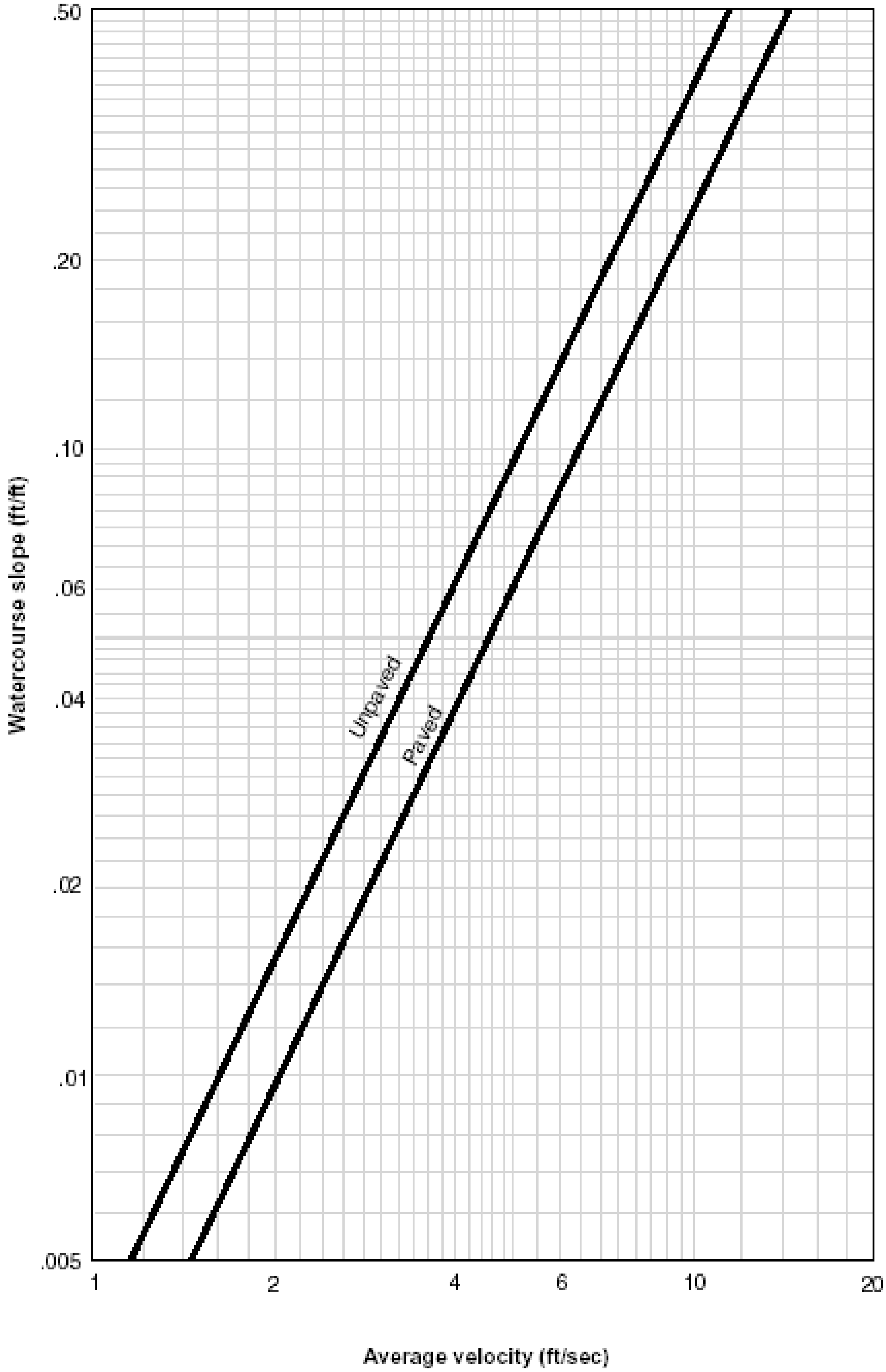
b. Shallow Concentrated Flow usually begins where overland flow converges to form small rills or gullies. Shallow concentrated flow can exist in small manmade **drainage ditches** (paved and unpaved) and in curb and gutters. Figure 2-2 provides a graphical solution for shallow concentrated flow. The input information needed to solve for this flow segment is the land slope and the surface condition (paved or unpaved).

Once the average velocity (V) is determined, the Time of Travel for shallow concentrated flow can be determined using the following equation:

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

Where:
Tt = travel time (hr)
L = flow length (ft)
V = average velocity (ft/s)
3600 = conversion factor from seconds to hours

FIGURE 2-2: Average Velocities for Estimating Travel Time for Shallow Concentrated Flow



(210-VI-TR-55, Second Ed., June 1986)

c. Channel flow occurs where flow converges in gullies, ditches or swales, and natural or manmade water conveyances (including storm drainage pipes). **Channel** flow is assumed to exist in **perennial streams** or wherever there is a well-defined channel cross-section. The Manning Equation is used for open channel flow and pipe flow, and usually assumes full flow or bank-full velocity. Manning coefficients can be found in **Table 2-6** for pipe flow, **Table 2-7** for constructed channels, and **Table 2-8** for natural streams.

Manning's Equation is:

$$V = \frac{1.49 r^{2/3} s^{1/2}}{n}$$

Where:
V = average velocity (ft/s)
r =hydraulic radius (ft) and is equal to a/p_w
a = cross sectional flow area (ft^2)
p_w = wetted perimeter (ft)
s = slope of the hydraulic grade line (**channel** slope, ft/ft)
n = Manning's roughness coefficient for open **channel** flow

TABLE 2-6a: Manning's "n" – Smooth Lined Pipes

Manning's "n" for Pipe Flow	
Material*	**"n"**
Smooth lined 60" and under	**0.015**
Smooth lined, larger than 60"	**0.013**

Source: ODOT L&D **Drainage** Manual

*The Manning's "n" values in Table 2-6 apply to all smooth lined pipes, including concrete, vitrified clay, PVC or HDPE.

TABLE 2-6b: Manning's "n" – Corrugated Pipes

Manning's "n" for Pipe Flow									
Corrugations	Annular	Helical							
		8"	10"	12"	18"	24"	36"	48"	>60"
1 1/2x1/4		0.012	0.014						
2 2/3x1/2 in	0.024			0.011	0.014	0.016	0.019	0.020	0.021
3x1 in	0.027							0.023	0.024
6x2 in									0.033

TABLE 2-7: Manning's "n" for Constructed Channels

Lining Material	From	To
Concrete Lined	0.012	**0.016**
Cement Rubble	0.017	**0.025**
Earth, Straight and Uniform	0.017	**0.022**
Rock Cuts, Smooth and Uniform	0.025	**0.033**
Rock Cuts, Jagged and Irregular	0.035	**0.045**
Winding, Sluggish Canals	0.022	**0.027**
Dredged Earth Channels	0.025	**0.030**
Canals with Rough Stony Beds, Weeds on Earth Banks	0.025	**0.035**
Earth Bottom, Rubble Sides	0.028	**0.033**
Small Grass Channels:		
Long Grass – 13"	0.042	
Short Grass – 3"	0.034	

TABLE 2-8: Manning's "n" for Natural Stream Channels

Lining Material	From	To
1. Clean, Straight Bank, Full Stage, No Rifts or Deep Pools	0.025	**0.030**
2. Same as #1, but Some Weeds and Stones	0.030	**0.035**
3. Winding, Some Pools and Shoals, Clean	0.033	**0.040**
4. Same as #3, Lower Stages, More ineffective Slope and Sections	0.040	**0.050**
5. Same as #3, Some Weeds and Stones	0.035	**0.045**
6. Same as #4, Stony Sections	0.045	**0.055**
7. Sluggish River Reaches, Rather Weedy with Very Deep Pools	0.050	**0.070**
8. Very Weedy Reaches	0.075	**0.125**

Adapted from Handbook of Hydraulics, Sixth Edition, Brater & King

Once the average velocity (V) is determined, the Time of Travel for channel flow can be determined using the following equation:

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

The following Worksheet 3 example shows how time of concentration is calculated. A blank Worksheet 3, taken from TR-55, Second Edition, June 1986, is included in the Appendix.

Worksheet 3: Time of Concentration (T_c) or travel time (T_t)

Project *Heavenly Acres*	By *DW*	Date *10/6/85*
Location *Dyer County, Tennessee*	Checked *NM*	Date *10/8/85*

Check one: ☐ Present ☒ Developed

Check one: ☒ T_c ☐ T_t through subarea

Notes: Space for as many as two segments per flow type can be used for each worksheet. Include a map, schematic, or description of flow segments.

Sheet flow (Applicable to T_c only)

	Segment ID	AB		
1.	Surface description (table 3-1)	Dense Grass		
2.	Manning's roughness coefficient, n (table 3-1)	0.24		
3.	Flow length, L (total L ≤ 300 ft) ... ft	100		
4.	Two-year 24-hour rainfall, P_2 ... in	3.6		
5.	Land slope, s ... ft/ft	0.01		
6.	$T_t = \frac{0.007\ (nL)^{0.8}}{P_2^{\,0.5}\ s^{0.4}}$ Compute T_t ... hr	0.30	+	= 0.30

Shallow concentrated flow

	Segment ID	BC		
7.	Surface description (paved or unpaved)	Unpaved		
8.	Flow length, L ... ft	1400		
9.	Watercourse slope, s ... ft/ft	0.01		
10.	Average velocity, V (figure 3-1) ... ft/s	1.6		
11.	$T_t = \frac{L}{3600\ V}$ Compute T_t ... hr	0.24	+	= 0.24

Channel flow

	Segement ID	CD		
12.	Cross sectional flow area, a ... ft^2	27		
13.	Wetted perimeter, p_w ... ft	28.2		
14.	Hydraulic radius, $r = \frac{a}{p_w}$ Compute r ... ft	0.957		
15	Channel slope, s ... ft/ft	0.005		
16.	Manning's roughness coefficient, n ...	0.05		
17.	$V = \frac{1.49\ r^{2/3}\ s^{1/2}}{n}$ Compute V ... ft/s	2.05		
18.	Flow length, L ... ft	7300		
19.	$T_t = \frac{L}{3600\ V}$ Compute T_t ... hr	0.99	+	= 0.99
20.	Watershed or subarea T_c or T_t (add T_t in steps 6, 11, and 19) ... Hr			1.53

Initial abstraction (Ia) is all losses before runoff begins. It includes water retained in surface depressions, water intercepted by vegetation, evaporation, and infiltration. The Curve Number (CN) is used to determine the initial abstraction (Ia) from Table 2-9:

TABLE 2-9: Ia Values for Runoff Curve Numbers

Curve Number	*Ia (in)*	*Curve Number*	*Ia (in.)*
40	3.000	70	0.857
41	2.878	71	0.817
42	2.762	72	0.778
43	2.651	73	0.740
44	2.545	74	0.703
45	2.444	75	0.667
46	2.348	76	0.632
47	2.255	77	0.597
48	2.167	78	0.564
49	2.082	79	0.532
50	2.000	80	0.500
51	1.922	81	0.469
52	1.846	82	0.439
53	1.774	83	0.410
54	1.704	84	0.381
55	1.636	85	0.353
55	1.571	86	0.326
57	1.509	87	0.299
58	1.448	88	0.273
59	1.390	89	0.247
60	1.333	90	0.222
61	1.279	91	0.198
62	1.226	92	0.174
63	1.175	93	0.151
64	1.125	94	0.128
65	1.077	95	0.105
66	1.030	96	0.083
67	0.985	97	0.062
68	0.941	98	0.041
69	0.899		

