CITY OF OXFORD

HOME OF MIAMI UNIVERSITY

Stormwater Management Design Manual

Revised May 2017

The purpose of stormwater management is to provide for effective management of a stormwater system within the city; to provide mechanism for mitigating the damaging effects of uncontrolled and unplanned stormwater runoff; to improve the public health, safety, and welfare by providing for the safe and efficient capture and conveyance of stormwater runoff and the correction of stormwater problems; to establish and implement a master plan for storm drainage including design, coordination, construction, management, operation, maintenance, inspection, and enforcement; and to encourage and facilitate urban water resources management techniques including detention of stormwater runoff, minimization of the need to construct storm sewers, and the enhancement of the environment. In order to accomplish the purpose of stormwater management, to protect the drainage facilities, improvements, and properties owned by the city, to secure the best results from the construction, operation, and maintenance thereof, and to prevent damage and misuse of any of the drainage facilities, improvements, or properties within the city, the City Engineer may make and enforce rules and regulations that are approved by the City Manager, and are necessary and reasonable:

(1) To prescribe the manner in which storm sewers, ditches, channels, and other stormwater facilities are to be designed, installed, adjusted, used, altered, or otherwise changed.

(2) To prescribe inspection and other fees permitted by this manual.

(3) To prescribe the manner in which such facilities are operated.

(4) To facilitate the enforcement of this manual.

(5) To protect the drainage facilities, improvements, and properties controlled by the division, and to prescribe the manner of their use by any public or private person, firm, or corporation.

(6) To protect the public health, safety and welfare.

Submission of a plan under provisions of this Design Manual shall not relieve any person from responsibility for damage to any person or property otherwise imposed by law, nor impose any liability upon the City for damage to any person or property.

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CHAPTER 1. INTRODUCTION

1.1 General

The City of Oxford (City) is responsible for all aspects of stormwater management in the City including creating a master plan for rehabilitating and establishing public stormwater facilities; financing, constructing, inspecting, and maintaining such facilities; collecting fees and charges for the associated services; and enforcing the provisions of this manual. It shall not be responsible for sanitary or combined sewers; sub-surface drainage systems intended solely to reduce hydrostatic pressure; and erosion, siltation, and sedimentation that do not affect stormwater facilities. Additionally, it shall maintain private facilities only when landowners fail to do so or when public health and safety is threatened and only at the landowner's expense.

All improvements made within the City that changes stormwater runoff or require new stormwater facilities and/or changes to existing facilities must be submitted to the City Engineer for review and approval. The City must approve beforehand, any construction, alteration, or change in any watercourse.

The purpose of this design manual is to provide organization and direction for mitigating the damaging effects of stormwater runoff in the City of Oxford.

In order to enforce the requirements of the design manual, the City Engineer may inspect construction premises and notify owners when the work does not comply with the design manual or the approved plans. When permitted, the City Engineer may issue a stop work order, revoke a permit, or abate an emergency condition.

The design manual contained herein provides engineering tools for developing control policies and procedures whereby the policies can be followed. Compliance with this design manual does not relieve Owners of compliance with all applicable codes and ordinances.

The design manual is not a text of hydrology or hydraulic design. It assumes the user has an understanding of hydrology and hydraulic engineering. It does not provide uniform solutions to all drainage problems. Stormwater system design presents an opportunity for the creative and innovative design engineer. The engineer should not be restricted to standardized designs or procedures. Nor should the City insist on rigid adherence to a standard set of design specifications. As reflected in this portion, the emphasis should be on performance.

The design manual provides a uniform design procedure and worksheets for summarizing and submitting the design plans in an acceptable and understandable manner to the City. While the designer is not restricted to these recommended procedures or worksheets, sufficient documentation must be provided with any submission to ensure that methods, procedures, and data are clear.

This design manual provides sufficient information to develop drainage systems in accordance with local policy. For a design engineer, such systems begin with the first drop of rainfall and end when the water is safely discharged to receiving waters having adequate channel and overbank capacity.

Rainfall is the first design element to be considered. This phenomenon is basic to the design of stormwater facilities. The following chapters outline the proper use of rainfall information and appropriate data sources relevant to the City of Oxford.

The behavior of rainfall on the ground, when it becomes runoff is responsive to a number of variables. Watershed area and shape, ground, slope, soils, seasons, and impervious areas determine the characteristics of runoff. Conveyance facilities, such as streets, storm sewers, culverts, and open channels, need to be used. Sample calculations, acceptable performance standards, and design situations are contained herein.

Often temporary storage of stormwater through controlled release is required to meet runoff control requirements. Stormwater runoff storage may be accomplished in many ways. Controlled release of stormwater runoff is the fundamental policy in this design manual. Standards for achieving a controlled release rate are detailed herein.

Drainage is only one part of a complex urban system. Drainage considerations do not have to dominate site development decisions. Yet, drainage does have its place on the site planner's checklist and is a very important function in the City's role to protect health and welfare.

1.2 Planning

The development of an urban drainage plan requires the consideration of four drainage elements. These are: minor drainage system, major drainage system, storage, and erosion and water quality control.

Planning and design must consider the regular, frequently occurring storm, that is, the minor storm, and the less frequent but more extensive major storm occurrence. Planning for storage is essential to insure water will go where it will not create a problem. Erosion and water quality controls must be considered before the earth is disturbed and significant losses and damage occur.

1.3 Minor Drainage System

The minor drainage system includes street curbs and gutters, underground storm sewer pipes and manholes, open drainageways, culverts, gutters, and small open channels. Its purpose is to eliminate inconveniences associated with runoff and to prevent health hazards associated with low areas where water might ordinarily stand. This portion of the urban drainage system has received the most attention from engineers and is what most citizens consider to be the total urban drainage system. It is what directly contributes to orderly community development by handling, without nuisance, the flow of most common storms.

Early planning can do more than provide a functional drainage system. The preliminary layout of the system has more effect on the cost of the storm sewers than the final hydraulic design, preparation of the specifications, and choice of materials. The ideal time to undertake the layout of the storm sewers is prior to finalization of street layout in a new development. Once the street layout is set, the options open to the drainage engineer are greatly reduced.

Streets serve an important and necessary drainage service, even though their primary function is for the movement of traffic. Traffic and drainage uses are compatible up to the point at which drainage must be subservient to traffic needs. Gutter flow in streets is necessary to transport runoff to storm inlets. Good planning of streets can help reduce the size and length of a storm sewer system. The longer street flow can be kept from concentrating in a street, the further the distance from a ridge line the storm sewer can begin. This is significant because a larger part of storm sewer construction cost is represented by small diameter laterals. Various layout concepts should be developed, reviewed, and analyzed to arrive at the best layouts.

1. 4 Major Drainage System

It is not economically feasible to size a storm sewer system to collect and convey infrequent storm runoff. However, runoff which exceeds the capacity of the storm sewer system must have a route to follow. Essentially, the complete drainage system of an urban area contains two separate drainage elements. While the storm sewers belong to the minor drainage system, surface drainage-ways must be provided for the major flow from more intense storms.

The intent of planning for the major drainage element is to ensure that stormwater runoff which exceeds the capacity of the minor drainage system has a route to follow which will not cause a major loss of property or any loss of life. It should be remembered that the major drainage system exists even when it is not planned and whether or not development takes place wisely with respect to it.

Street rights-of-way are a common choice for conveying major drainage flows. Again, such use must be anticipated when the street layout is established. Side and rear lot lines offer one alternative to the street. The problem with this alternative is the possibility that individual property owners may usurp the major drainage easement. Rarely is the problem recognized until the infrequent rainstorm occurs and the major system fails to operate properly.

1.5 Storage

The emphasis of policy in these rules and regulations is to control the increase of runoff resulting from development with various storage mechanisms. While considerable storage can be achieved within channels and storm sewers and on lawns and natural surface depressions, it is likely that special storage or detention facilities (either single or multipurpose) will have to be established for new development. Like the remainder of the drainage system, both the location and type of storage facilities should be determined as part of the site plan.

Park land presents an excellent opportunity for the temporary detention of runoff from adjacent areas. In many cases, the use of park land for this purpose allows storm drainage, which is often considered both a nuisance and a hazard, to be used productively in permanent ponds.

Alternative storage procedures should be explored and evaluated for their appropriateness within different developments. Parking lots, rooftop storage, permanent pools, infiltration trenches, and other procedures may be used and are discussed in Chapter 4. The greatest chance for success can be achieved if storage is considered at the earliest stages of site planning.

1.6 Erosion and Water Quality Control

Erosion is a natural process, and zero erosion is an unrealistic goal. However, accelerated erosion which occurs at the time of development when land surfaces are cleared of vegetation can create costly problems. Accelerated erosion may undermine and weaken foundations of buildings. Once deposited in streams and storm sewers, sediment can block the flow of water causing upstream flooding and even forcing streams to cut new channels.

Erosion and water quality control must be programmed into the development process. It must be considered as part of the land disturbance activity.

CHAPTER 2. GENERAL PROVISIONS AND POLICIES

There are a number of general provisions that must be met by any drainage system plan. The items include, but are not necessarily limited to, the following.

2.l Control of Stormwater Runoff

This design manual is premised on the policy that land uses and development which increase the runoff rate or volume shall be required to control the discharge rate of runoff prior to its release to off-site land. The purposes of this policy are to:

A. Allow development without increasing the flooding of other lands.
B. Reduce damage to receiving streams and impairment of their capacity and quality which may be caused by increases in the quantity and rate of water discharged.
C. Establish a basis for design of a storm drainage system which will preserve the rights and options of all property owners and assure the long-term adequacy of storm drainage systems.

This runoff control policy applies to all land developments and redevelopments, except land prepared for agricultural crops, orchards, wood lots, sod farms and nursery operations, land grading or leveling for erosion control under direction of the local soil conservation district, and land subdivisions for residential purposes with minimum lot size of 1 acre or more. When a phased construction is planned, total land area to be developed shall be considered when planning stormwater facilities.

2.2 Failure to Complete Detention Facilities

If a permit is granted conditioned an providing a detention facility, and the development work has begun prior to completion of the detention facility, the City Engineer is authorized to take such action as deemed necessary to ensure that the detention facility is completed.

2.3 Joint Development of Stormwater Control System

Stormwater control systems may be planned in coordination with two or more property owners. When jointly planned, a joint maintenance agreement from all property owners shall be required before approving such facility. This agreement shall be recorded by the property owners with the Butler County Recorder’s Office and a copy provided to the City Engineer.

2.4 Maintenance of Detention Facilities

Detention facilities can become quite obtrusive to the character of the area. If not maintained, these facilities tend to become polluted, visually and materially.

The owner of the property or his agent shall maintain the facility, both functionally and aesthetically. Outlets and inlets shall be drained; erosion remedied; trees, grass, and weeds cut; and other maintenance performed.

For facilities belonging to the City of Oxford, it shall be the duty of the City Engineer to oversee the maintenance of these facilities.

Maintenance of stormwater facilities belonging to other public agencies or jurisdictions and located within the City of Oxford shall be required of each of those agencies or jurisdictions.

2.5 Stormwater Runoff Control Criteria

Stormwater runoff control addresses peak rate of runoff.