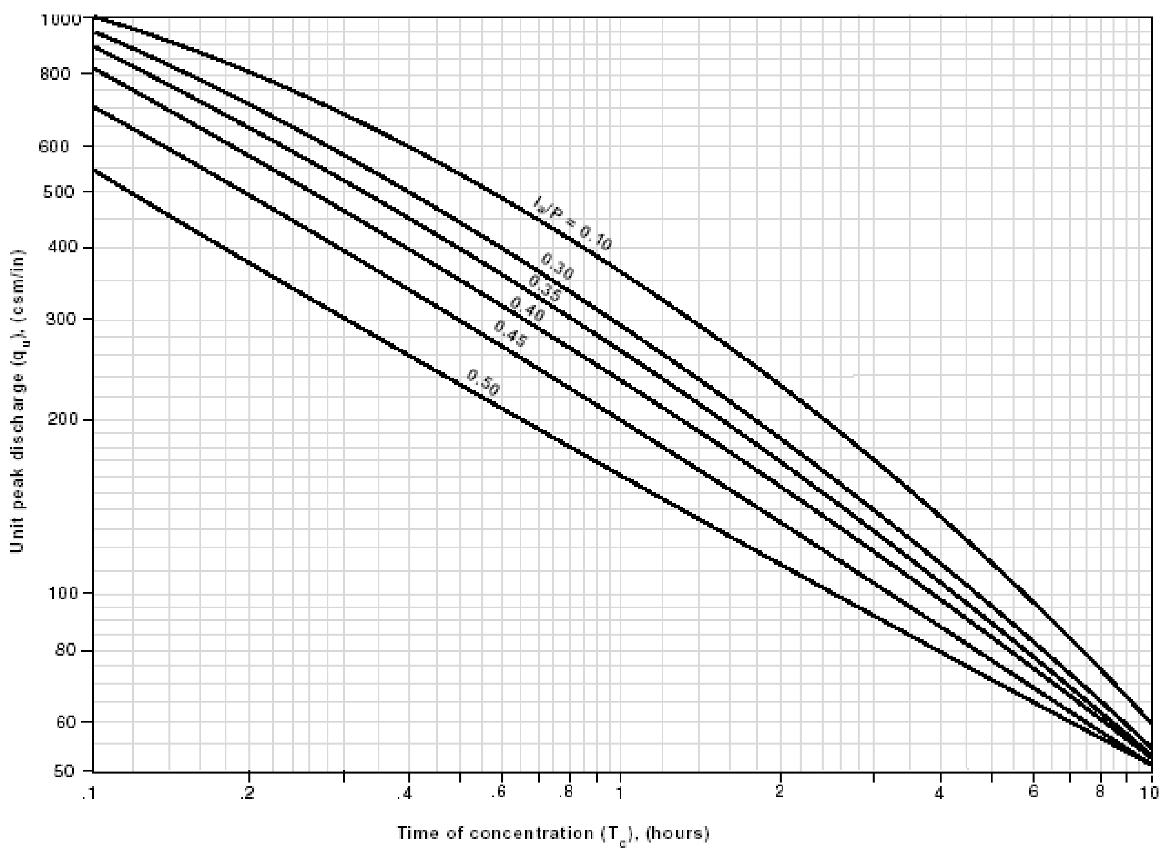
The Fp factor is an adjustment for pond and swamp areas that are spread throughout the watershed. It can only be applied for ponds or swamps that are not in the Tc path.

TABLE 2-10: Adjustment Factors for Pond and Swamp Areas, Fp

Pond & Swamp Areas (%)	Fp
0	1.00
0.2	0.97
1.0	0.87
3.0	0.75
5.0	0.72

The unit peak discharge, q_u, is calculated using Tc and Ia/P with Figure 2-3.

FIGURE 2-3: SCS Type II Unit Peak Discharge Graph



2.3.3 Design Procedure

Step 1: The 24-hour rainfall depth is determined from Table 2-3 for the selected **storm frequency**.

Step 2: The runoff curve number (CN) is estimated from Worksheet 2 and Table 2-4.

Step 3: The CN value is used to determine the initial abstraction (Ia) from Table 2-9. The ratio (Ia/P) is then computed.

Step 4: The watershed time of concentration is computed using Worksheet 3 and is used with the ratio Ia/P to obtain the unit peak discharge (qu) from Figure 2-3.

Step 5: The pond and swamp adjustment factor if estimated from Table 2- 10.

Step 6: The peak runoff rate is computed using the Peak Discharge Equation.

$$Qp = quAQFp$$

The following Worksheet 4 example shows how the peak **runoff** rate is calculated. A blank Worksheet 4, taken from TR-55, Second Edition, June 1986, is included in the Appendix.

Worksheet 4: Graphical Peak Discharge method

Project Heavenly Acres	By RHM	Date 10/15/85
Location Dyer County, Tennessee	Checked NM	Date 10/17/85

Check one: ☐ Present ☒ Developed

1. Data

Drainage area .... A_m = 0.39 mi² (acres/640)

Runoff curve number ....CN = 75 (From worksheet 2), Figure 2-6

Time of concentration .... T_c = 1.53 hr (From worksheet 3), Figure 3-2

Rainfall distribution .... = II (I, IA, II III)

Pond and swamp areas sprea throughout watershed .... = – – percent of A_m (– – acres or mi² covered)

		Storm #1	Storm #2	Storm #3
2. Frequency	yr	25		
3. Rainfall, P (24-hour)	in	6.0		
4. Initial abstraction, I_a (Use CN with table 4-1)	in	0.667		
5. Compute I_a/P		0.11		
6. Unit peak discharge, qu (Use T_c and I_a/P with exhibit 4– II)	csm/in	270		
7. Runoff, Q (From worksheet 2). Figure 2-6	in	3.28		
8. Pond and swamp adjustment factor, F_p (Use percent pond and swamp area with table 4-2. Factor is 1.0 for zero percent pond ans swamp area.)		1.0		
9. Peak discharge, q_p	cfs	345		

(Where $q_p = q_u A_m Q F_p$)

2.4The S.C.S. - Unit Hydrograph Method

2.4.1Methodology

SCS method described above to calculate the peak discharge can be applied to estimate a **hydrograph** when detention facilities are designed and pond routing is necessary. It may also be used to design culverts. The SCS has developed a tabular hydrograph procedure that can be used to determine the hydrograph for drainage areas less than 20 Sq. Mi.

2.4.2Resources

The designer is referred to the procedures outlined by the SCS in Technical Release 55 “Urban Hydrology for Small Watersheds” (TR-55). Hydrologic computer models are made available for download at the **USDA** Natural Resources Conservation Service (**NRCS**) website.

http://www.wcc.nrcs.usda.gov/hydro/hydro-tools-models-wintr55.html

2.5Other Methods

Mahoning County will accept the following USGS methods to calculate Stormwater runoff. These methods are not described here but the designer is directed to obtain copies of the individual reports from USGS:

2.5.1Water-Resources Investigations Report 03-4164

Techniques for Estimating Flood-Peak Discharges of Rural, Unregulated Streams in Ohio

http://www.dot.state.oh.us/research/2003/Hydraulics/14740-FR.pdf

2.5.2Water-Resources Investigations Report 93-4080

Estimation of Flood Volumes and Simulation of Flood **Hydrographs** for Ungaged, Small Rural Streams in Ohio

http://oh.water.usgs.gov/reports/Abstracts/wrir.93-4080.html

2.5.3Water-Resources Investigations Report 93-135

Estimation of Peak-Frequency Relations, Flood **Hydrographs**, and Volume-Duration-Frequency Relations of Un-gauged Small Urban Streams in Ohio

http://oh.water.usgs.gov/reports/Abstracts/ofr.93-135.html

SECTION 3 STORM DRAINAGE SYSTEMS

3.0 STORM DRAINAGE SYSTEMS

3.1 Overview

Proposed development sites and existing improvements shall be protected from flood damage and excessive ponding of water, springs, and other surface waters. The design and construction of **drainage** facilities within the proposed development shall be such that **runoff** passing through the development will be carried through and away from the site without causing flood damage to any structure. Additionally, these waters must not adversely affect the proposed sanitary sewer system or individual sewage systems. **Runoff** entering the proposed development shall be received and discharged from the site at the locations and, as nearly as possible, in the same manner that existed prior to construction.

The **drainage** system layout should be made in accordance with the urban **drainage** objectives, following the natural topography as closely as possible. Design of **drainage** systems shall not cause **runoff** to be diverted from one **watershed** to another. Existing natural **drainage** paths and **watercourses** such as streams and creeks should be incorporated into the storm **drainage** system.

3.2Minor System Design

The minor system consists chiefly of the storm system comprised of inlets, conduits, manholes and other appurtenances designed to collect and convey the storm runoff resulting from a ten year storm.

3.2.1Layout of Storm Sewers

The layout of the storm system shall place the storm and sanitary sewers on opposite sides of the roadways and within the tree lawn areas where practical. Where opposite side construction is not practical, every effort shall be made to separate the storm and sanitary sewers by six feet (6') barrel to barrel.

The minimum size of all storm sewers, excluding connections and yard drains, shall be 12 inches in diameter. The minimum yard drain size shall be 8 inches in diameter.

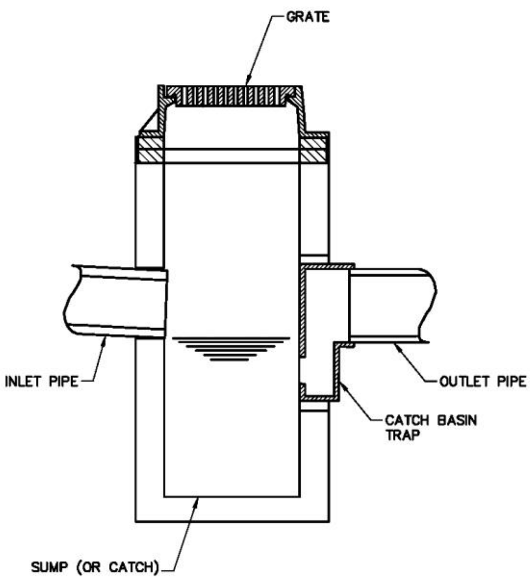
Lateral storm connections to building sites shall be a minimum of six inches in diameter.

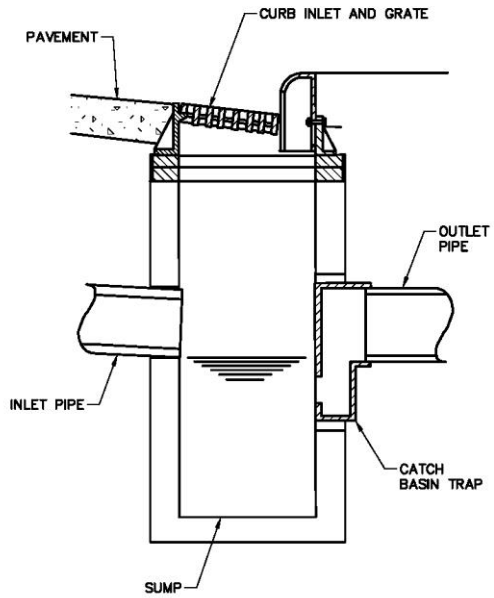
Storm sewers shall have a minimum flowing full velocity of three feet (3) per second and a maximum velocity of 12 feet per second.

For sewers sized less than 36 inches in diameter, manholes shall be spaced at not over 400 feet. For sewers 36 inches through 60 inches in diameter, manholes shall be spaced at not over 600 feet. In sewers larger than 60 inches in diameter, manhole spacing shall not exceed 1,000 feet.

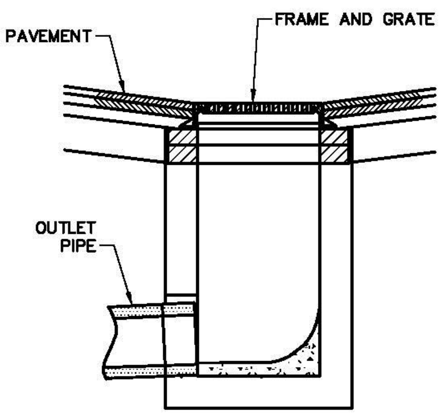
3.2.2Inlet Types and Locations

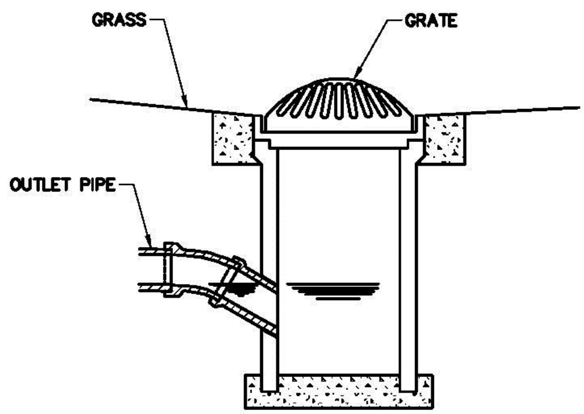
FIGURE 3-1: Storm Inlet Types





CATCH BASIN CURB INLET CATCH BASIN





INLET BASIN YARD BASIN

NOTE: The inlet structure details above are for illustrative purposes only and shall not be used for construction. The user is referred to the following ODOT website to download current standard details:

http://www.dot.state.oh.us/se/standard/Hydraulic/index.htm

Storm Inlet structures are defined in Figure 3-1. The location of these structures is as follows:

- Place upstream of all intersections, bridges, pedestrian ramps, commercial drive aprons, intersection return radii, and curb termini.
- Structures should be placed 10’ off drive aprons, intersection return radii, pedestrian ramps, or curb termini when practicable.
- Place structure in pavement sags.
- Flank catch basin in sag on both upstream directions at 0.2 feet above the flow line of the inlet of the sag catch basin when practicable.