A. The peak rate of runoff from an area after development shall not exceed the peak rate of runoff from the same area before development for 1-, 2-, 5-, 10-, 25-, 50-, and 100-year frequency, 24-hour storm.

2.6 Multijurisdiction Activities

The City of Oxford is surrounded by Butler County. Stormwater, in its trek to an outlet, does not respond to jurisdictional boundaries. Therefore, cooperation between adjoining political jurisdictions is necessary for proper discharge of stormwater.

If the stormwater plan developed under this design manual is in conflict with other jurisdictions, the City Engineer may request a waiver when it is determined that such an exception will enhance the management of stormwater. When stormwater enters the City of Oxford from adjoining watersheds, the City Engineer will request that new facilities in the adjoining body abide by the contents of this design manual.

If necessary, the City Engineer will meet with the designer of these facilities and provide any appropriate assistance. When the City of Oxford contributes runoff to adjoining bodies, the City of Oxford facilities shall be designed and constructed in accordance with this design manual.

2.7 National Flood Insurance Program

Various areas of the City of Oxford and Butler County are included in the National Flood Insurance Program. These areas are defined in the 100-year storm flooded area and included in the Federal Emergency Management Agency (FEMA) Flood Insurance Study (FIS) Reports.

The flooded area is based on Flood Boundary and Floodway Maps prepared by the FEMA for the City of Oxford and Butler County. The maps for the City of Oxford are available for review at the City's office and the County maps are available at the County Engineer's office.

2.7.l Flood Protection Within the Development

Finished floor elevations including basements shall be set a minimum of l foot above the 100-year water level computed within the development. For commercial or industrial developments, dry flood proofing may be substituted in lieu of elevating the finished floor.

2.7.2 Development Within Areas of Special Flood Hazard (100-year Flood)

All development within areas of special flood hazard, as defined by the FIS Reports, or as determined by the City Engineer, shall comply with the following requirements:

A. Establish, to the satisfaction of the City, the elevation of the base flood (100-year flood) at the site of the development. As-built certification is required by a registered surveyor, architect, or professional engineer.
B. Set the minimum finished floor elevation including basement at least 1 foot above the elevation of the base flood for all developments. For commercial or industrial developments, the substitution of dry flood proofing in lieu of elevating the finished floor may be allowed on a case-by-case basis.
C. Provide compensating storage for all flood water displaced by development below the elevation of the base 100-year flood. Compensating storage is to be accomplished between the normal high water of the special flood hazard area and the estimated 100-year flood elevation.

All developments within riverine flood hazard areas shall be designed to maintain the flood carrying capacity of the floodway such that the base flood elevations are not increased, either upstream or downstream.

2.8 Subdivision Regulations
The City has prepared “Rules and Regulations” for subdivision designs. This design manual shall be adhered to in the subdivision of land for private use and street developments.

The City will review the plans and specifications submitted for the development to evaluate the stormwater facilities and to ensure conformance with the rules and regulations and the master plan so developed. The basic design data included in the subdivision regulations shall be used and augmented with the design manual included herein. The most stringent requirements shall be used if a variation is found between the two codes.

2.8.1 Off-site Drainage

Water from off-site areas should drain into a natural drainage course, sewer system, or detention facility.

Off-site areas which drain to or across a site proposed for development must be accommodated in the stormwater management plans for a development. The stormwater management system for the development must be capable of transporting existing off-site flows through or around the development without increasing stages or flows upstream or downstream of the development. The estimation of the off-site flows must be done separately from the estimation of on-site pre- and post-development flows (i.e., separate off-site and on-site hydrographs must be computed, due to the typically significant differences in land user characteristics). It is strongly recommended that the applicant meet with the City engineering staff prior to generating final detailed design calculations, in order to establish off-site drainage design requirements for a particular project.

2.8.2 Phased Projects

Projects that are to be developed in phases will normally require the submission of a master plan of the applicant's contiguous land holdings and/or anticipated purchases of adjacent land. The City's primary interest is to ensure continuity between phases, satisfactory completeness of individual phases should the project be incomplete as planned, and preservation of adjacent property owners' rights. This includes adjacent property owners created by the sale of incomplete phases.

2.9 Easements

Drainage easements shall be required where necessary. Easements shall follow the lot lines where feasible. Off-site easements for stormwater management facilities shall be required when either of the following conditions exist:

A. The discharge is into any man-made facility for which the City does not have either a drainage easement or right-of-way.

B. The discharge is into a natural system such that the rate or character (i.e., sheetflow vs. concentrated flow) of the flow at the property line has been changed. The easement will be required to a point at which natural conditions are duplicated.

On both sides of any watercourse or drainage channel, easements for stormwater drainage shall be provided adequate for maintenance and/or improving such watercourse or channel for drainage purposes as indicated on the plan. All easements shall contain a parcel number; a reference to actual property involved; a metes and bounds description or map description; restriction clause; statement of adoption and conformance; notarized statement acknowledging owner's voluntary act in signing easement; and deed reference. In addition, the easement shall be in a form so that it can be recorded in Butler County by the County Clerk thereby satisfying any additional requirements imposed by the Recorder’s Office. Once the easement has been properly prepared, it shall be submitted to the City for acceptance and then recorded with the Recorder’s Office.

2.10 Swimming Pool Discharge

Discharge from swimming pool filter systems is defined as wastewater and shall be discharged into sanitary sewers. The water pumped directly from pools shall be considered as stormwater and may be discharged into stormwater systems. Also, the discharge from drainage systems around pools shall be connected to stormwater systems.

2.11 Cooling Water Discharge

Water discharged from cooling facilities or processed water may not be connected to the stormwater system unless specifically approved by the City. A National Pollutant Discharge Elimination System (NPDES) permit from the Ohio Environmental Protection Agency (Ohio EPA) is required for all processed water. If approval is granted by the Ohio EPA and the City Engineer, then such waters may be discharged into the storm drainage system.

2.12 Oil Runoff

Discharge from parking lots and other facilities that contains large quantities of oil must have the oils removed prior to being discharged into the storm drainage system.

2. 13 Trees

Any new tree plantings shall be at least 10 feet from any stormwater facility. An exception to this may be above ground detention ponds where trees may be needed for aesthetic or any other reason.

2.14 Private Streets

Drainage facilities located on private street and private property (unless City owned) are the responsibility of the property owner. Discharge from private facilities into the public system must conform to this design manual.

2.15 Bonds

The City of Oxford requires a security bond for any construction work involving excavation, sewer extension, and embankment over a storm sewer.

2.16 Filling of Streams and Watercourses

No part of a stream or watercourse may be filled in unless such amount of preempted cross section is compensated for by an equivalent amount of channel excavation. No filling of streams or watercourses shall be allowed unless approved by the City Engineer.

CHAPTER 3. STORMWATER FACILITIES DESIGN PROCESS AND DRAINAGE REQUIREMENTS

3.l General

The City Engineer has the authority to review all plans and issue a permit. The facility projects that require plans submitted to the City Engineer are described herein. The City Engineer is designated as the person who is responsible for the review of plans and specifications for all stormwater facilities for approval. Various types of review by the City Engineer shall consist of, but not be limited to, the fallowing.

A. Projects by the City or other agencies of the City.
B. Facilities for other public bodies.
C. Plans prepared by consulting engineers for stormwater facilities belonging to private organizations and individuals.
D. Stormwater facilities included in building projects.

For each improvement involving stormwater control facilities, a submittal shall be made to the City outlining the work to be accomplished. The submittals to construct stormwater facilities may be made directly to the City or through the building permit process.

Where stormwater facilities are planned in connection with building projects, approval for the stormwater facilities alone shall be a part of the building permit system. The Community Development Department shall submit the appropriate portions of the plans to the City Engineer for review and comment. Where ~~a~~ approval is to be granted for stormwater projects only, the plan shall be reviewed and approved by the City Engineer.

The developer, the person requesting approval, or his engineer shall discuss the proposed stormwater plan, while still in sketch form, with the City Engineer so that a mutual agreement can be reached as to the general concept.

Subsequently, three sets of plans, and two sets of specifications, calculations, and other supporting data shall be transmitted to the City.

3.2 Design Process for the Public Agencies

The City of Oxford has a master plan for the development of stormwater facilities within the corporate boundaries. Whenever it is desired to have a portion of this master plan implemented or for other reasons of municipal need, plans shall be drawn for these facilities. These plans may be provided by the City.

For stormwater facilities designed by other public bodies, such as the Ohio Department of Transportation (ODOT), the submittals shall be as follows. Plans and specifications shall be submitted to the City along with calculations, drawings, and other supporting data with a memo describing the proposed work.

3.3 Design Process for Private Applicants

For the facilities being planned by individuals or private corporations, the submittal shall be as follows:

Step I — The owner or his engineer shall submit a sketch plan and meet with the City Engineer, if preliminary analysis and direction.

Step II — The owner or his agent shall make an application for the proposed new facilities.

Step III — The owner or his agent shall pay any fees as is required by the current City of Oxford Fee Ordinance.

Step IIIa — For private development or multiple owners, the owners shall submit a maintenance agreement and state who is the owner of the facility.

Step IV — The City Engineer shall review the submitted plans and submit his review within 30 days of the application date.

Step V — If the plans are approved, a permit shall be granted.

Step VI — If the plans are not approved, changes shall be made and resubmitted to the City Engineer.

Step VII — The City Engineer shall review the plans again and return his findings within 30 days.

Step VIII — Approval shall be granted. The final payment of review fees shall be made as per the current City of Oxford Fee Ordinance.

3.3.1 Fees

The City shall collect a fee or assessment for the following:

A. Permit and Inspection Fees, payable at the City's office.

B. Direct charges. This charge shall be collected from owners and developers for the cost of designing and constructing stormwater facilities and for the administrative costs and related expenses when the City designs and/or constructs or contracts for the construction of such facilities.

C. Direct assessment. This charge shall be collected from owners in localized areas that desire stormwater drainage facilities not considered a part of the regional development or where an improvement is desired ahead of the priority status.

D. Inspection and plan review. Fees for review shall be based on an hourly rate reasonably related to the cost to the City. The owner is responsible for all plan review and inspection fees. A deposit shall be required to provide for plan review and/or inspection.

3.4 Drainage Plan Submittals

The drawings submitted in the application for approval shall be prepared in a manner generally following these guidelines.
Plans shall be submitted on 24” x 36” sheets. The plans shall have a title block containing the name of the project, owner, engineer, and scale.

The preliminary sketch or concept plan shall be in sufficient detail to identify drainage flows entering and leaving the development and general drainage patterns. Drawings shall be at a scale large enough to show the positions of all drainage from the upper end of any off-site basins that will affect the project to be constructed. Drawings shall identify any major construction, channels, storm sewers, sanitary sewers, existing detention and stormwater facilities, culverts, etc., along the entire path of the drainage route.

<u>All storm drainage plans and calculations must be signed and sealed by a Professional Engineer registered in the State of Ohio, in accordance with State law.</u>

All construction shall be done in accordance with specifications of and subject to inspection by the City of Oxford.

The information included in the plans submitted for review to the City shall contain, but not be limited to, the following.

A. Drainage boundaries, including all areas draining to the proposed subdivision.
B. Sufficient topographical information with elevations to verify the location of all ridges, streams, etc. (2-foot contour intervals). All elevations shall correlate to the United States Coast and Geodetic Survey datum unless waived by the City Engineer.
C. High water data on existing structures upstream and downstream for the subdivision.
D. Notes indicating sources of high water data.
E. Notes pertaining to existing standing water, areas of heavy seepage, springs, wetlands, streams, etc.
F. Property lines, all existing and proposed easements (public or private).
G. Existing drainage features (ditches, roadways, ponds, etc.). Existing drainage features are to be shown for a minimum distance of 1,000 feet downstream of the proposed development unless the ultimate outfall system is a lesser distance.
H. Subdivision layouts with horizontal and vertical controls.
I. Drainage features, including locations of inlets, swales, ponding areas, etc.
J. Delineation of drainage subareas.
K. Detention areas shown and ingress/egress areas for detention facilities.
L. General type of soils present (obtain from soil survey of Butler County).
M. The 100-year flood elevations for any areas in or within 100 feet of the property. The source of these elevation statistically shall also be shown on the plans.
N. Description of current ground cover and/or land use.
0. Existing and proposed land use including appropriate area in acres.
P. Plans and profiles of proposed stormwater facilities with grades and sizes.
Q. Street rights-of-way and other pertinent details, such as north arrows.

R. Erosion control plan.

3.5 Stormwater Calculations

Stormwater calculations shall be submitted to sufficiently review the project end shall include, but not be limited to, the following.

3. 5. l Storm Sewers

A. Location and type of structures, including downspouts.
B. Type and length of line.
C. Drainage subbasin tributary to each structure.
D. Runoff coefficient per subbasin.
E. Time of concentration to structure.
F. Each stormwater flow to and from drainage structure or junction point.
G. Hydraulic gradient for the 10-year, 25-year, and 100-year frequency storm event.
H. Estimated receiving water elevation for each frequency storm with sources of information, if available.
I. Diameters of pipes.
J. Outlet and pipe velocities.
K. Typical section of swale, ditch, or channel.
L. For any existing or proposed detention facility, incorporate information outlined in Article 3.5.2 of this section.

3. 5. 2 Detention Areas

Pre- and post-development stormwater calculations for detention areas, including design high water elevations for 1-, 2-, 5-, 10-, 25-, 50-, and 100-year storm events, shall include, but not be limited to, the following:

A. Predevelopment hydrograph, post-development runoff hydrograph to the stormwater pond, and the routed post-development hydrograph discharged from the stormwater pond.
B. Stage area storage calculations for the stormwater pond.
C. Stage discharge calculations for the outfall control structure.
D. Recovery calculations for the stormwater pond.
E. Soil storage or curve number calculations per subbasin.
F. Time of concentration calculations per subbasin.
G. Routing of off-site drainage flow through the project.
H. 100-year floodplain compensating calculations, if applicable.
I. Cross section of retention/detention facilities.
J. Typical swale, ditch, or channel section.
K. Drainage easements including drain impoundment limits.
L. Fencing plan, if any.
M. Ingress/egress easements.
N. Erosion control plan.
0. Maintenance plan and/or agreement as needed.

3.6 Datum for Elevations

All reference to datum used for elevations shall correlate to the United States Coast and Geodetic Survey datum unless waived by the City Engineer.

3.7 Revision to Plan and Specifications

Nothing in this code shall prohibit the filing for revisions to plans and specifications at any time during which the application is being processed by the City and before the permit is issued or the application is rejected. Such changes shall be made a part of the plans and specifications and filed as such. Approval of the City Engineer is necessary for all plan changes affecting stormwater drainage.

3.8 Construction of Stormwater Facilities

Design and construction of stormwater drainage facilities shall be in accordance with these rules and regulations in addition to ODOT construction and material specifications and city supplements to these specifications.

3.9 Finished Construction Plans

As-constructed finished plans (As-Builts) for all improvements shall be submitted to the City before the acceptance of the improvements.

The as-constructed finish plans (As-Builts) shall be submitted on mylars and as an AutoCad file.

City of Oxford
Building Permit Application
Sample
Site Plan Check List

Street and No. ______________________________________ Building Permit No. ________________

Owner _________________________________ Address _______________________________________

Information requested to be show on the site plan

Item	Indicated	Not Indicated
1. Engineers, architect or surveyors seal; directional arrow		
2. Title, scale (Min. Scale: 1"=50'), date, vicinity map, benchmark		
3. Distance from intersection street		
4. Existing and proposed contours or elevations		
5. Existing and proposed building or structures (with dimensions)		
6. Easements		
7. Location and size of all existing sewers (storm, sanitary)		
8. Location of all proposed sewers, manholes, and inlets		
9. Watercourses, drainage ditches (natural and manmade)		
10. Location of downspouts, leaders, and storm lateral		
11. Parking layout, with dimensions and driveways Showing drainage and type of pavement and curbs		
12. Location of street sewers and inlets		
13. The geographical position of both the natural features and the works of man indicate areas to remain undisturbed.		
14. Lot dimensions with bearings		
15. Lot area in square feet		
16. Street status (existing or proposed), dedicated or private.		

Survey Complete: Yes ______ No _____ By: ______________________________

Date: _____________________________

Remarks:____
____

Form T3-1

CHAPTER 4: BEST MANAGEMENT PRACTICES

4.1 PURPOSE

The purpose of this chapter is to provide the reader with guidance, options and tools that can be used to protect the City's water quality, enhance the City's water availability and reduce the City's flooding potential through effective stormwater management. These readers include, but are not limited to, the City staff, planners, land developers, engineers, contractors, and others involved with planning, designing, reviewing, approving, and constructing land development projects.

This chapter and its accompanying Appendixes describe a stormwater management approach to the land development process that strives to:

- prevent or minimize stormwater problems through comprehensive planning and development techniques, and
- mitigate any remaining potential problems by employing non-structural and structural Best Management Practices (BMPs).

Readers are strongly encouraged to follow the progression of prevention first and mitigation second. Throughout this chapter the concept of an integrated stormwater management program, based on a broad understanding of the natural land and water systems, is a key and recurring theme. Such a thorough understanding of the natural systems demands an integrated approach to stormwater management, so critical to "doing it better, doing it smarter."

This chapter provides guidance on managing all aspects of stormwater: rate, volume, quality, and groundwater recharge. Controlling the peak rate of flow during extreme rainfall events is important, but it is not sufficient to protect the quality and integrity of the Greater Oxford area streams. Reducing the overall volume of runoff during large and small rainfall events, improving water quality, and maintaining groundwater recharge for wells and stream flow are all vital elements of protecting and improving the quality of all streams and waterways.

The City of Oxford also recommends all site designers to review the contents of Chapter 1 and 2, Ohio Department of Natural Resources' Rainwater and Land Development Manual. It describes more thoroughly common impacts to prevent as well as the major objectives to apply in order to protect water resources during the development process. Understanding the nature of the impacts prepares site designers to better manage these through alternative site layout and the implementation of practices.

4.2 MISSION AND GOALS

Mission

As with all municipalities, the City of Oxford (Oxford) looks towards future growth and re-development as a key component to its health and vitality. However, with these improvements and modifications come tradeoffs and consequences of which increase storm water runoff is one. Increases in impervious surfaces, decreases in natural water holding and filtering areas, and the potential of more severe storm events all add up to larger volumes of water over shorter periods of time – only amplifying erosion, flooding and pollution problems already documented or creating entirely new pragmatic situations.

Oxford is dedicated to developing a storm water management program that contributes to protecting the environment. This includes coordinating with others towards this common goal, continuing with and improving upon the successful programs the City currently has in place, and providing educational information and opportunities to the residents of Oxford.

Oxford will achieve its mission by encouraging proactive involvement through leadership in developing innovative solutions for community environmental concerns.

Goals

1. Protect existing and new development by minimizing the increase of storm water runoff volume beyond that experienced under predevelopment conditions and by reducing peak storm water flows.
2. Promote responsible land use practices in all areas of the watersheds of the Greater Oxford area, particularly within floodplains and floodways.
3. Protect existing water resources, including lakes, streams, floodplains, wetlands and groundwater, from detrimental and unnecessary modifications so that their beneficial functions are maintained and public expenditures and damages are minimized.
4. Integrate non-structural BMPs with structural BMPs in the City's storm water management program, as strongly recommended by the Ohio EPA.

4.3 STATE REQUIREMENTS

Stormwater management has regulatory support in the form of programs administered by the Ohio EPA including: the NPDES Permit for Discharges Associated with Construction Activities and the NPDES Permit for Small Municipal Separate Storm Sewer System (MS4) programs, as well as under the Ohio Water Pollution Control Act (Ohio Revised Code Chapter 6111). The most current OEPA MS4 General Permit can be viewed at:

http://www.epa.ohio.gov/dsw/storm/index.aspx

These regulatory programs utilize narrative based effluent limitations in the form of BMPs to achieve the regulatory standard of preventing pollution. BMPs used to manage post construction stormwater runoff must ultimately protect the water quality of special protection waters and protect, maintain, and restore water uses for all surface waters.

- Ohio EPA's Phase II National Pollutant Discharge Elimination System (NPDES**)**

The U.S. EPA has determined the best way to mitigate storm water impacts is to use practices to treat, store, and infiltrate runoff onsite before it can affect water bodies downstream. Innovative site designs that reduce imperviousness and smaller-scale low impact development practices dispersed throughout a site are excellent ways to achieve the goals of reducing flows and improving water quality. The U.S.

EPA recommends that communities addressing the post-construction minimum measure should focus on low impact development and smart growth as key components to their storm water program.

In 2005, Oxford was included in the Ohio EPA's Phase II NPDES storm water program. The development, implementation, and enforcement of this stormwater management program is intended to reduce pollutant discharges from Oxford's storm water runoff to the maximum extent practical under current state law, to help protect surface water quality and channel stability in the tributaries and Four Mile Creek cross- and down-gradient from Oxford, and to comply with the Ohio EPA's Phase II storm water program and the appropriate water quality requirements of Ohio Revised Code 6111 (Water Pollution Control).

- Guidance, Options and Tools

In order to successfully manage stormwater, thus avoiding or minimizing increased flooding, water quality degradation, stream channel erosion, reduced groundwater recharge, and/or loss of aquatic species, a more thorough and comprehensive effort must be direct towards creating better site designs.

Traditional post-construction site design has focused on the peak rate of runoff during large storm events; that is, how fast the stormwater runoff is leaving the site after development. Detention facilities are built to slow down the rate of runoff leaving a site during large storms so that the rate of runoff after development is not greater than the rate before development. While this is extremely important, it does not do enough to protect streams and water quality. With a change in land surface, such as with a housing development, not only does the peak rate of runoff increase, the volume of runoff also increases. While a stormwater detention facility may slow the rate of runoff leaving a site, there may still be an increased volume of runoff.

For example, little runoff will occur from most wooded sites until over an inch of rainfall has fallen. In contrast, a paved site will generate runoff almost immediately. After development, runoff will occur with greater frequency than before development, and runoff may be observed with every rainfall. The design of stormwater systems that collect, convey and concentrate runoff may further degrade conditions. Thus the combination of more runoff, more often and at higher rates will create localized flooding and damage even in small storm events.