3.2.3 Storm Sewer Requirements

The design storm frequencies for each type of development are as follows:

- Residential/Subdivisions 10 Year Frequency
- Multifamily 10 Year Frequency
- Schools 10 Year Frequency
- Industrial/Commercial 10 Year Frequency
- Major Urban Business Area 10 Year Frequency

The hydraulic grade line shall be determined for the 25 year storm event. The hydraulic grade line shall be below the grate and/or cover of all structures. Note: The hydraulic grade line should never be below the normal depth of flow in the conduit. If it is, then use the normal depth of flow elevation as the hydraulic grade line elevation.

3.2.4 Storm Sewer Design

A **drainage** map delineating each sub-basin area and labeled accordingly shall be prepared. The **drainage** map shall show the proposed improvements, contours and storm sewers system.

The rational method as described in Section 2.2 shall be used to determine the contributing inflow into the system.

The Storm Sewer Computation Sheet shall be used and completed to correctly size the storm sewers. A blank Storm Sewer Computation Sheet is included in the appendix.

Regardless of the type of smooth-lined pipe, ie RCP, PVC, HDPE – the Manning’s “n” value shall be as shown on Table 2-6a. Values for Corrugated Metal pipe shall be as shown on Table 2-6b.

The increased values are recommended for sewers to compensate for minor head losses incurred at catch basins, inlets and manholes located in a storm sewer system.

3.2.5Storm Sewer Computation Sheet – Design Procedures

Please refer to example sheet (Figure 3-2).

Column 1: Structure number. Assigned by the designer. Usually numbered from lowest elevation to highest elevation. The main line trunk is numbered first and then the laterals.

Column 2: Station of the structure as referenced from the centerline or baseline.

Column 3: Right, Left or on the Centerline.

Column 4: **Drainage** area for the referenced structure.

Column 5: Total **drainage** area. This number is found by summing the DA from the current structure to the SA directly upstream of it.

Column 6: Time of concentration to the current structure. In some cases, this time may be calculated based upon the length of the conduit and the velocity of the flow if there is no discharge into the next adjacent structure.

Column 7: Total time of concentration. This number is found by summing the individual time of concentration from the current structure (column 6) to the structure directly upstream of it.

Column 8: The rainfall intensity based upon the design year storm. At time equal to ST (column 7)

Column 9: The rainfall intensity based upon the hydraulic grade year storm. This intensity is based upon the greatest time of concentration to the outlet. It is used for the entire upstream storm sewer system. Do not complete until the greatest Tc is known. This intensity is used for the entire storm upstream.

Column 10: The weighted coefficient for the **watershed**.

Column 11: The multiplication of the **drainage** area for the structure and the weighted coefficient for the **watershed** (column 4 x column 10)

Column 12: Summation of the DCA value of the current structure added to the upstream SCA value.

Column 13: The design discharge found by the multiplication of the SCA and the design intensity (column 12 x column 8).

Column 14: The design discharge found by the multiplication of the SCA and the hydraulic grade intensity (column 12 x column 9). Do not complete until #9 is determined.

Column 15: The diameter of the conduit.

Column 16: The length of the conduit.

Column 17: The slope of the conduit.

Column 18: The invert of the incoming conduit to the current structure.

Column 19: The invert of the outgoing conduit from the structure.

Column 20: The velocity based upon the Manning's "just full equation". *(see notes)*

Column 21: The discharge based upon the Manning's "just full equation".

Column 22: The hydraulic friction slope. **

Column 23: The headloss due to friction in the conduit. hL=L*(Sf) or other equation

Column 24: The elevation of the hydraulic grade line. Calculated by adding the head loss to the hydraulic grade elevation of the downstream structure. At the outlet the hydraulic grade elevation is either the water surface elevation or it is calculated by the (critical depth+diameter)/2.

Column 25: The elevation of the structure grate or cover.

Column 26: The difference of the structure grate or cover elevation and the hydraulic grade elevation (column 25- column 24).

Notes:

· A common mistake is to not use the smallest intensity (longest time of concentration) for the hydraulic grade check.
· The critical depth is calculated using the nomographs in the appendix of ODOT The Location and Design Manual, Volume 2 or it can be approximated by using 0.8 x Diameter.
**Sf= [(Q*N)/(0.465*D^(8/3))]^(2)

A blank Storm Sewer Computation Sheet, taken from the ODOT Location and Design Manual, is included in the Appendix.

FIGURE 3-2: Storm Sewer Computation Sheet (Example)

Form LD-34
(Revised July 2002)

STORM SEWER COMPUTATION SHEET

Calculated by........JES........Date.....06-27-02.....
Checked by........DAG........Date.....06-27-02.....

Just Full Capacity ....10.....Yr. Frequency
Hydraulic Gradient ....25.....Yr. Frequency
Interstate Sag ....50.....Yr. Frequency

Project........LAW-7-2.17........
Sheet.....1.....of.....1.....

Manning's "n" for ...0.015... Year Design Frequency...10...
Manning's "n" for ...0.015... Year H.G. Frequency...25...

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
	MH CB or I	Station	Side	Drainage Area In Acres		Time of Concentration In Minutes		Rainfall in Inches/Hour		Runoff Coef.	C X A		Discharge in cfs CA X i		Size of Pipe in Inches	Length of Pipe in Feet	Slope of Pipe in Ft./Ft.	Inlet F/L of Pipe	Outlet F/L of Pipe	Mean Velocity in Ft./Sec.	Just Full Capacity (......Year Q)	Friction Slope in Ft./Ft.	Head Loss in Feet	Elevation of Hyd. Gradient (for 25 year Q)	Grate or Cover Elev.	Cover Elev minus H.G. Elev.
	No.			ΔA	ΣA	Δt	Σt	i_{10}	i_{25}	C	ΔCA	ΣCA	Q_{10}	Q_{25}	Ø	L	S_o	Elev.	Elev.	V_m	cfs	S_f	H	Elev.	Elev.	
CB	1	210+50	RT	1.6	1.6	15	15	4.6	5.19	0.68	1.09	1.09	5.0	5.65												
															15	200	0.008	610.55	610.55	4.51	5.4	0.010	2.03	616.59	618.00	1.41
CB	2	208+50	RT	1.9	3.5	18	18	4.2	5.19	0.68	1.29	2.38	10.0	12.35												
															15	225	0.035	608.95	608.95	9.43	11.31	0.048	10.94	614.56	615.50	0.94
MH	3	206+25	RT	0	3.5	0.39	18.39	4.19	5.19	0	0	2.38	9.97	12.35												
															15	100	0.035	601.08	601.08	9.43	11.31	0.048	4.86	603.62	605.00	1.38
HW	4	206+50	RT			0.17	18.57		5.19		0	2.38		12.35												
																		597.58						598.76		
																						$\frac{Qc+D}{2}$ =	$\frac{1.1+1.25}{2}$	= 1.18		

...\Example Storm\stormcalc.dgn 06/19/2003 10:13:54 AM

3.2.6 Culvert Design

Culverts shall be designed to easily convey the 10-year design storm. As a check, the headwater depth shall not be within 12" of the final pavement (crown) elevation for the 25-year storm.

Hydraulic analysis of all culverts shall be performed per the following report:

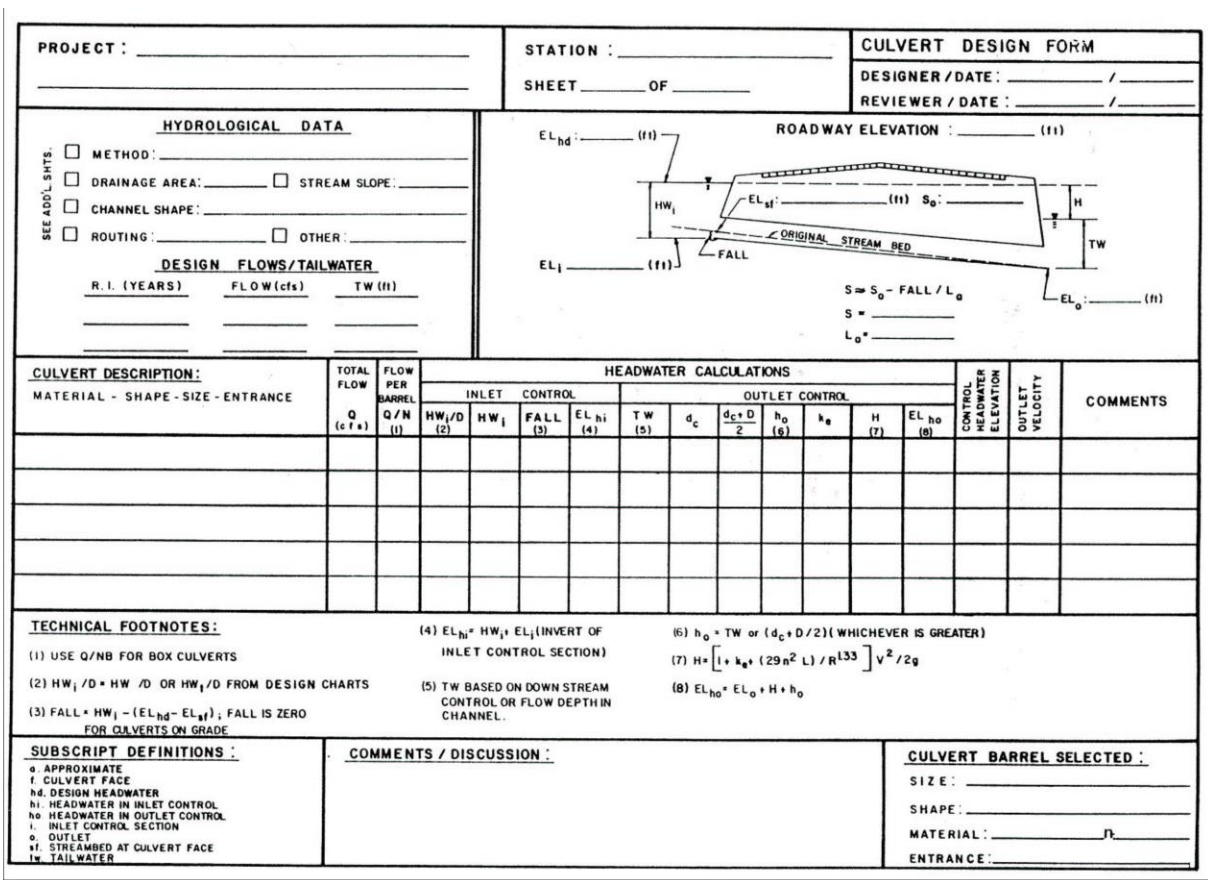
Federal Highway Administration, Report No. FHWA-IP-85-15, Hydraulic Design Series No. 5, "Hydraulic Design of Highway Culverts", September 1985.

A copy of the report can be obtained at:

http://www.fhwa.dot.gov/bridge/hds5SI.pdf

Figure 3-3 is an example culvert design form that will be required for submittal. A blank form is included in the appendix.

FIGURE 3-3: Culvert Design Form



PROJECT : ____________

STATION : ____________

SHEET ______ OF ______

CULVERT DESIGN FORM

DESIGNER / DATE : ________ / ________

REVIEWER / DATE : ________ / ________

HYDROLOGICAL DATA

SEE ADD'L SHTS.