Today's post-construction site designs, on the other hand, incorporate pollution controls and stream protection as important design elements. Imbedding non-structural and structural BMPs within these site designs reduce pollutants, meet state and local permits and reduce downstream erosive effects of runoff. While all stormwater management practices require maintenance, the City has focused on those that emphasize lower maintenance and provide self-sustaining processes.

4.4 APPENDIX DESCRIPTIONS

- Appendix I - A Recommended Site Design Procedure for Comprehensive Stormwater Management

Not all of these BMPs are appropriate for all land development activities or every site. How can BMPs be selected to maximize their performance? What is the optimal blend between non--structural and structural BMPs? How can stormwater management be best integrated into the site planning process?

A flow chart depicting a Site Design Procedure for Comprehensive Stormwater Management (Procedure) is set forth in this Appendix. This procedure begins with an assessment of the site and its natural systems and then proceeds to integrate both non-structural and structural BMPs in the formulation of a comprehensive stormwater management plan. The intent of the planning process is to promote development of stormwater management "solutions" which achieve the rigorous quantity and quality standards set forth within State and City regulations.

- Appendix II - Non-Structural Best Management Practices (BMPs)

These developmental concepts integrate site design and planning techniques that preserve natural systems and hydrologic functions on a site through the use of non-structural BMPs. Non-structural BMP deployment is not a singular, prescriptive design standard but a combination of practices that can result in a variety of environmental and financial benefits. Reliance on non-structural BMPs encourages the treatment, infiltration, evaporation, and transpiration of precipitation close to where it falls while helping to maintain a more natural and functional landscape. The BMPs described in this Appendix preserve open space and working lands, protect natural systems, and incorporate existing site features such as wetlands and stream corridors to manage stormwater at its source. Some BMPs also focus on clustering and concentrating development, minimizing disturbed areas, and reducing the size of impervious areas. Four non-structural examples are contained in this Appendix – Low Impact Development (LID), Conservation Development, Stream Setbacks, and Wetland Setbacks. Other non-structural BMPs may exist but are not identified in this manual.

- Appendix III - Structural Best Management Practices (BMPs)

Structural BMPs are specifically engineered measures that are designed to reduce and mitigate the impacts of development. They are much more location specific and explicit in their physical form than non-structural BMPs. Many structural BMPs are based on natural systems and rely upon vegetation and soil mechanisms in order to perform as intended while others are considered more conventional "brick and mortar" techniques.

The use of the "structural BMPs" is considered the second step in stormwater management design (non-structural BMPs being the first step). As mentioned earlier, the primary objective in stormwater management is to maximize stormwater "prevention" through use of non-structural BMPs. Once prevention has been maximized, some amount of stormwater peaking and volume control will likely remain to be managed. These stormwater management needs should be met with an array of natural-system based structural BMPs which includes a wide variety of practices and devices, from large-scale retention ponds and constructed wetlands, to small-scale underground treatment systems, infiltration facilities, filter strips, bioretention, wet ponds, permeable paving, grass swales, sand filters, detention basins, manufactured devices, etc.

- Appendix IV- Best Management Practices References

For a more thorough understanding of best management practices, it is encouraged to review this appendix. It contains more comprehensive descriptions and specifications of each non-structural and structural BMPs.

This information is in various forms.

- Manuals
- Books
- Journals and Research Papers
- Web Sites

This information originates from various sources.

- Individual Field Experts
- National Associations
- Universities
- Federal, State and Local Governments
- Federal, State and Local Organizations

4.5 APPENDIX I – RECOMMENDED SITE DESIGN PROCEDURES FOR COMPREHENSIVE STORMWATER MANAGEMENT (BEST MANAGEMENT PRACTICES)

Obviously, not all of these BMPs are appropriate for all land development activities or every site. How can BMPs be selected to maximize their performance? What is the optimal blend between non- structural and structural BMPs? How can stormwater management be best integrated into the site planning process?

A flow chart depicting a Site Design Procedure for Comprehensive Stormwater Management (Procedure) is set forth in Figure 1. This procedure begins with an assessment of the site and its natural systems and then proceeds to integrate both non-structural and structural BMPs in the formulation of a comprehensive stormwater management plan. The intent of the planning process is to promote development of stormwater management "solutions" which achieve the rigorous quantity and quality standards set forth within State and City regulations. Some aspects of the procedure will not be fully applicable in all land development cases. For example, non-structural BMPs may be challenging to apply in those cases where higher densities/intensities are proposed on the smallest of sites in already developed areas.

An essential objective of the Procedure is to maximize stormwater "prevention" through use of non-structural BMPs. Once prevention has been maximized, some amount of stormwater peaking and volume control will likely remain to be managed. These stormwater management needs should be met with an array of natural-system based BMPs (Vegetated Swales, Vegetated Filter Strips, etc.), with the remaining stormwater management needs met with structural BMPs such as infiltration basins, trenches, porous pavement, wet basins, retention ponds, constructed wetlands, and others.

This Procedure, or a process similar to it, is an integral part of comprehensive stormwater management and transcends the bounds of conventional stormwater management that has existed in most Ohio municipalities. Perhaps most importantly, the Procedure involves the total site design process. Conventional stormwater management has usually been relegated to the final stages of the site design and overall land development process, after most other building program issues have been determined and accommodated. To the contrary, the Procedure places stormwater management in the initial stages of site planning process, when the building program is being fitted and tested on the site. In this way, comprehensive stormwater management can be integrated effectively into the site design process.

4.5.1 SITE PLANNING AND DESIGN PROCEDURE

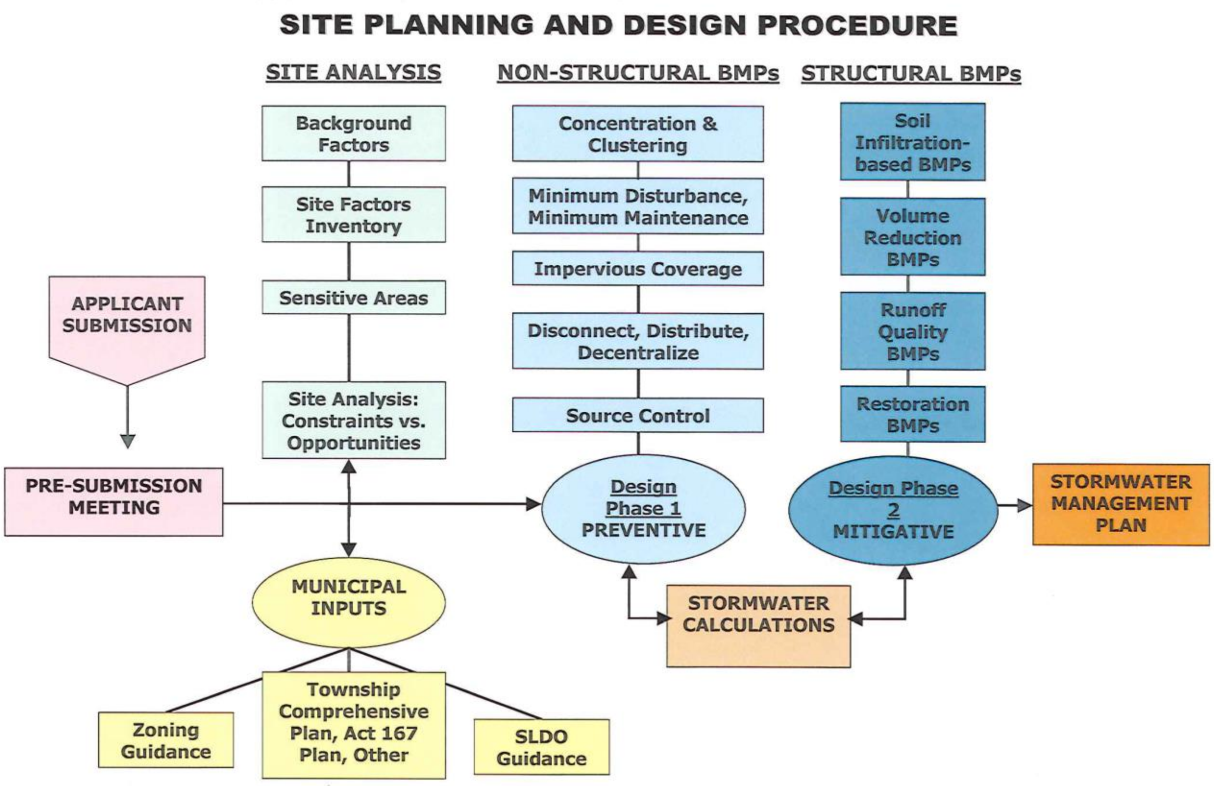


Figure 1

Much of the information relied on for the Procedure is information already required to satisfy other aspects of existing municipal land development ordinances. The Procedure is intended to more effectively utilize this already-collected site data to generate better stormwater management in the context of a markedly improved site plan. To the extent that this information is not already being collected and assessed, the information needs to be collected as part of the site design process.

4.5.2 SITE DESIGN CHECKLIST FOR COMPREHENSIVE STORMWATER MANAGEMENT

Coordinated with the Recommended Site Design Procedure for Comprehensive Stormwater Management is a series of questions structured to facilitate and guide an assessment of the site's natural features and stormwater management needs. The Site Design Checklist for Comprehensive Stormwater Management is intended to help facilitate the Procedure.

A) BACKGROUND SITE CONDITIONS - SITE ANALYSIS

Background Site Features

- Describe hydrologic context and other natural elements:
  - Ohio EPA stream use designation (Beneficial Use Designation, OAC 3745-1-08 to 3745-1-32, with 3745-1-21 addressing the Great Miami River Drainage Basin)
    - Special Protection Waters
    - Fishery/Aquatic Life Use
  - Any U.S. EPA Chapter 303(d)/impaired stream listing classification
  - Aquatic biota sampling
  - Existing water quality sensitivities downstream (water supply source)
  - Location of any known downstream flooding
  - Includes any Special Areas
  - Brownfields
    - Ohio EPA Beneficial Use Designation
    - Urban Areas
    - Carbonated Limestone
    - Slide Prone areas
    - Other

Site Factors Inventory

- Describe the size and shape of the site:
  - Special constraints/opportunities
  - Special site border conditions and adjacent uses
- Describe the existing developed features of the site (if any):
  - Existing structures/improvements, structures to be preserved
  - Existing cover/uses
  - Existing impervious areas
  - Existing previously maintained areas
  - Existing public sewer and water
  - Existing storm drainage systems at/adjacent to site
  - Existing wastewater, water systems onsite
- Describe Important natural features of site:
  - Existing hydrology (drainage swales, intermittent/perennial waterways
  - Existing topography, contours, sub-basins
  - Soil series found onsite and their Hydraulic Soil Group ratings
  - Areas of vegetation (trees, scrub, shrub)
  - Special Value Areas Such as:
    - Wetlands, hydric soils
    - Floodplains/alluvial soils
    - High quality woodlands, other woodlands and vegetation
    - Riparian buffers
    - Naturally vegetated swales/drainage ways
    - Sensitive Areas
    - Steep Slopes
    - Special geologic conditions (limestone)
    - Shallow bedrock (less than 2 feet below grade)
    - High groundwater table (less than 2 feet below grade)
    - Ohio Natural Heritage Database areas or species

Site Factor Analysis

- Characterize the constraint-zones at the site
  - Avoid development on or near special and sensitive natural features
- Characterize the opportunity-zones at the site
  - Location of well-draining soils
  - Location and quality of existing vegetation
  - Has a Potential Development Area been defined
  - Does building program fit the constraints and opportunities of natural features

B)

BACKGROUND SITE CONDITIONS – MUNICIPAL INPUT

Municipal and/or Township Comprehensive Plan and Zoning guidance:

- Guidance in Comprehensive Plan
- Existing Zoning District
  - Total number of units allowed
  - Type(s) of units
  - Density of units
- Any allowable options

Municipal and/or Township Subdivision and Land Development Ordinance (SLDO) guidance and options:

- Performance standards for neo-traditional, subdivision/land development planning
- Reduce building setbacks
- Curbs required
- Street width, parking requirements, other impervious requirements
- Cut requirements
- Grading requirements
- Landscaping requirements

Municipal and/or Township SLDO/storm water requirements:

- Peak rate and design storms
- Total runoff volume
- Water quality provisions
- Methodological requirements
- Maintenance requirements

Is applicant submission complete, and fully responsive to municipal zoning/SLDO requirements

Are municipal zoning/SLDO requirements inadequate

Is useful interaction at sketch plan or pre-sketch plan phases occurring

C) **DESIGN PHASE 1: PREVENTIVE – NON-STRUCTURAL BMPs**

Lot Concentration and Clustering:
- Reduced individual lots size
- Concentrate/cluster uses and lots
- Configure lots to avoid critical natural areas
- Configure lots to take advantage of effective mitigative practices
- Orient built structures to fit natural topography
- Minimize site disturbance (excavation / grading) at site
- Minimize site disturbance (excavation / grading) for each lot

Minimum Disturbance/Maintenance:
- Define disturbance zones for site Such as:
  - Protect maximum total site area from development disturbance
  - Protect naturally sensitive and special areas from disturbance
- Minimize total site compaction
- Maximize zones of open space and greenways
- Consider re-forestation and re-vegetation opportunities

Impervious Coverage Reduction:
- Reduce road widths and/or lengths
- Utilize turnarounds and/or Cul-de-sacs with vegetated islands
- Reduce driveway lengths and widths
- Reduce parking ration
- Reduce parking sizes
- Examine potential for shared parking
- Utilize porous surfaces for applicable parking features (overflow)
- Design sidewalks for single-side movement

Disconnect/Distribute/Decentralize
- Rooftop Disconnection
  - Existing downgradient yard are opportunities
  - Existing downgradient vegetated areas/woods
- Disconnection from storm sewers/street gutters
  - Front/side yard opportunities
  - Space for vegetative swales, rain gardens, etc.

Source Control
- Provisions for street sweeping Other

D) **DESIGN PHASE 1: MITIGATIVE – STRUCTURAL BMPs**

Volume/Peak Rate Through Infiltration:

- Porous Pavement with Infiltration Beds
- Infiltration Basins
- Infiltration Trenches
- Rain Garden/Bioretention
- Dry Wells/Seepage Pits
- Vegetated Swales
- Vegetated Filter Strips
- Infiltration Berm/Retentive Grading

Volume/Peak Rate Reduction:

- Vegetated Rooftops
- Capture and Reuse:
  - Cisterns
  - Rain Barrels
  - Other

Runoff Quality/Peak Rate Reduction:

- Constructed wetland
- Wet pond/retention basin
- Dry extended detention basin
- Water quality filters: constructed and Other:
  - Sand and sand/peat
  - Multi-chamber catch basins and inlets
  - Other types

Others:

- Level Spreaders
- Special Detention Storage: Parking lots, other

Site Restoration for Stormwater:

- Riparian Buffer Restoration
- Landscape Restoration
- Soil Amendments/Restoration

Protocols:

- Soil Testing
- Site Infiltration

E) **STORMWATER CALCULATIONS – STORMWATER METHODOLOGY AND CALCULATIONS**

Alternative Process Occurring Throughout Planning and Design Practices to Maximize Non-Structural and Structural Design Practices

Use acceptable methods, such as Soil Cover Complex Method U.S. Department of Agriculture, Natural Resource Conservation Service, Technical Release (TR-55) for calculations
(Do not use Weighted Curve Numbers)

Strive to:

Minimize to pre-to post-development increase in Curve Numbers
Maximize post-development Time of Concentration
Assume "conservative" pre-development cover conditions (i.e., Curve Numbers) such as "Meadow Good" or "Woods" for all pre-development pervious areas
Respect natural sub-areas in the design and engineering calculations

Strive to Achieve Standards of Comprehensive Stormwater Management:

No increase in volume of runoff, pre- to post-development, for up to a 2-year storm
No reduction in total volume of recharge, for up to a 2-year storm
No increase in peak rate runoff for small to large storms
No increase in pollutant loading

F) **PLAN – DEVELOP COMPREHENSIVE STORMWATER MANAGEMENT PLAN**

Has There Been a Thorough Approach to Use of Both Non-Structural and Structural BMPs?

If not, what non-structurals and structurals might be used
Should the building program be modified

What Related Benefits Are Being Achieved Through the Use of BMPs

4.5.3 IMPORTANCE OF SITE ASSESSMENT

Comprehensive storm water management begins with a thorough assessment of the site and its natural systems. Site assessment includes inventorying and evaluating the various natural resource systems which define each site and pose problems and opportunities for storm water management. Resources include the full range of natural systems such as water quantity, water quality, floodplains and riparian areas, wetlands, soils, geology, vegetation, and more. Natural systems range in scale from resources of area wide importance on a macro-scale, down to micro- and site-specific detail.

- Background Site Factors

Broader system characteristics should be described, including presence of Ohio EPA Beneficial Use Designation, source water supply designations, flooding history, and other information that provides an understanding of how a particular site is functioning within its watershed context. More specific questions would include:

Does the site drain to special water bodies with special water quality needs?
Does the site ultimately flow into a reservoir or other water body where special water quality sensitivities exist, such as use as a water supply source?

Is the site linked to a special habitat system, such as delineated by the Ohio Department of Natural Resources? For both water quality and temperature reasons, approaches and practices that achieve a higher order of protection may became especially important.

Determine if a special fishery exists.

- Site Factor Inventory

Site-specific factors that influence comprehensive storm water management include the following items:

How does site size and shape affect storm water management?

As site size increases, the ability to use a variety of non-structural and structural BMPs increases. Comprehensive storm water management, especially through site planning and the use of non-structural BMPs, can reduce the space requirements at a site and offer greater BMP flexibility. Oddly shaped sites can also be better adapted with BMPs set forth here, given their wide variety of shapes and sizes.

What are the important natural features characterizing the site?

At the heart of the comprehensive storm water management procedure is an understanding of the natural systems characterizing each site. Existing vegetation and soil have tremendous importance and is the key to understanding land development impacts on natural systems. Careful accounting of existing vegetation is an important prerequisite for comprehensive storm water management, followed closely by soils mapping for permeability ratings, and natural pre-development surface flow patterns. Critical site features, such as wetlands, floodplains, riparian areas, natural drainage ways, special habitat areas, special geological formations (e.g., carbonate), steep slopes, shallow depth to water table, shallow depth to bedrock, and other factors should be inventoried and understood. Critical areas include those with special positive functions that can be translated into real economic value or benefit. Elimination or reduction of these functions through the land development process leads to real economic losses. These special value areas, including wetlands and floodplains and riparian areas should be conserved and protected during land development. Critical natural areas also include sensitive areas, such as steep slopes, shallow bedrock, high water table areas, and other constraining features, where encroachment by land development creates unnecessary or unanticipated problems. Care must be taken to avoid these potential pitfalls.

- Site Factor Analysis

Identify site factors that constrain comprehensive stormwater management, and identify site factors that can be viewed as opportunities.

- How is the site constrained?

Determine where buildings, roads, and other disturbances should be avoided and why.

- Where are the zones of site “opportunity”, in terms of storm water management?

Determine where the most infiltration occurs in terms of vegetation and in terms of soils. Both constraints and opportunities are grounded in the natural systems present at the site. Constraints and opportunities are not necessarily simple opposites in terms of direct land disturbances and building construction, yet also provided significant opportunity in terms of stormwater management, quantity, and quality. Woodlands, which should be protected from direct land development, provide excellent opportunity for storm water management, provided that the correct approaches and practices are used. Vegetated riparian buffers should not be disturbed for building and road construction, yet they can be used carefully with level spreading devices to receive diffuse storm water runoff. Soils with maximum permeability at the site should not be made impervious with buildings and roads, but used for storm water management where feasible. Conversely, buildings and other impervious areas should be located on those portions of the site with the least permeable soils. Site opportunities for volume control can typically be defined in terms of vegetation types that minimize runoff, as well as soil types with maximum permeability.

4.6 APPENDIX II – NON-STRUCTURAL BEST MANAGEMENT PRACTICES

Non-structural BMPs take the form of broader planning and design approaches – even principles and policies – which are less “structural” in their form, although non-structural BMPs do have very important physical ramifications.

Sometimes referred to as Low Impact Development (LID) or Conservation Design techniques, these environmentally sensitive approaches to site development and stormwater management minimizes the effect of development on water, land and air. These developmental concepts integrate site design and planning techniques that preserve natural systems and hydrologic functions on a site through the use of non-structural BMPs. Non-structural BMP deployment is not a singular, prescriptive design standard but a combination of practices that can result in a variety of environmental and financial benefits. Reliance on non-structural BMPs encourages the treatment, infiltration, evaporation, and transpiration of precipitation close to where it falls while helping to maintain a more natural and functional landscape. The BMPs described in this Appendix preserve open space and working lands, protect natural systems, and incorporate existing site features such as wetlands and stream corridors to manage stormwater at its source. Some BMPs also focus on clustering and concentrating development, minimizing disturbed areas, and reducing the size of impervious areas.

From a developer’s perspective, these practices can reduce land clearing and grading costs, reduce infrastructure costs, reduce stormwater management costs, and increase community marketability and property values. Conventional land development frequently results in extensive site clearing, where existing vegetation is destroyed, and the existing soil is disturbed, manipulated, and compacted. All of this activity significantly affects stormwater quantity and quality. These conventional land development practices often fail to recognize that the natural vegetative cover, the soil mantle, and the topographic form of the land are integral parts of the water resources system that need to be conserved and kept in balance, even as land development continues to occur.