☐ METHOD : ____________

☐ DRAINAGE AREA : ______ ☐ STREAM SLOPE : ______

☐ CHANNEL SHAPE : ____________

☐ ROUTING : ______ ☐ OTHER : ______

DESIGN FLOWS/TAILWATER

R.I. (YEARS)	FLOW (cfs)	TW (ft)

CULVERT DESCRIPTION: MATERIAL - SHAPE - SIZE - ENTRANCE	TOTAL FLOW Q (cfs)	FLOW PER BARREL Q/N (1)	HEADWATER CALCULATIONS: INLET CONTROL HW_i/D (2)	HW_i	FALL (3)	EL_{hi} (4)	OUTLET CONTROL TW (5)	d_c	$\frac{d_c+D}{2}$	h_o (6)	k_e	H (7)	EL_{ho} (8)	CONTROL HEADWATER ELEVATION	OUTLET VELOCITY	COMMENTS

TECHNICAL FOOTNOTES:

(1) USE Q/NB FOR BOX CULVERTS

(2) $HW_i/D = HW/D$ OR HW_i/D FROM DESIGN CHARTS

(3) $FALL = HW_i - (EL_{hd} - EL_{sf})$; FALL IS ZERO FOR CULVERTS ON GRADE

(4) $EL_{hi} = HW_i + EL_i$ (INVERT OF INLET CONTROL SECTION)

(5) TW BASED ON DOWN STREAM CONTROL OR FLOW DEPTH IN CHANNEL.

(6) $h_o = TW$ or $(d_c + D/2)$ (WHICHEVER IS GREATER)

(7) $H = \left[1 + k_e + (29n^2 L)/R^{1.33}\right] V^2/2g$

(8) $EL_{ho} = EL_o + H + h_o$

SUBSCRIPT DEFINITIONS :

a. APPROXIMATE
f. CULVERT FACE
hd. DESIGN HEADWATER
hi. HEADWATER IN INLET CONTROL
ho. HEADWATER IN OUTLET CONTROL
i. INLET CONTROL SECTION
o. OUTLET
sf. STREAMBED AT CULVERT FACE
tw. TAILWATER

COMMENTS / DISCUSSION :

CULVERT BARREL SELECTED :

SIZE : ____________

SHAPE : ____________

MATERIAL : ______ n ______

ENTRANCE : ____________

Computer programs such as FHWA's "HY-8", ODOT's "HYDRA", or Haestad Methods "CulvertMaster" software packages may be used. HY-8 and HYDRA can be downloaded at the following websites:

FHWA "HY-8"

http://www.fhwa.dot.gov/bridge/hyddescr.htm#hy_8_culvert_analysis

ODOT "HYDRA"

http://www.dot.state.oh.us/se/hy/dloads.htm

Haestad Methods "CulvertMaster" can be ordered at the following website:

http://www.haestad.com/software/culvertmaster/

3.3Major System Design

The major **drainage** system will come into operation once the minor system's capacity is exceeded during storm events larger than the minor system's design storm. Thus, an overflow system must be planned to insure that the storm **runoff** will be directed to the **Stormwater** storage facility(s). The major **drainage** system may consist of open **channels** (including roadway, parking lot, swales, etc.), an over designed storm sewer system, or combinations of both. For the purposes of this manual, the 100 year storm event will serve as the design storm of record for the major **drainage** systems.

3.4Stormwater Storage Facilities Design

This section discusses the general design procedures for designing storage to provide standard detention of **Stormwater runoff** to meet **critical storm** requirements.

Stormwater storage(s) can be classified as surface detention, underground detention, extended dry detention or wet retention. Some facilities include one or more types of storage. See Section 4.0 for detailed information regarding each of these storage types.

NOTE: The design procedures for all structural control storage facilities are the same whether or not they include a permanent pool of water. In the latter case, the permanent pool elevation is taken as the "bottom" of storage and is treated as if it were a solid basin bottom for routing purposes.

A stage-discharge curve defines the relationship between the depth of water and the discharge or outflow from a storage facility. A typical storage facility has two outlets or spillways: a principal outlet and a secondary (or emergency) outlet. The principal outlet is usually designed with a capacity sufficient to convey the design flows without allowing flow to enter the emergency spillway. A pipe culvert, weir, or other appropriate outlet can be used for the principal spillway or outlet.

The emergency spillway is sized to provide a bypass for floodwater during a flood that exceeds the design capacity of the principal outlet. This spillway should be designed taking into account the potential threat to downstream areas if the storage facility were to fail. The stage-discharge curve should take into account the discharge characteristics of both the principal spillway and the emergency spillway.

*NOTE: The location of structural **Stormwater** controls is very important as it relates to the effectiveness of these facilities to control downstream impacts. In addition, multiple storage facilities located in the same **drainage** basin will affect the timing of the **runoff** through the conveyance system, which could decrease or increase flood peaks in different downstream locations. Therefore, a downstream peak flow analysis should be performed as part of the storage facility design process.*

In multi-purpose multi-stage facilities such as **Stormwater** ponds, the design of storage must be integrated with the overall design for water quality treatment objectives. See Chapter 4.0 for further guidance and criteria for the design of structural **Stormwater** controls.

3.4.1Design Procedures

A general procedure in order to design storage facilities is presented below:

Step 1: Compute the inflow **hydrographs** for **runoff** from each of the design storms using the hydrologic methods outlined in Section 2.4. Calculate the allowable discharges for each of the design storms. See **Critical Storm** Method in Section 3.4.2.

Step 2: Perform preliminary calculations to approximate detention storage requirements for the **hydrographs** from Step 1. See Sections 3.4.3 or 3.4.4.

Step 3: Determine the physical dimensions necessary to hold the estimated volume from Step 2, including freeboard. Locate and grade the proposed **Stormwater** facility using contours. Determine the stage-storage curve using the methods described in Section 3.4.5, or other acceptable methods – ie. Conical, to compute the incremental volume between pond contours. The incremental volumes are then summed to create a volume rating table of cumulative pond volumes.

Step 4: Select the type of outlet and size the outlet structure. Determine the stage-discharge curve for the chosen outlet using the methods described in Section 3.4.6.

Step 5: Perform routing calculations using inflow **hydrographs** from Step 1 to check the preliminary design using a storage routing computer model. If the routed post-development peak discharges exceed the allowable development peak discharges, then revise the available storage volume, outlet device, etc., and return to Step 3.

Step 6: Evaluate the downstream effects of detention outflows to ensure that the routed **hydrograph** does not cause downstream flooding problems.

Step 7: Evaluate the control structure outlet velocity and provide **channel** and bank **stabilization** if the velocity will cause **erosion** problems downstream.

3.4.2Critical Storm Method

Rrunoff for proposed development and redevelopment sites shall be calculated using an S.C.S. method, the allowable discharges shall be determined using the critical storm method.

Because of limitations with the S.C.S methods, the minimum time of concentration shall be six minutes.

The allowable discharges from proposed development and redevelopment sites shall be designed using the critical storm method. The post-construction **Stormwater** control methods chosen shall meet the following criteria:

1. The peak discharge rate of **runoff** from the **critical storm** and all more frequent storms occurring under post-development conditions does not exceed the peak discharge rate of **runoff** from a two (2)-year frequency, 24-hour storm occurring on the same **development drainage area** under pre-development conditions. The peak discharge rate of **runoff** from the one (1)-year storm post-developed conditions shall not exceed the one (1)-year storm pre-developed conditions.

2. Storms of less frequent occurrence (longer return periods) than the **critical storm** up to and including the 100-year storm have peak **runoff** discharge rates no greater than the peak **runoff** rates of the pre-developed 10 year storm.

3. The **critical storm** for a specific **development drainage area** is determined as follows:

   Step 1: Use SCS TR-55 or other appropriate and approved hydrologic simulation model to determine the total volume (**acre**-feet) of **runoff** from a two (2)-year, 24-hour storm occurring on the **development drainage area** before and after development. Include clearly in your calculations the **lot** coverage assumptions used for full build out of the proposed condition. Curve numbers for pre-developed or improvements or expansion to a developed condition must reflect the average type of land use over the past 10 years and not only the current land use. *(To account for* *unknown future cosmetic improvements to a construction site, an assumption of an* ***impervious*** *surface such as asphalt or concrete must be utilized for all parking areas or driveways, even if stone/gravel is to be utilized in construction.)*

For sites which are currently developed and are scheduled to be re-developed, the pre-developed condition shall be defined to be 100% of the site as grassland for critical storm and volume storage calculations.

Step 2: From the volumes determined in step 1 above, determine the percent increase in volume of **runoff** due to development. Using this percentage, select the 24 hour **critical storm** from the following table:

TABLE 3-1:
Critical Storm Determination Table

IF THE PERCENTAGE OF INCREASE IN VOLUME OF RUNOFF IS:		**THE CRITICAL STORM WILL BE:**
EQUAL TO OR GREATER THAN:	**LESS THAN:**	
	10	**1 year**
10	20	**2 year**
20	50	**5 year**
50	100	**10 year**
100	250	**25 year**
250	500	**50 year**
500		**100 year**

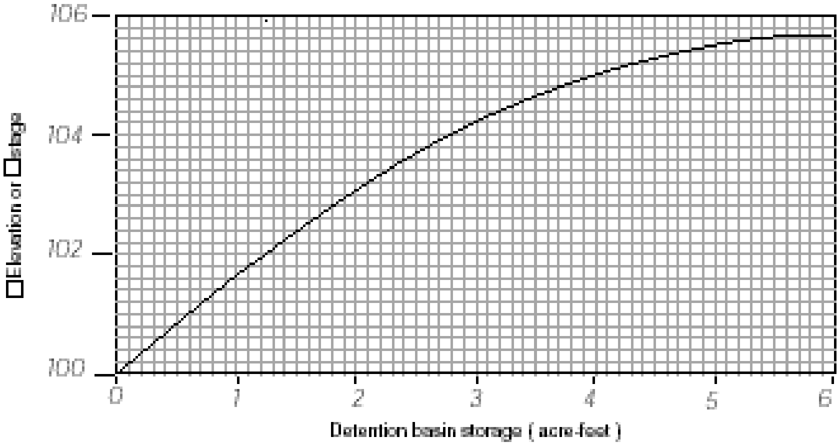
For example, if the percent increase between the pre-development and post-development **runoff** volume for a 2 year storm is 35%, the **critical storm** is a 5-year storm. The peak discharge rate of **runoff** for all storms up to this frequency shall be controlled so as not to exceed the peak discharge rate from the 2-year frequency storm under pre-development conditions in the **development drainage area**. The post-development **runoff** from all less frequent storms, up to and including the 100-year storm, need only be controlled to meet the pre-development peak discharge rate for the 10 year storm.

In no case shall the post developed runoff exceed the pre-developed runoff condition for an equivalent storm event.

3.4.3 Estimate Storage Requirements using S.C.S. Methods

When using S.C.S. methods to calculate runoff the necessary storage volume can be estimated using Worksheet 6a. The following is a completed example worksheet. A blank Worksheet 6a, taken from TR-55, Second Edition, June 1986, is included in the Appendix.

Worksheet 6a: Detention basin storage, peak outflow discharge (q_o) known



Project: Robbinsville	By: SWR	Date: 11/5/85
Location: Dyer County, Tennessee	Checked: RGC	Date: 11/8/85

Check one: ☐ Present ☒ Developed — Single stage structure

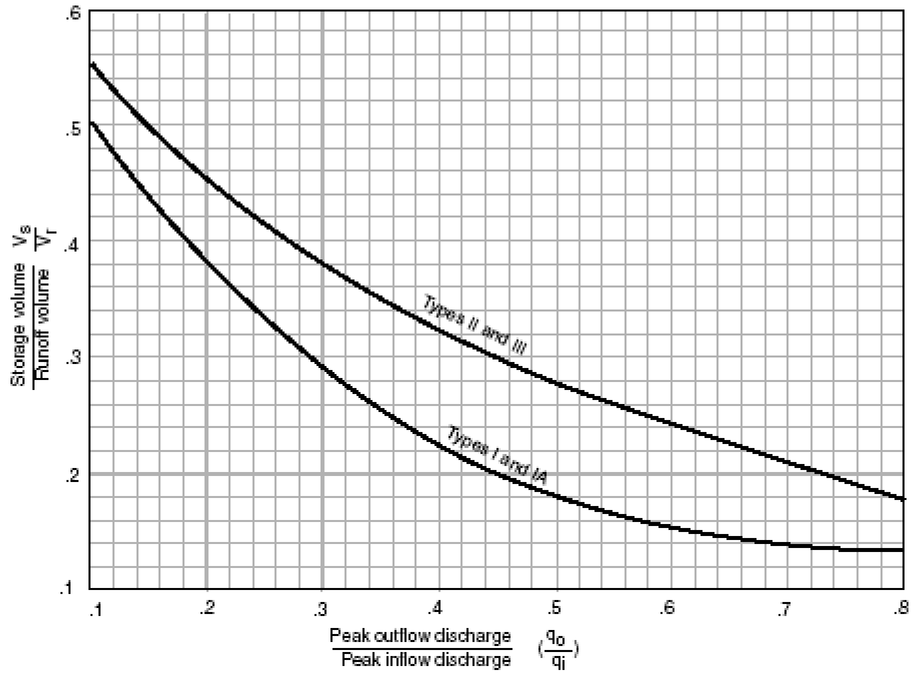
1. Data:
   Drainage area .... A_m = 0.117 mi²
   Rainfall distribution type (I, IA, II, III) = II

	1st Stage	2nd Stage
2. Frequency .... yr	25	
3. Peak inflow discharge q_i ....cfs (from worksheet 4 or 5b)	360	
4. Peak outflow discharge q_o .... cfs [1/]	180	
5. Compute $\frac{q_o}{q_i}$	0.50	
6. $\frac{V_s}{V_r}$ .... (Use $\frac{q_o}{q_i}$ with figure 6-1)	0.28	
7. Runoff, Q .... in (From worksheet 2)	3.4	
8. Runoff volume V_r .... ac-ft ($V_r = QA_m$ 53.33)	21.2	
9. Storage volume, V_s .... ac-ft ($V_s = V_r (\frac{V_s}{V_r})$)	5.9	
10. Maximum storage E_{max} (from plot)	105.7	

1/ 2nd stage q_o includes 1st stage q_o.

Calculation 6 shall be determined by using the following figure:

FIGURE 3-6: Approximate detention basin routing graph



6–2 (210-VI-TR-55, Second Ed., June 1986)

3.4.5 Stage-STORAGE Calculations

For retention/detention, basins with vertical sides such as tanks and vaults, the storage volume is simply the bottom surface area times the height. For basins with graded (2H:1V, 3H:1V, etc.) side slopes or an irregular shape, the stored volume can be computed by the following procedure. Figure 3-7 is a stage-storage computation worksheet, a copy of which is included in the Appendix.

Note: Other methods for computing basin volumes are available, such as the Conic Method for Reservoir Volumes, but they are not presented here.

Step 1: Planimeter or otherwise compute the area enclosed by each contour and enter the measured value into Columns 1 and 2 of Figure 3-7. The invert of the lowest control orifice represents zero storage. This will correspond to the bottom of the facility for extended-detention or detention facilities, or the permanent pool elevation for retention basins.

Step 2: Convert the planimetered area (often in square inches) to units of square feet in Column 3 of Figure 3-7.

Step 3: Calculate the average area between each contour.

The average area between two contours is computed by adding the area planimetered for the first elevation, column 3, to the area planimetered for the second elevation, also Column 3, and then dividing their sum by 2. This average is then written in Column 4 of Figure 3-7.

This procedure is repeated to calculate the average area found between any two consecutive contours.

Step 4: Calculate the *volume* between each contour by multiplying the average area from step 3 (Column 4) by the contour interval and placing this product in Column 6. From Figure 3-7:

This procedure is repeated for each measured contour interval.

FIGURE 3-7: Stage Storage Worksheet

PROJECT: ______________________ SHEET ____ of ____

COUNTY: __________ COMPUTED BY: __________ DATE: __________

DESCRIPTION: ______________________

ATTACH COPY OF TOPO: SCALE – 1"=_______ *ft.*

1	2	3	4	5	6	7	8
ELEV.	AREA (in^2)	AREA (ft^2)	AVG. AREA (ft^2)	INTERVAL	VOL. (ft^3)	TOTAL VOLUME (ft^3)	(*ac. ft.*)

Figure 3-8 is an example Stage-storage curve used to determine required storage.

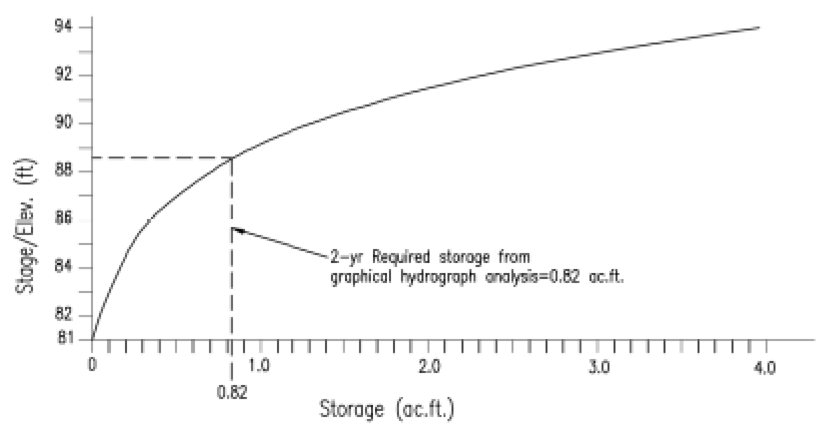


FIGURE 3-8: Stage vs. Storage Curve, Example

3.4.6 Stage-DISCHARGE Calculations

A principal spillway system that controls the rate of discharge from a **Stormwater** facility will often use a multi-stage riser for the outlet structure.

A multi-stage riser is a structure that incorporates separate openings or devices at different elevations to control the rate of discharge from a **Stormwater** basin during multiple design storms. Permanent multi-stage risers are typically constructed of modified pre-cast catch basins or manholes. The geometry of risers will vary from basin to basin.

In a **Stormwater management** basin design, the multi-stage riser is of utmost importance since it controls the design water surface elevations. In designing the multi-stage riser, many iterative routings are usually required to arrive at a minimum structure size and storage volume that provides proper control. Each iterative routing requires that the facility's size (*stage-storage* curve) and outlet shape (*stage-discharge table* or *rating curve*) be designed and tested for performance.

The most common types of devices to control discharge are discussed below. These include orifice, weir, inlet box and circular culvert (with inlet control).

1. OUTLET STRUCTURE TYPE - ORIFICE

An **orifice** should be provided to allow for smaller storms to bypass the structure without damage to the detention basin or surrounding area.

The equation for a single orifice is:

$$Q = AC(64.4H)^{1/2}$$

Where:

A = Area of orifice (ft^2)
H = Head on orifice as measured to the centerline of the orifice (ft)
C = Orifice coefficient

Table 3-4:
Orifice Coefficients

C	Description
0.66	Use for thin materials where the thickness is equal to or less than the orifice diameter.
0.80	Use when the material is thicker than the orifice diameter.

Source: CALTRANS, Stormwater Quality Handbooks, Project Planning and Design Guide, September 2002.

Due to the increased probability of blockage, the minimum allowable diameter for any orifice in a control structure is 4". *This requirement pertains to the primary spillway of a Stormwater storage facility only and not to the outlet structure of a water quality pond.* This requirement does not relieve the designer from considering all means to prevent blockage of all sized orifices.

2. OUTLET STRUCTURE TYPE – SHARP CRESTED WEIRS

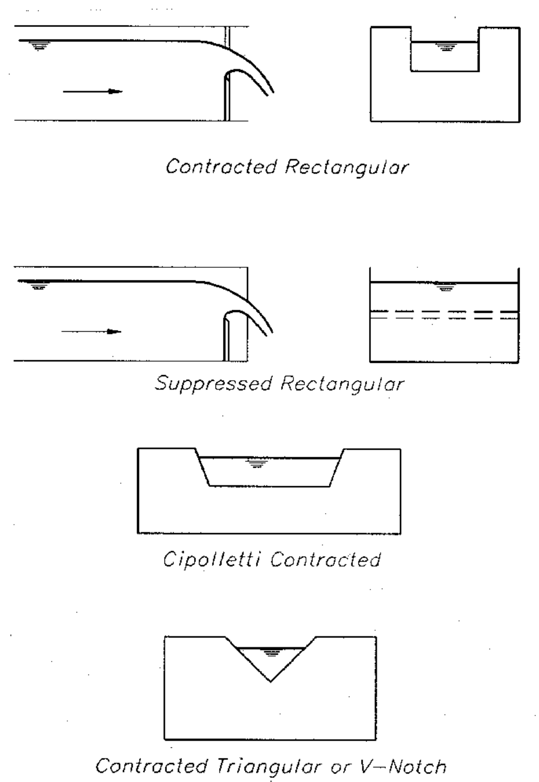


FIGURE 3-9: Weir types

The most common types of sharp crested weirs are shown in Figure 3-9. The equations for each type are described below:

- **Contracted Rectangular Weir**

$$Q = 3.33H^{3/2}(L-0.2H)$$

Where:

Q = discharge in ft^3/s neglecting velocity of approach
L = length of crest (ft)
H = depth of flow above elevation of crest (ft)

- **Suppressed Rectangular Weir**

$$Q = 3.33LH^{3/2}$$

Where:
Q = discharge, (ft^3/s)
L = length of crest (ft)
H = depth of flow above elevation of crest (ft)

- **Contracted Cipolletti Weir (trapezoidal)**

$$Q = 3.367\ L\ H^{3/2}$$

Where:
Q = discharge, (ft^3/s)
L = length of crest (ft)
H = depth of flow above elevation of crest (ft)

- **Fully Contracted Standard 90-Degree V-Notch Weir**

$$Q=2.49H^{2.48}$$

Where:
Q = discharge, (ft^3/s)
H = depth of flow above elevation of crest (ft)

NOTE: The user may choose to use any one of a variety of orifice shapes or geometries. Regardless of the selection, the orifice will initially act as a weir until the top of the orifice is submerged. See Figure 3-10. Therefore, the discharges for the first stages of flow are calculated using the weir equation.

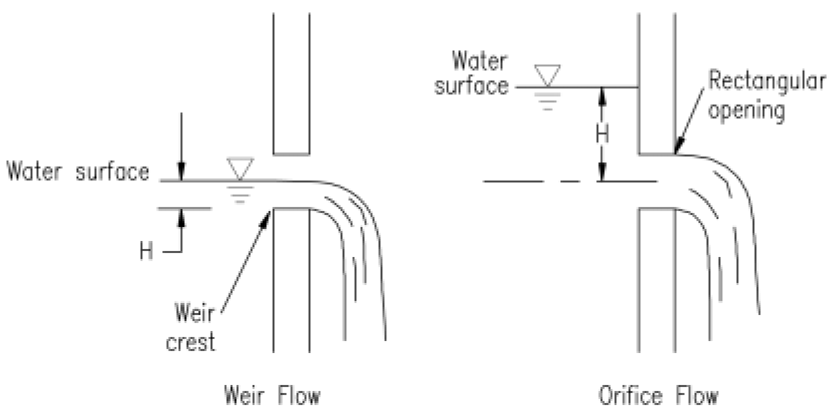


Figure 3-10: Weir and Orifice Flow

3. OUTLET STRUCTURE TYPE - INLET BOX

This structure is an inlet riser with its opening oriented parallel with the water surface. It is typically made from a modified pre-cast catch basin. During low head flow the perimeter of the structure behaves as a weir. As the head increases, the flow transitions from a weir to horizontal orifice condition. The flow can be calculated using the orifice and suppressed rectangular weir equations as described above for the respective condition.

The transition from weir to orifice flow is not instantaneous; rather it occurs during a "zone" of transition. For the purposes of this manual, the transition height shall be considered the head elevation over the structure when the weir flow equals the orifice flow.

4. OUTLET STRUCTURE TYPE – CULVERT

There are various types of culverts for outlet structures, the circular culvert with inlet control being the most widely used. The user is referred to Section 3.2.6 for culvert design.

Full height concrete headwalls, or wingwalls, shall be installed on the inlet end of all culvert structures. Anti-seep collars shall be designed and installed on the length of the culvert through the embankment (See Section 3.4.10).

3.4.7Hydrograph Routing Procedures and Resources

Of the various methods available to route a flood flow through a detention pond, the **storage-indication method** will be the only one discussed briefly in this manual. If additional information is needed on other routing techniques, it is suggested that the user refer to the SCS's National Engineering Handbook Section 4 Hydrology (reference 49).