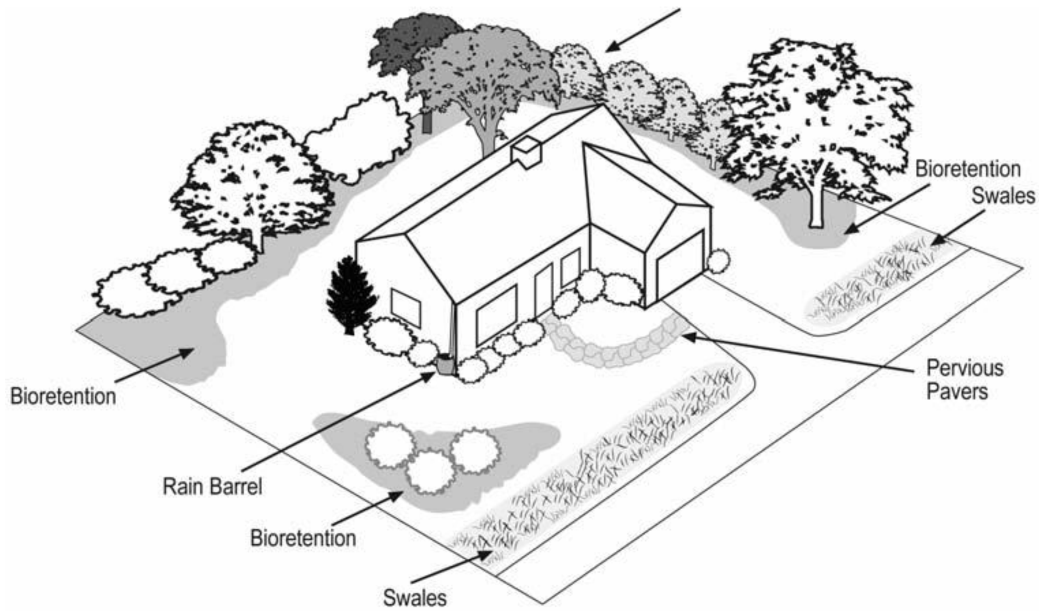
Therefore, identifying a site's natural resources and evaluating their values and functional importance is the first essential step in addressing the impact of stormwater generated from land development (Appendix I). Where they already exist on a proposed development site, these natural resources should be conserved and utilized as a part of the stormwater management solution.

For more comprehensive information concerning structural BMP placement and construction, refer to Chapter 2, Ohio Department of Natural Resources Rainwater and Land Development Manual.

The following non-structural BMPs include the following information:

1. Description
2. Conditions Where Practice Applies
3. Planning and Design Criteria
4. Maintenance
5. Plans and Specifications
6. References and Web Sites

4.6.1 LOW IMPACT DEVELOPMENT (LID)



Description

LID-is a site design approach, which seeks to integrate hydrologically functional design with pollution prevention measures to compensate for land development impacts on hydrology and water quality. LID's goal is to mimic natural hydrology and processes by using small-scale, decentralized practices that infiltrate, evaporate, detain, and transpire stormwater. LID stormwater controls are uniformly and strategically located throughout the site.

LID is achieved by:

- Minimizing stormwater runoff impacts to the extent practicable through preservation of existing landscape features and their hydrologic functions.
- Maintaining predevelopment time of concentration through strategic routing of flows using a variety of site design techniques.
- Dispersing runoff storage measures through a site's landscape through the use of a variety of detention, retention, and runoff practices.

LID practices manage stormwater at its source. LID measures reduce impervious cover, minimize disturbance, preserve and recreate natural landscape features, increase hydrologic disconnects and facilitate infiltration and detention opportunities. LID creates a multifunctional landscape which relies on natural features and processes and emphasizes simple, nonstructural, low-tech methods.

Conditions Where Practice Applies

LID can be used in a broad range of land use situations. Due to maintenance considerations, LID may be most appropriately utilized on institutional, industrial, commercial and governmental developments. However, LID in tandem with conventional stormwater control features can be successfully integrated into any development. LID has been demonstrated to work in new developments and constrained sites involving urban infill or retrofit to reduce combined storm sewer inflows.

Planning Considerations

LID is a design approach and represents a collection of stormwater management practices that may be utilized together to manage stormwater. LID measures are often used as a supplement to conventional stormwater practices to meet the state critical storm criteria and provides post construction water quality benefits.

Nine steps in the LID Site Planning Process.

1. Determine the applicable zoning, land use, and subdivision regulations,
2. Define development envelope (total areas that affect hydrology on site),
3. Use drainage/hydrology as a design element,
4. Reduce total site impervious areas,
5. Integrate preliminary site layout plan,
6. Minimize directly connected impervious areas,
7. Modify/increase drainage flow patterns,
8. Compare pre & post development hydrology and identify Integrated Management Practices,
9. Complete LID site plan.

The LID principals are designed to minimize disturbance and manage the stormwater as close to its source as possible. Specific low impact development controls called Integrated Management Practices (IMP's) are tools for developers to utilize to manage stormwater at its source rather than relying solely on centralized BMP's such as detention basins. Common IMP's are detailed below under Design Criteria. Each IMP will have specific planning considerations; however the following details several of the common planning considerations.

- Clay Soils: Higher proportions of clay particles in the soil (greater than 27%) will reduce the effectiveness of infiltration-based measures and require greater use of surface depression measures.

- High Water Table: High water table, even high seasonal water tables, may restrict the use of some IMP's. Provide at least 2 to 4 feet of separation between the bottom of the IMP and the top of the seasonally high water table elevation. On-site soil evaluation by a qualified professional is highly recommended.

- Building Foundation and Structures: IMPs should not be located near foundations of buildings or other structures.

- Deed Restrictions: Maintaining distributed depression storage measures within residential subdivisions will require deed restrictions on individual parcels as well as homeowner education programs to ensure measures are maintained.

- Zoning Variances: Variances from zoning, subdivision, building, stormwater management, and drainage regulations may be required unless LID is permitted.

- Snow: Parking lot LID measures will need to consider snow storage and the effects of road salt on any plant material.

- Design Costs: Up-front design costs may increase over design of conventional stormwater management approaches due to the need to "fingerprint" the site and complete microscale design of the integrated management practices. However, construction and maintenance costs often decrease.

- Public Health: Public health concerns exist about West Nile Virus, Zika and other mosquito borne diseases. Brackish water pools may serve as the breeding ground for the mosquitos that may carry diseases. Proper design and construction of stormwater management facilities are necessary to minimize or eliminate this issue.

- Maintenance Access: Easements may be necessary to give the community access for maintenance on IMPs.

- Contractor Guarantees: Obtaining contractor guarantees for some integrated management measures may not be possible due to lack of standard construction and material specifications.

- Public Education: Public education materials are essential for long term management of IMPs.

LID is a relatively new approach to stormwater management in the U.S and has not been used extensively in Ohio because of historic focus on water quality control, climatic factors, lack of regional design standards and cost. However, many of the IMPs, including bioretention, vegetated swales, filter strips and porous pavers, have been utilized individually. LID may also be an important tool to reduce the effects of land use changes near ecological sensitive areas.

<u>Design Criteria</u>

The goal of LID is to mimic the predevelopment hydrology through runoff volume control, peak runoff rate control, flow frequency/duration control, and water quality control. To effectively manage stormwater using LID, the developer must define the hydrologic control (runoff, groundwater recharge, infiltration), evaluate the site constraints (slopes, soils), evaluate and select IMP's that are appropriate considering the hydrologic scheme and site constraints. The addition of some conventional controls may be necessary to complete the stormwater management scheme for the developed site.

Applicable design criteria also include grassy swales, and bioretention. There is no limit to the number of BMP's which may be implemented as part of a low impact development. Other designs are listed below.

Biofiltration	Dry Wells	Filter/Buffer Strips	VegetatedSwales
Green Roof	Wetland Channels	Soil Amendment	Infiltration Trench
Impervious Surface Reduction		Cistern & Rain Barrels	

Pervious Paver Installation

Bioretention

<u>Maintenance</u>

LID may be most appropriately used in institutional, industrial, commercial and governmental developments, as these facilities are more likely than residential developments to receive maintenance on LID features over residential developments. When maintenance is required, additional easements may be necessary to facilitate maintenance access. In residential developments the landowners or homeowners association are often responsible for any required maintenance. Regular inspections, by or for the responsible party, must be completed to ensure LID and conventional stormwater control features continue to operate properly.

<u>References</u> – See Appendix IV, page 104-113.

4.6.2 CONSERVATION DEVELOPMENT

Description

Conservation Development refers to development practices that allow land to be developed while conserving a sense of rural character, protecting natural resource features, and insuring water quality. In the process, property rights are protected, the community retains its unique identity and resources, the developer benefits with a high-quality project, and the environmental impacts of development are reduced.

Conservation Development typically allows higher density on a portion of the site in order to leave the rest of the site undeveloped. This results in the same number of structures that would be allowed in a traditional development on a particular parcel of land being located with more flexibility while requiring that a substantial (35% to 45% based on the zoning density of the land) portion of the land be set aside as permanent open space. The resulting protected open space provides room for conservation practices that serve to buffer the impacts of the development. The conservation practices selected and used can:

1. Reduce stormwater flow through retention and detention basins.
2. Reduce impervious surface area.
3. Increase the filtering of stormwater runoff.
4. Reduce heat reflectance.
5. Retain the original vegetation.
6. Retain historic structures.
7. Allow for the continuation of economically viable agriculture.
8. Allow for the protection of other environmental benefits.

Conservation Development vs. Low Impact Development

Conservation Developments should not be confused with Low Impact Developments. The basic difference is:

- Conservation Development involves the overall layout of the property to retain open space. It may or may not include Low Impact Development measures in its site plan.

- The Low Impact Development concept applies to how a development is laid out with on-site measures being taken for stormwater retention and management. Low Impact Developments are previously discussed in this section of the manual.

Conditions Where Conservation Development Practice Applies

This concept is appropriate in all communities regardless of its current development pattern. Each community, large or small, can use the Conservation Development concept as it develops current open space and redevelops existing built-up areas.

Planning and Design Criteria

Ultimately, communities meeting with the most success at achieving a balance of conservation and development will be those that implement a range of tools for different zoning purposes. Outright purchase, use of conservation easements, purchase of development rights, and conservation zoning are all examples of tools that communities can use for land preservation. Each tool has a different set of circumstances under which it works best; and each community will have a unique set of situations of which it can take advantage.

Conservation Development techniques are implemented at the planning, zoning and project levels to soften the impact of development on community resources. Conservation Development is one of several tools communities should utilize if they desire to achieve a balance of Conservation and Development that is critical to their long-term quality of life.

Conservation Development vs. Conventional Development

Conventional development patterns result in uniformity despite differences in terrain, climate or site features. Much of this is the result of uniform zoning standards dating to the 1940s. Many of these codes also required practices that are damaging to the rural and natural environment. For example, wide road pavements multiply stormwater problems through increased impervious area and flow-concentrating curb and gutter systems that often send large quantities of untreated stormwater into local streams.

Applying conservation development concepts to a development site utilizes the uniqueness of each site. By preserving significant areas of open space, original woodlands, wetlands, or stream corridors, the site maintains natural and cultural values. Some agricultural uses can be continued; rock outcroppings, old barns, heritage trees, and windrows can be focal points. Open space areas also serve to reduce stormwater runoff and improve its quality. Conservation developments also provide the flexibility to buffer views of development from the road, retaining a sense of openness.

A Typical Conservation Development Project

1. Decisions on site layout and character depend upon the land itself, the community in which it is located, and the intended market of the project. While each conservation development project is unique, there are several characteristics common to most projects.
2. Flexible lot layouts: Within a development, the permitted number of structures are placed on somewhat smaller lots, and the remaining land is set aside as open space. For example, providing one acre lot sizes in a two acre zoned area allows half the land to be preserved.
3. Retain significant amounts of open space: Forty percent (40%) of land area or greater is retained in large, contiguous parcels appropriate to the conservation objective for the area - whether it is a stream corridor, a hillside meadow, a woodland, or farmland.
4. Competitive economic return to property owner and developer: Studies have shown that homes in Conservation Development subdivisions sell for the same, or even greater value and appreciate faster than homes in comparable traditional layouts. This is associated with each home's view and access to permanent open space.
5. Open space is retained permanently in private ownership: Typically these projects have a properly structured homeowner's association conservation easement agreement, which includes legal and financial provisions to ensure preservation of open space and to secure its management and maintenance. Usually, the homeowners' association retains ownership and maintenance responsibilities; a conservation easement dedicated to a third party conservation organization ensures the land will not be developed.
6. Retention of rural character: Large open space acreage allows flexibility to buffer views of the development from the road, and to preserve historic structures and landscapes.
7. Reduced length and size of roads and utilities: Sometimes private roads and shared driveways are provided. This aspect is a benefit both to the community, which has less to maintain, and the developer, who has less to build. Environmental impacts related to increased impervious surfaces are reduced. Consideration needs to be made for police, fire and other public vehicles that need to use the road.
8. Commercial development projects also have an emphasis on compatibility with rural aesthetics, reduction of pavement and other impervious surfaces, and providing a community enhancing experience for the customer and passerby.

References – See Appendix IV, page 104-113.

4.6.3 STREAM SETBACK AREA

Description

Stream setbacks (also known as streamways or riparian buffer areas) minimize property damage and protect water quality by providing areas where over bank flooding, meander migration, and stream processes freely occur and thereby encourage stability, habitat, and water quantity and quality functions. On high quality creeks and rivers these areas represent the most biologically diverse and active areas where in-stream and riparian habitat abounds, sediments are exported to floodplain areas, pollutants are assimilated and stormwater is stored and conveyed. On more impacted or lower quality creeks and rivers, stream setbacks represent areas where meander migration or floodplain redevelopment is likely to occur and where natural stream adjustments are predicted to occur.

This practice establishes the setback area based on the predicted belt width of stream, the lowest elevation ground in the valley and the stream location. The streamway is determined at intervals using the stream's drainage area and regional or locally developed stream data.

NOTE: This practice reflects the site development scale. Additional resources should be consulted when developing a model ordinance or implementing stream setbacks throughout a watershed or community.

To provide the greatest benefits, riparian areas should be predominately native vegetation, preferably forested. However, passive uses such as trails and picnic areas may be maintained.

Stream setbacks are strongly linked to the protection of public health or safety of watershed residents by setting aside areas that:

- Reduce flood hazards resulting from high flows and high velocities;
- Recharge groundwater;
- Reduce pollution in stream flows and surface water by filtering, settling and chemical transformation in floodplain areas and stream side soils;
- Reduce sediment loads from stream bank erosion; and allow recovery of previously degraded or channelized streams;
- Provide adequate room for stream meander patterns or channel migration;
- Provide high quality habitats for wildlife;
- Limit the need for costly measures such as channel armoring that would otherwise be necessary to protect structures and reduce property damage;
- Protect natural aesthetics and the environmental quality of stream corridors and the value of nearby property.

Conditions Where Practice Applies

Setbacks are appropriate for all sizes of stream channels from ephemeral or intermittent streams up to large rivers. The importance of these areas increases as a watershed is developed. Streams and associated corridors most subject to encroachment or modification (drainage areas less than 10 square miles) are most in need of established protection. These size channels are small enough that they can be more easily modified and are less likely to have adequately mapped or protected floodplain areas.

The width of the setback area is based on empirical stream data and the predicted belt width of the stream, but setback areas on sites with existing development must be implemented to minimize potential conflicts between current land uses and the stream setback. For example, setback shall be implemented to ensure that development gets no closer to the stream, thus effectively setting the setback for that parcel at the line of the existing foundation/structure. Still the recommended setback area provides the zone where channel movement is predicted and stream processes are most beneficial and should be sustained as much as possible.

Planning Considerations

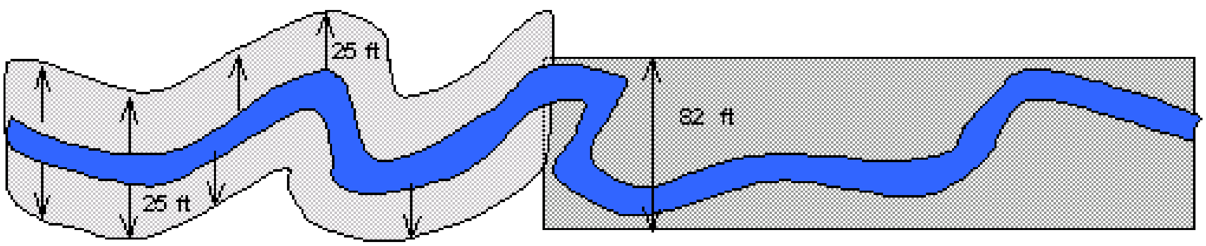
- The Stream Setback is Based Primarily on Stream Processes

  The stream setback is based on the most critical land area needed to sustain natural stream processes. These processes are responsible for the common meandering pattern that streams exhibit and for channel and floodplain forms that are dynamically stable and beneficial to water quality and overall stream integrity. With this in mind, it should be noted that many Ohio streams are not in the condition of “best potential”. Many have been altered directly by straightening or channelization or degraded in response to land use changes within the watershed. Thus the existing meander pattern (the stream’s plan form) is often narrower than it was historically and erosion and deposition may be working to re-establish a wider pattern along with a more dynamically stable channel form. A stream setback establishes the area in which these processes can continue to occur.

While this area provides many benefits it may need to be expanded to accomplish additional objectives. For instance, some communities may require more extensive preservation of floodplain or upland wildlife areas.

- Existing Local Requirements

Some counties, townships and municipalities across Ohio have already adopted riparian setbacks. In the event that these setbacks differ from those described here, the larger of these is suggested. Please note when comparing distances that this practice predicts the full meander belt width that contains the stream, while other local stream protection setbacks may utilize a setback distance from each bank of the stream. To compare this practice to a setback distance from each bank, the latter should be doubled and added to the width of the stream for proper comparison (see Figure below).



Comparing a traditional stream setback to the streamway-based setback.

- Encourage Rehabilitation of Streams in the Stream Setback

Because so many Ohio streams have been channelized or have degraded it is advantageous to promote channel and floodplain rehabilitation activities that provide channels with greater access to an active floodplain. This will insure more natural stability and higher function. General grading that occurs during development may provide an opportunity to rehabilitate an entrenched stream and therefore provide a higher quality stream corridor. Applicable practices may be floodplain rehabilitation, primarily lowering of high banks. This setback practice does not limit rehabilitation activities.

- Adjustments to the Setback Width

In some circumstances, site conditions justify altering the width of the setback area. These may be situations of narrow, confined valleys smaller than the setback width, floodplains that extend beyond the area, wetlands contiguous to the area, or adjacent hillsides prone to slippage or being undercut as a result of stream flows. This is best accomplished with GIS or other more regional tools that can be used to incorporate adjustments to the setback area width.

For large rivers with extensive setback areas, further refinement of acceptable land uses within the area may be necessary. After maintaining a forested riparian area immediately adjacent to the river, other uses such as open fields or recreation areas are appropriate provided that the floodplain characteristics are not impaired.

<u>Design Criteria</u>

- Calculating the Setback Area Width

  The setback area width is a total width, which crosses the channel and is calculated according to the drainage area (square miles).

- Size

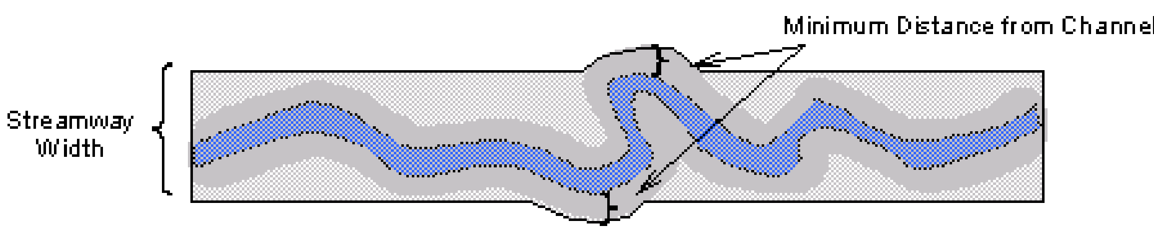
  The setback area shall combination of two overlapping areas, one Streamway based and the other based on a minimum distance from the channel bank, equivalent to one channel width as illustrated in the Figure below.

  The Streamway size appropriate to accommodate the meander belt is:

  Streamway width = 147 (Drainage Area in square miles) $^{0.38}$
  (Approximately 10 channel widths)

  In addition, at no point shall the distance between the setback boundary and the channel be less than:

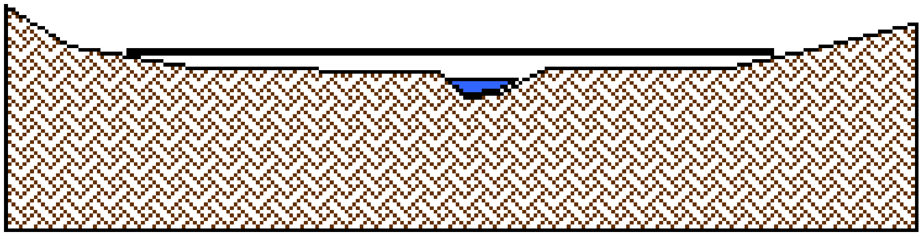
  Minimum distance from channel = 14.7 (Drainage Area in square miles) $^{0.38}$
  (Approximately 1 channel width)



Setback areas combine the streamway and a minimum distance from the channel.

- Location

  A Streamway is more a feature of a valley than individual bends or the present location of a channel, thus the setback area may not always be exactly centered over the stream, especially as streams meander. It is more aptly visualized as a flood path or roughly the flood way. Thus, setback areas should be fit to the valleys. They shall be positioned so that corresponding left and right boundary elevations match and the setback area incorporates the lowest elevations in the valley.



Center setback areas over the floodway with matching elevations at either boundary.

- Avoid concentrating flow into the setback area

  Maintaining diffuse sheet flow into the setback area maximizes the treatment processes that occur in riparian and floodplain areas. Convert concentrated flows from storm drains and swales (with limited drainage areas) to uniform shallow sheet flow as it enters the stream setback area. Grading and constructing level spreaders can help accomplish this. Ditches and streams with access to an active floodplain will better utilize these areas than deep entrenched channels.