The primary idea behind a routing is to determine the impact that the detention pond will have on the inflowing flood peak by using the **continuity equation.** The equation can be thought of as **Inflow** (to the detention basin) minus **outflow** (from the detention basin) equals **change in storage** (in the detention basin). In equation form:

$$I_{ave} + S_1/dt - O_1/2 = S_2/dt + O_2/2$$

where:
S_1 - is the storage at t1 (the beginning of the routing interval).
O_1 - is the outflow at t_1
S_2 - is the storage at t_2 (the end of the routing interval).
O_2 - is the outflow at t_2.
I_{ave} - is the average inflow for the time interval $(I_1 + I_2)/2$.

The following steps can be used to route a flood hydrograph through a detention basin by "hand", using the storage indication method.

Step 1: **Develop stage-storage curve for the detention pond**. This curve can be developed using procedures discussed in Section 3.4.5. The storage units should be consistent with the stage-discharge curve (such as acre-feet or cubic feet).

Step 2: **Develop a rating curve for the outlet structure**. The rating curve can be developed using procedures discussed in Section 3.4.6. The rating curve will show the discharge for a given elevation for the outlet structure. The discharge should be expressed in units that are consistent with the storage volume. Units of acre-feet will result in numbers that are considerably smaller than if cubic feet are used. (One acre-foot = 43560 cubic feet, one cubic foot/second = .083 acre-feet /hour).

Step 3: **Combine the curves developed** in steps 1 & 2 to form a relationship between storage and discharge. The following table is an example of storage volumes and discharges for a range of elevations.

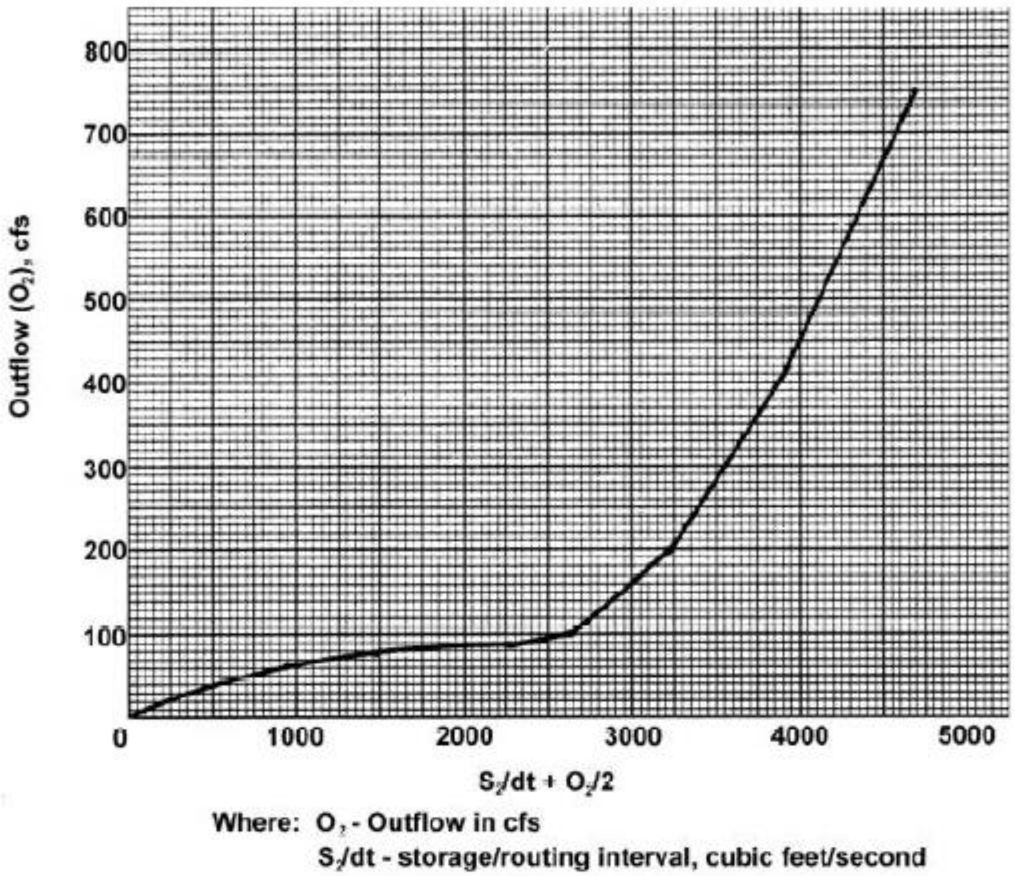
Table 3-5: Storage-Discharge Relationship (Example)

Elevation	Storage	Discharge
	100,000	
feet	cubic feet	cfs
604.3	0.0	0
606.0	8.3	61
607.0	13.1	74
608.0	17.9	87
609.0	23.1	100
610.0	28.3	200
611.0	33.5	420
612.0	38.8	750

Step 4: **Select a routing interval (dt)**. Typically for small watersheds the routing interval will be less than an hour, usually 0.25 hour to 0.5 hour.

Step 5: **Prepare the working curves**, and plot O_2 versus $S_2/dt + O_2/2$ (Figure 3-11). Using the storage-discharge relationship in Table 3-5, an example working curve is developed below:

FIGURE 3-11: Working Curve (Example)



Step 6: **Set-up operations table**. Column 1 contains the time at the selected increment, and column 2 contains the inflow taken from the inflow hydrograph. The average inflow in column 3 is the average of the flow at the current time and the previous time interval. As an example, at a time of 0.50 hrs, the average inflow of 43 cfs is the average between 0.25 hrs (30 cfs) and 0.50 hrs (55 cfs).

TABLE 3-6a: Working Table A (Example)

(1) Time	(2) Inflow	(3) Avg. Inflow	(4) $S_2/dt=O_2$	(5) O_2
(hrs)	(cfs)	(cfs)	(cfs)	(cfs)
0.00	0	0		
0.25	30	15		
0.50	55	43		
0.75	80	68		
1.00	100	90		
1.25	138	119		
1.50	190	164		
1.75	380	285		
2.00	610	495		
2.25	785	698		
2.50	850	818		
2.75	730	790		
3.00	620	676		
3.25	485	552		
3.50	440	463		
3.75	395	418		
4.00	370	383		
4.25	335	353		
4.50	315	325		

The last two columns (4 & 5) will be completed during the routing.

Step 7: **Route the inflow through the detention pond**.

The routing would include:

a) Determine inflow, storage, and outflow for initial conditions. In many cases, the initial inflow, outflow, and storage will be 0.

b) Subtract outflow (column 5) from column 4 and add average inflow (column 3) for the next time increment. The computed value is placed in column 4 for the next time increment. (In the table below under initial conditions, columns 4 and 5 are each 0. At the time of 0.25 hours, the average inflow is 15 cfs. Column 4, at the time of 0.25 hours, is equal to 0 - 0 + 15 = 15). As a further example, at the time of 0.75 hours, column 4 shows a value of 123 cfs; from Figure 3-11, the outflow in column 5 is 11 cfs; the average inflow at time 1.00 hour is 90 cfs. Column 4 at 1.00 hours is 123 - 11 + 90 = 202).

TABLE 3-6b: Working Table B (Example)

(1) Time	(2) Inflow	(3) Avg. Inflow	(4) $S_2/dt{=}O_2$	(5) O_2
(hrs)	(cfs)	(cfs)	(cfs)	(cfs)
0.00	0	0	0	0
0.25	30	15	15	1
0.50	55	43	57	2
0.75	80	68	123	11
1.00	100	90	*202	

* (123 - 11 + 90)

c) From the plot of $S_2/dt + O_2$ vs. O_2, determine the outflow O_2, for the computed value of $S_2/dt + O_2$. As examples, from Figure 3-11, when $S_2/dt + O_2 = 123$, the outflow is 11 cfs; when $S_2/dt + O_2 = 202$, $O_2 = 19$ cfs.

TABLE 3-6c: Working Table C (Example)

(1) Time	(2) Inflow	(3) Avg. Inflow	(4) $S_2/dt{=}O_2$	(5) O_2
(hrs)	(cfs)	(cfs)	(cfs)	(cfs)
0.00	0	0	0	0
0.25	30	15	15	1
0.50	55	43	57	2
0.75	80	68	123	11
1.00	100	90	202	19
1.25	138	119	302	27
1.50	190	164	439	33
1.75	380	285	724	50
2.00	610	495	1169	70
2.25	785	698	1797	81
2.50	**850**	818	2534	95
2.75	730	790	3229	200
3.00	620	675	3704	343
3.25	485	552	3913	413
3.50	440	463	3963	**433**
3.75	395	418	3948	422
4.00	370	383	3809	408
4.25	335	353	3854	392

d) Repeat the steps until routing is complete.

The results of the partial routing indicate that the peak inflow has been reduced from a discharge of 850 cfs, to an outflow of 433 cfs. From the outlet rating curve (Table 3-5) the maximum stage on the detention pond is 611.1 feet.

If required, the routing could be continued until the entire outflow hydrograph is developed.

Hand routing of **hydrographs** through storage facilities is very time consuming, especially when several different designs are evaluated. It is encouraged for the designer to use one of the many available computer programs to perform **hydrograph** routing and modeling of storage facilities. The following are sources for **hydrograph** routing computer programs:

- Haestad Methods "PondPack"

  http://www.haestad.com/software/pondpack

- HydroCAD

  http://www.hydrocad.net

3.4.8Emergency Spillway Design

An emergency spillway must be included to handle storms greater than the 100-year storm . An emergency spillway typically consists of a wide channel cut over the embankment to provide a flow path for a major storm event. The spillway must be designed and installed to protect against erosion problems.

The banks should be constructed such that a minimum of one (1) foot of freeboard is above the emergency spillway.

3.4.9Berm Embankment/Slope Stabilization

- Pond embankments are exempt from the ODNR Dam classification if the following are met; 1) is 6 feet or less in height regardless of total storage, 2) less than 10 feet in height with not more than 50 acre-feet of storage, or 3) not more than 15 acre-feet of total storage regardless of height. If the embankment does not meet these criteria, the design is subject to review and approval from ODNR.

  NOTE: Height of dam is defined as the vertical dimension as measured from the natural streambed at the downstream toe of a dam to the low point along the top of the dam.

- Pond embankments over six (6) feet shall require design by a Geotechnical or Civil engineer licensed in the State of Ohio. For berm embankments of 6 feet or less (including 1 foot freeboard), minimum top width shall be 6 feet or as recommended by the geotechnical or civil engineer.

- Pond berm embankments must be constructed on native consolidated soil (or adequately compacted and stable fill soils analyzed by a geotechnical report) free of loose surface soil materials, roots and other organic debris.

- Exposed earth on the side slopes and bottom should be sodded or seeded with the appropriate seed mixture as soon as is practicable. If necessary, geotextile or matting may be used to stabilize slopes while seeding and sodding become established.

3.4.10 Anti-Seep Collar Design

An anti-seep collar shall be installed on conduits through earth fills. The following criteria apply to anti-seep collars:

A. Spacing between adjacent collars shall be between 5-14 times the vertical projection of each collar.

B. Place all collars within the saturation zone.

C. All anti-seep collars and their connections shall be watertight.

3.4.10.1 Methodology

The assumed normal saturation zone (phreatic line) shall be determined by projecting a line at a slope of 4:1 from the point where the normal water depth (riser grate) touches the upstream slope of the embankment to a point where this line intersects the invert of the culvert. The area below this projected line is assumed to be within the saturated zone.

The length of the saturated zone (Ls) must first be determined). The nomograph below should then be used to determine the number and size of collars.

$L_S = y (z + 4) [1 + (\text{pipe slope}/(0.25 – \text{pipe slope}))]$

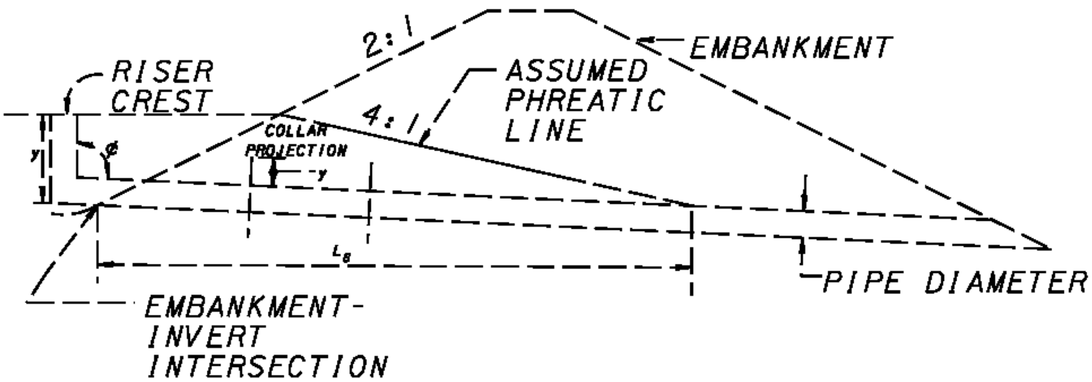
Where: L_S = length of pipe in the saturated zone (ft.)

y = distance in feet from upstream invert of pipe to highest normal water level expected to occur during the life of the structure, usually the top of the riser.

z = slope of upstream embankment as a ratio of z ft. horizontal to 1 ft., vertical.

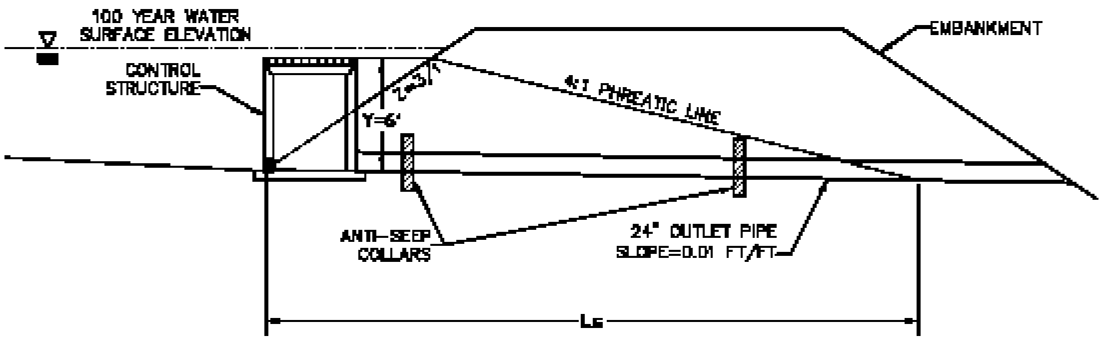
Pipe slope = slope of pipe in feet per foot.

FIGURE 3-12: Anti-Seep Collar Schematic



3.4.10.2 Example

FIGURE 3-13: Anti-Seep Collar Design (Example)



Step 1: Determine Saturation Length (Ls):

Ls = Y(Z+4)[1+(PIPE SLOPE/(.25-PIPE SLOPE))]

Given: Y = 6'
Z = 3/1
Pipe Slope = 0.01

Ls = 6'(3+4)[1+(0.01/(.25-0.01))]
Ls = 6'(7)[1+0.04166]
Ls = 43.75'

Step 2: Determine Size of Collars:

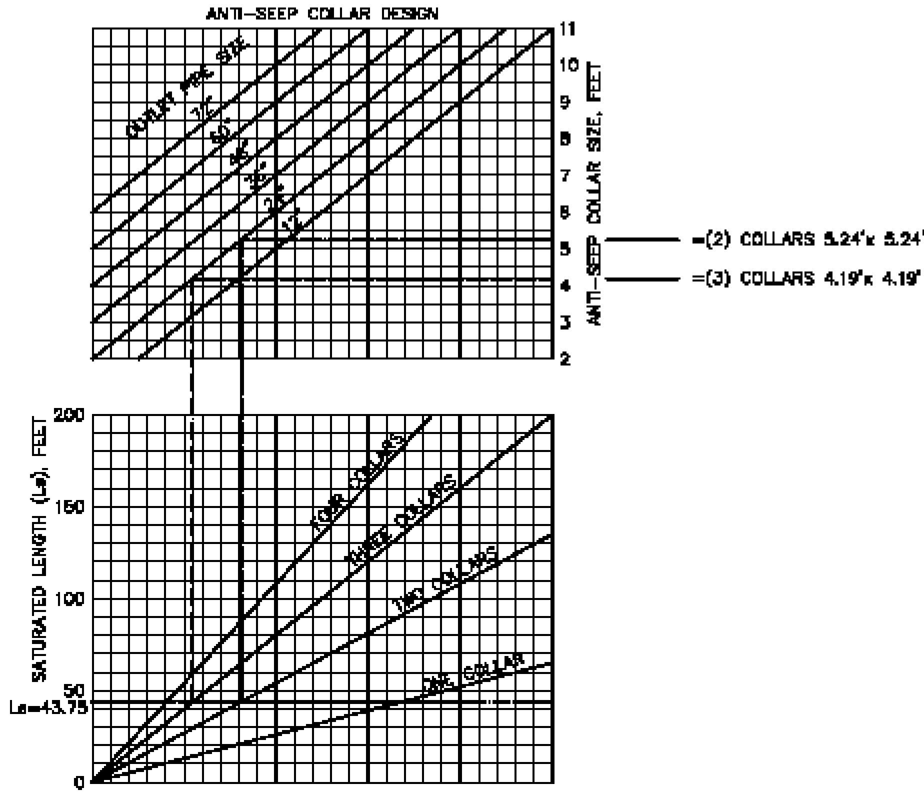
Beginning from the lower graph with an Ls = 43.75'

- 1-4 collars may be used, however spacing may limit the amount.

Assuming 2 collars – project up to the 24" pipe at a collar size = 5.24'x5.24'

Assuming 3 collars – project up to the 24" pipe at a collar size = 4.19'x4.19'

FIGURE 3-14: Anti-Seep Collar Graph



A blank copy of the anti-seep collar graph is included in the appendix.

Step 3: Spacing of the Collars:

- Note that the collars must be fully in the saturated zone.
- Spacing can vary from 5-14 times the vertical projection of the collars. The vertical projection is defined as the height of the collars above the outlet pipe.

The 5.24' collars have a vertical projection above the 24" outlet pipe = (5.24'-2')/2 = 1.62'. Therefore, the collars need to be spaced (1.62'*5) up to (1.62'*14) feet apart, or 8.1' to 22.68', respectively.

The 4.19' collars have a vertical projection above the 24" outlet pipe = (4.19'-2')/2 = 1.10'. Therefore, the collars need to be spaced (1.10'*5) up to (1.10'*14) feet apart, or 5.5' to 15.4', respectively.

- The length of the saturation zone may limit the number of collars that can fit based upon their minimum spacing requirements.

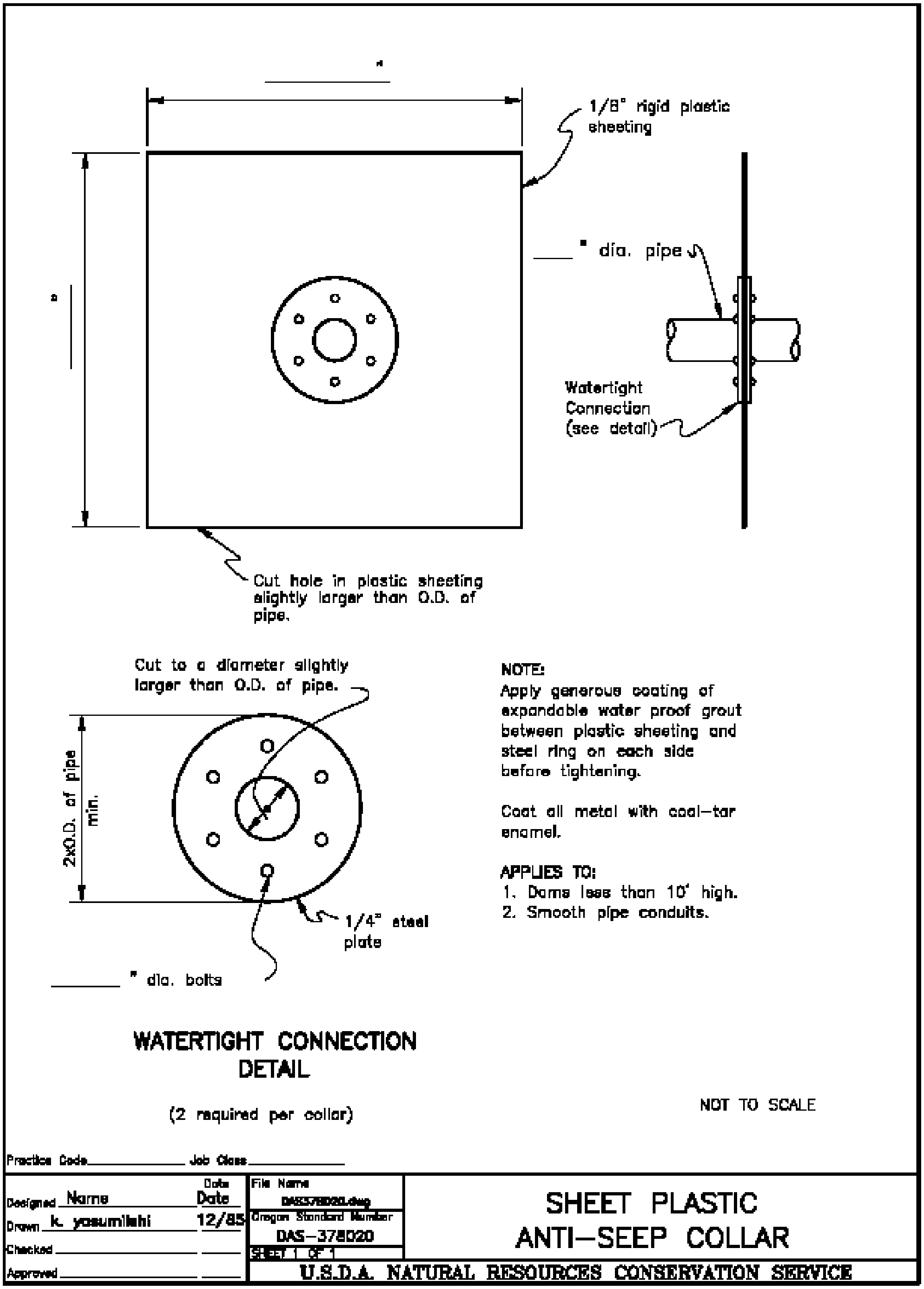
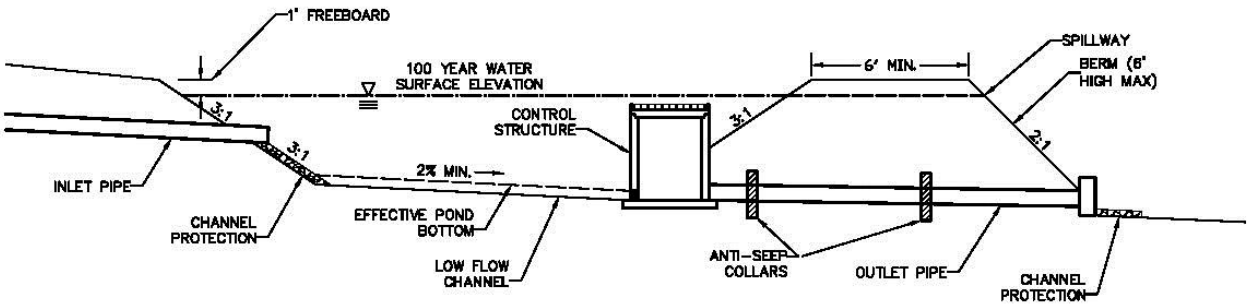


FIGURE 3-15: Anti-Seep Collar Detail

FIGURE 3-16: Typical Pond Section



TYPICAL SECTION – DRY DETENTION POND

SECTION 4 POST-CONSTRUCTION STORMWATER MANAGEMENT REQUIREMENTS

4.0POST-CONSTRUCTION STORMWATER MANAGEMENT REQUIREMENTS

4.1OVERVIEW

Post-construction **runoff** controls are permanent controls which are intended and shall be designed to increase or maintain a receiving stream's physical, chemical and biological characteristics. In addition, stream functions are maintained and post-construction **Stormwater** practices shall provide continued management of both quality and quantity facilities.

Detailed drawings and maintenance plans shall be provided for all post-construction **Best Management Practices** (**BMP's**). Maintenance plans shall also be provided by the permittee to the post-construction operator of the site (including homeowner associations). For sites located within a community with a regulated municipal separate storm sewer system (MS4), the permittee, land owner or other entity with legal control over the property shall be required to develop and implement a maintenance plan to comply with local MS4 requirements. The use of innovative and/or emerging **Stormwater management** post-construction technologies shall be at the discretion of the Mahoning County **Engineer** and could require monitoring to ensure compliance with current OEPA Construction General Permit (CGP) requirements. The Post-Construction portion of the **Stormwater** Pollution Prevention Plan shall include the following required elements:

- Description of post-construction **BMP's** to be installed during construction. Description shall include estimated installation schedule and sequencing plan.
- Rationale for selection shall incorporate anticipated impacts on the **channel** and floodplain, morphology, hydrology and water quality.
- Detailed Post-Construction **BMP** drawings shall be provided.
- **BMP** Maintenance plan- Maintenance plan shall be developed for all **BMPs** selected and presented to post-construction operator.
- Maintenance plan shall include a disposal statement for structural **BMP's**- Ensure pollutants collected within structural **BMP's** are disposed of in accordance with local, state and federal regulations.
- Linear Projects – No net increase in **impervious** areas, no need to comply with post-construction conditions of the CGP permit. Linear projects must minimize number of stream crossings and width of disturbance. **Erosion** and **sedimentation** controls are required for all projects with a minimum of 1-**acre** of land disturbance. Linear projects shall be required to document land disturbance area estimates and develop an **erosion**/**sedimentation** control plan.

4.2Post-Construction Stormwater Control Method

The Mahoning County **Engineer** requires that the increased peak rates and volumes of **Stormwater runoff** shall be controlled to reduce **sediment** laden pollution from entering public waterways and protect **watercourses** and water bodies from the effects of

erosion caused by accelerated **Stormwater runoff** from developed or developing areas.

For large construction activities that will disturb five or more **acres** of land or will disturb less than five **acres** but is part of a **larger common plan of development** or sale which will disturb five or more **acres** of a land, the post-construction **Stormwater** control methods chosen shall meet the following criteria:

1. The peak discharge rate of **runoff** from the **critical storm** and all more frequent storms occurring under post-development conditions does not exceed the peak discharge rate of **runoff** from a two (2)-year frequency, 24-hour storm occurring on the same **development drainage area** under pre-development conditions. The peak discharge rate of **runoff** from the one (1)-year storm post-developed conditions shall not exceed the one (1)-year storm pre-developed conditions.

2. Storms of less frequent occurrence (longer return periods) than the **critical storm** up to the 100-year storm have peak **runoff** discharge rates no greater than the peak **runoff** rates of the pre-developed 10 year storm.

3. The **critical storm** for a specific **development drainage area** is determined as follows:

   a. Use SCS TR-55 or other appropriate and approved hydrologic simulation model to determine the total volume (**acre**-feet) of **runoff** from a two (2)-year, 24-hour storm occurring on the **development drainage area** before and after development. Include clearly in your calculations the **lot** coverage assumptions used for full build out of the proposed condition. Curve numbers for pre-developed or improvements or expansion to a developed condition must reflect the average type of land use over the past 10 years and not only the current land use. *(To account for unknown future cosmetic improvements to a construction site, an assumption of an* ***impervious*** *surface such as asphalt or concrete must be utilized for all parking areas or driveways, even if stone/gravel is to be utilized in construction.)*

      For sites which are currently developed and are scheduled to be re-developed, the pre-developed condition shall be defined to be 100% of the site as grassland for critical storm and volume storage calculations.

   b. From the volumes determined in (a) above, determine the percent increase in volume of **runoff** due to development. Using this percentage, select the **critical storm** from Table 4-1:

TABLE 4-1:
Critical Storm Determination Table

IF THE PERCENTAGE OF INCREASE IN VOLUME OF RUNOFF IS:		THE CRITICAL STORM WILL BE:
EQUAL TO OR GREATER THAN:	LESS THAN:	
	10	**1 year**
10	20	**2 year**
20	50	**5 year**
50	100	**10 year**
100	250	**25 year**
250	500	**50 year**
500		**100 year**

(For example, if the percent increase between the pre-development and post-development **runoff** volume for a 2 year storm is 35%, the **critical storm** is a 5-year storm. The peak discharge rate of **runoff** for all storms up to this frequency shall be controlled so as not to exceed the peak discharge rate from the 2-year frequency storm under pre-development conditions in the **development drainage area**. The post-development **runoff** from all less frequent storms need only be controlled to meet the pre-development peak discharge rate for the 10 year storm.)

In no case shall the post developed runoff exceed the pre-developed runoff condition for an equivalent storm event.

4.3Post-Construction Design Methodology

The structural **BMP** selected shall be additionally sized for protection of **watercourses** from **erosion** (quantity) and include water quality volumes for controlling **sediment** volumes. The following method is taken directly form the OEPA's construction general permit:

- WQ_v = Volume of **runoff** from a 0.75 inch rain event (Blended average rainfall event).
- WQ_v determined according to one of the two following methods:
-
    - Through a site hydrologic study approved by the Mahoning County Engineers Office that uses continuous hydrologic simulation and local long-term hourly precipitation records or,
    - Using the following equation: WQv = C * P * A/12

Where:

WQv = **channel** protection and water quality volume in **acre**-feet

C = **runoff** coefficient appropriate for storm less than 1 inch (See Table 4-2)

P = 0.75 inch precipitation depth

A = area draining into the **BMP** in **acres**

TABLE 4-2:
Runoff Coefficients Based on Type of Land Use for (WQv) Calculation

Land Use	Runoff Coefficient (C)
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 the 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 Stormwater 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

- An additional volume equal to 20 percent of the WQv shall be incorporated into the BMP for sediment storage and/or reduced infiltration capacity during construction.
- BMP's shall be designed such that the drain time is long enough to provide settlement treatment, but short enough to provide storage available for successive rain events as described in Table 4-3 below.

TABLE 4-3:
Target Drawdown (Drain) Times for Structural Post-Construction Treatment Control Practices

Best Management Practice (BMP)	Drain Time of WQv
Infiltration Basin^	24 - 48 hours
Enhanced Water Quality Swale	24 hours
Dry Extended Detention Basin*	48 hours
Wet Extended Detention Basin **	24 hours
Constructed Wetlands (above permanent pool)***	24 hours
Sand & OtherMedia Filtration	40 hours
Bioretention Cell^	40 hours

Best Management Practice (BMP)	Drain Time of WQv
Pocket Wetland^^	24 hours
Vegetated Filter Strip	24 hours

* Dry basins must include forebay and micropool each sized at 10% of the WQv
** Provide both a permanent pool and an extended detention volume above the permanent pool, each sized at 0.75 * WQv
***Extended detention shall be provided for the full WQv above the permanent water pool
^ The WQv shall completely infiltrate within 48 hours so there is no standing or residual water in the BMP
^^ Pocket wetlands 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.

4.4 Recommended Post-Construction Best Management Practices

The following post-construction best management practice controls are identified in OEPA's CGP and shall be incorporated in project development and design. OEPA has identified nine structural **BMP's** to be considered and incorporated into **Stormwater management** for site development. The Mahoning County **Engineer** will also consider non-structural practices in combination with these structural practices in reviewing site plans. The Mahoning County **Engineer** requires supporting documentation of non-structural **BMP** estimated pollutant removal information, map of BMP locations on-site, description of **BMP** type, and frequency with which the **BMP** will be performed or maintained. Examples of non-structural BMP's include: site **impervious** area sweeping, natural buffers, creative mowing practice, etc. The nine (9) post-construction structural **BMP's** (as presented in the CGP) are addressed below.

The County Engineer will consider alternatives to these structural post-construction **BMP's** after all have been considered during the project development process. Supporting rationale as to why they cannot be implemented, designed or incorporated into the site development must be provided. The County Engineer reserves the right to review and recommend alternatives or accept/reject alternatives based on level of maintenance requirements, public health or safety risks, limited water quality benefits and functionality.

SECTION 5 STORMWATER POLLUTION PREVENTION PLANS AND EROSION/SEDIMENTATION CONTROL REQUIREMENTS

5.1Submittal and Review

The Storm Water Pollution Prevention Plan (**SWP3**) shall be prepared in accordance with sound engineering and/or conservation practices by a professional engineer (P.E.) registered in the State of Ohio or A Certified Professional in Erosion and Sediment Control (CPESC) experienced in the design and implementation of standard **erosion** and **sedimentation** controls and **storm water management** practices addressing all phases of construction. The following are required as part of the SWP3:

- Permittee shall make the SWP3 available upon request of the local agency approving **sediment** and **erosion** control plans, grading plans, **storm water** pollution prevention or **storm water management** plans, to local governmental officials, or to operators of Municipal Separate Storm Sewer Systems (MS4) receiving **drainage** from the permitted site.

- Two copies shall be submitted, one set for Mahoning County **Engineer** and one set for Mahoning County **Soil and Water Conservation District**.

- During site development, layout and planning, consideration shall be given to selection of proper **erosion and sediment control** practices and designs. Site layout and **drainage** shall integrate sound **erosion** and **sedimentation** practices and should be developed or design by **persons** experienced in **drainage**, hydraulics, **storm water management** or other **erosion** and **sedimentation** control techniques.

- The following statement shall be included with all submitted **erosion** and **sedimentation** control plans and **SWP3** plans:

- *I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gathered and evaluated the information submitted. Based on my inquiry of the **person** or **persons** who manage the system or those **persons** directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief true, accurate and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.*

5.2 SWCD Requirements

Minimum Standards: The SWPPP must address all minimum components of the Mahoning County Erosion and Sediment Control Rules, Ohio EPA Construction General Permit and be designed in accordance with specifications of the Rainwater and Land Development handbook, published by the Ohio Division of Natural Resources (ODNR) in cooperation with the Ohio EPA and the Natural Resources Conservation Service.

- When greater than one (1) acre of earth disturbance is to occur during a land development project, a *Storm Water Pollution Prevention Plan* must be submitted to the Mahoning Soil & Water Conservation District 30 days prior. This should coincide with submittal of construction drawings to the Township Zoning Department or the Mahoning County Engineer's office, whichever is applicable. The fee for the review of the SWPPP is due at this time, payable to the Mahoning SWCD.

- The proposed SWPPP will be reviewed by the Urban Conservationist at the SWCD. Initial review comments will be returned to the developer within 21 calendar days. The plan will be revised as needed until deemed appropriate to effectively control erosion and sedimentation on the site. An approval letter will be forwarded to respective entities.

- Following approval of the SWPPP, a pre-construction meeting must be scheduled. Attendees of this meeting should be the owner/developer, contractor, design engineer, staff of the SWCD and county engineer. The purpose of this meeting is to: 1) determine an exact construction sequence; 2) ensure that all responsible parties understand the SWPPP in its entirety; 3) determine responsible parties for all aspects of SWPPP implementation; 4) provide signatures of pertinent parties for SWCD files.

- Following the pre-construction meeting, earth disturbance on the site may begin according to plans.

- Designated, qualified personnel on construction site are to perform and document erosion and sediment control inspection per terms of Construction General Permit.

- SWCD staff will conduct inspections to determine compliance with terms of permit.

- Prior to recording of plat, all erosion and sediment controls must be in place, functioning as designed and approved by Mahoning SWCD.

5.3 Notice of Termination

- Filing **Notice of Termination** (**NOT**) - Terms and conditions of this permit shall remain in effect until a signed **Notice of Termination** form is submitted. Failure to submit a **NOT** constitutes a violation of this permit and may affect the ability of the permittee to obtain general permit coverage in the future.

- Submitting an **NOT** - Compliance with this permit is required until an **NOT** form is submitted (Form is included in Appendix D). Permittee's authorization to discharge under this permit terminates at midnight of the day the **NOT** form is submitted. All permittees must submit an **NOT** within 45 days of completing all permitted land disturbance activities. Enforcement actions may be taken if a permittee submits an **NOT** form without meeting one or of the following conditions:

    - **Final stabilization** has been achieved on all portions of the site. Another operator has assumed control over all areas of the site that have not been finally stabilized. Final stabilization status will be determined by Mahoning SWCD or OEPA. Owner, or appointed representative, may request inspection upon completion of project, prior to submittal of NOT.
    - Temporary **stabilization** has been completed and the **lot** has been transferred to homeowner (residential construction only).
    - Individual **lots** sold by the developer without housing must undergo **final stabilization** prior to termination of permit coverage (residential construction only).

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