- Insure long-term protection of the area

  Zoning, conservation easements and public ownership are options to consider long-term protection of the area. Local government may utilize zoning to set appropriate land uses for the stream setback area. In addition, many local governments will accept ownership of such properties if deeded in fee simple to the community. In this case, a credit may be applicable toward local open space or parkland set aside requirements.

  Conservation easements offer one of the best ways to protect riparian areas. These maintain private ownership, while maintaining the limitations on the uses and actions that can be taken in the setback area. Easements can be held by a legally qualified conservation organization (such as a land trust) or a government agency. Easements should be regularly monitored and violations of easement agreements addressed in order to insure long-term protection.

- Clearly identify the setback area boundaries on the plat map, construction plans and the site.

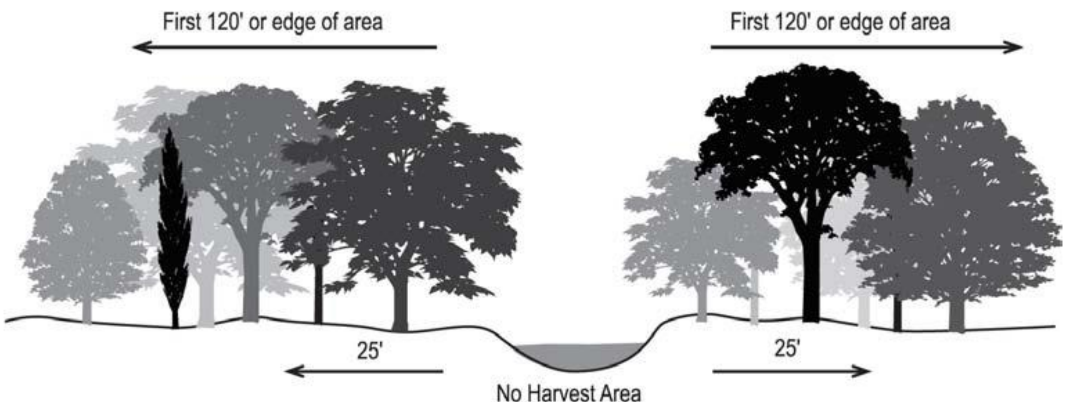
  Install temporary fencing and best management practices appropriately to prevent encroachment during construction.

  Following construction erect a fence or visual barrier identifying the area or portions of the area, which are to be no-mow zones or permanently forested areas. Sections of split rail or similar unobtrusive fencing provide a visual marker that will allow the area to remain distinct of other land uses.

- Vegetative Goals

  Setback areas are to be established in native vegetation, which for most Ohio streams is forest. Areas may also be divided into primary (closest to the stream) and secondary areas with different vegetative targets that allow for surrounding land uses. Forested areas should be maintained for a minimum of the first 50 feet of the area on either bank.

  Harvesting on privately held areas should not be done within 25 feet of either bank. Removal of invasive species is allowable at any time and is highly recommended for maintenance of the setback as a natural area.



<u>References</u> – See Appendix IV, pages 104-113

4.6.4 WETLAND SETBACK

Description

Wetland Setbacks are areas retained around existing or created wetlands in order to protect the natural functions of the wetland. Wetland Setbacks left in or restored to a "natural" vegetated state provide an enhanced level of wetland protection not currently afforded by state and federal wetland regulations.

This practice recognizes the valuable services that wetlands provide, while acknowledging that these wetlands have been formed under conditions of less stormwater pollution and imperviousness. Wetland Setbacks reduce wetland degradation associated with development by treating surface runoff for pollutants, transferring surface runoff to subsurface flow and providing a vegetated buffer from more intensive land uses.

By maintaining functional wetlands within our community, the City and landowners ensure that the natural services provided by wetlands are not lost or transferred out of their watershed.

Conditions Where Practice Applies

Wetland Setbacks are appropriate on all lands surrounding wetlands which receive runoff from development or redevelopment areas. Wetland Setbacks can be utilized in a low impact or conservation development design plan, as part of the regulatory permitting process or normal site design planning. Wetland Setbacks may be most appropriate on those wetlands that are hydrologically connected to other water sources such as springs or streams.

Wetland Setbacks are an appropriate best management practice in the City's Stormwater Program (e.g., NPDES Phase II) or as part of their land use planning. Wetland Setbacks can be incorporated into local zoning codes.

Wetland Setbacks are applicable where the site designer has the objective of mimicking the redevelopment hydrology, reducing the amount of stormwater and maintaining natural features.

Establishing wetland setbacks and the associated protection of wetland resources may also be used to demonstrate avoidance of impacts as part of a wetland permitting process.

Wetland Setbacks are also appropriate for ponds, lakes and Water Quality Ponds; however, these features may need to have maintenance access incorporated into any setback area.

Wetland Definition and Value

Generally, wetlands are those areas near streams and in uplands that are inundated or saturated by enough water to be dominated by vegetation adapted for life in saturated soil. In Ohio, wetlands include swamps, marshes, fens, bogs and similar areas.

Wetlands are legally defined in section 40 Code of Federal Regulations (CFR) 232. The U.S. Army Corps of Engineers also has specific regulations covering activities in wetlands as well as technical guidance on determining the extent of wetlands.

Wetlands provide a variety of services to communities and landowners, including

- **Flood Control**: Wetlands reduce peak flood flows, store floodwaters, and maintain stream base flows.
- **Erosion Control**: Wetlands minimize stream bank and bed erosion by regulating water volume and velocity. Note: natural wetlands are not to be utilized for construction site runoff control.
- **Ground Water Protection**: Wetlands minimize impacts on ground water quality by filtering pollutants from stormwater runoff. Many wetlands recharge ground water reserves.
- **Surface Water Protection**: Wetlands minimize impacts on surface water quality by reducing sediment pollution from stream bank erosion, and by trapping sediments, chemicals, salts and other pollutants from runoff.
- **Habitat**: Wetlands provide essential habitat, particularly for nesting and breeding for many aquatic and terrestrial organisms.

Planning Considerations

- Existing Local Requirements

  Some counties, townships and municipalities across Ohio have already adopted wetland setbacks. In the event that these setbacks differ from those described here, the larger of these requirements should be used.

- Adjustments to the Setback Width

  The setback widths given in this practice offer minimum protection and should be considered for expansion if any of the following conditions apply:

  - Areas crucial to the hydrology of the wetland such as springs, floodplains or streams extend beyond the standard wetland setback. These areas should be considered for incorporation in the setback area, since maintaining the hydrologic support for the wetland is critical to its continuing function.

  - The wetland is a rare, sensitive or high value wetland system. These systems need greater buffer widths to ensure protection of the current quality.

  - Habitat protection, either of wetland species or species that utilize the wetland, is a major objective. Greater than 100 feet is recommended, but wildlife expertise may be necessary to determine the conditions and width needed for the particular species.

  - Larger setbacks may be appropriate for drainage from a commercial or industrial facility that may require pretreatment and flow attenuation

  - Areas that are steep or sparsely vegetated will have lower effectiveness in providing water quality protection for adjacent wetlands and therefore should be expanded.

- Storm water management and site planning needed in addition to setbacks

  Wetland setbacks will help protect wetland systems, but more is needed as development occurs. Storm water controls will still be needed to control high-energy flows and to mitigate for increased pollution.

- Encourage wetland protection through community support and planning

  Wetland setbacks are a tool that can be used to protect water quality and water resources. Local planning officials should consider how to facilitate wetland setbacks through wetland identification tools (soils, wetland and land use maps), landowner assistance, zoning code and land acquisition.

  Utilizing publicly available resources to produce planning or land use maps can help communities identify where wetlands and wetland setbacks are most likely to be applied. The Natural Resource Conservation Service and the local Soil and Water Conservation District provide soils maps and a list of hydric soils. National Wetlands Inventory (U.S. Fish and Wildlife Service) and ODNR's Ohio Wetlands Inventory maps may also be useful in finding wetland locations for planning purposes. Note these maps are not appropriate for making wetland delineations. Wetland delineation information is available from the Ohio EPA, the U.S. Army Corps of Engineers, and the local soil and water conservation districts.

Finally protect wetland setbacks and the wetlands they surround by placing these areas under a conservation easement. Note that deed restrictions are much less protective since a judge can abolish them at the request of a landowner without public notice.

- Landowner Assistance

  Several publicly funded organizations are available to assist interested landowners in managing wetlands on their properties, including:

  - Soil and water conservation districts,
  - Natural Resource Conservation Service
  - Ohio Environmental Protection Agency
  - Ohio Department of Natural Resources, and
  - Ohio State University Extension Service.

  These organizations can advise landowners on what to plant near wetlands, where to locate soil disturbing activities to minimize short and long term damage to these services, and any applicable local, state, or federal regulations that may apply to an activity the landowner wishes to undertake. Ohio EPA and the U.S. Army Corps of Engineers are available to assist landowners in understanding specific regulations that may apply to proposed activities.

  Communities can facilitate wetland setbacks and other wetland management by connecting interested landowners to available county, state, and federal conservation services.

- Land Acquisition

  Communities may acquire properties that include wetlands that are providing flood control, erosion control, water quality protection, or habitat services either through direct purchase of land, conservation easements, or some other form of permanent preservation. This approach is appealing to communities because it is non-regulatory and enables direct community control over local wetland resources.

- Incorporating Wetland Setbacks into Zoning

  Zoning regulations that direct the location of development away from wetlands must detail the public health and safety functions of the community's wetlands including flood control, erosion control, and water quality protection, and must be built on technical information supporting these services from the lands being regulated.

  Zoning for Wetland Setbacks, unlike landowner assistance or land acquisition, allows communities to directly influence the location of new development and redevelopment. The goal of any zoning code that incorporates Wetland Setbacks is to ensure lots remain buildable and subdivision lot yields are maintained to the extent possible, while pulling soil-disturbing activities back from wetland areas. Thus zoning setbacks should be flexible incorporated to allow variances to other zoning setbacks, such as front and side yard setbacks, to allow site designers to maintain development lot yields. The disadvantages of implementing Wetland Setbacks through zoning controls are that it is an additional regulation and requires community staff to develop and implement.

Regional planning agencies and watershed organizations may also be able to offer assistance in establishing local ordinances and resolutions that maintain wetlands within developing communities.

- Permitting For Wetland Impacts

  In Ohio, the regulatory permits required to impact "Waters of the State," including lakes, wetlands and streams, may involve both the Army Corps of Engineers (Corps) and Ohio EPA through 404 Permits, 401 Water Quality Certification and/or Isolated Wetland Permits. Additional information regarding these permits can be found in the Appendix section.

  The Army Corps of Engineers and Ohio EPA both utilize a three-tier approach to proposals to impact water resources that consist of avoidance, minimization and mitigation. Wetland setbacks can and should be a vital part of these proposals.

Design Criteria

- Define the Wetland Boundary

  Wetland boundaries are determined by utilizing the delineation protocols acceptable to the U.S. Army Corps of Engineers at the time. Delineations must be submitted to the U.S. Army Corps of Engineers for concurrence. Wetland setbacks should be measured in a perpendicular direction from the defined wetland boundary.

- Evaluate Wetland Quality Category

  Ohio EPA wetland categories are used to determine the width of the wetland setback. These are general characterizations of a wetland's quality and are determined using the most recent version of the Ohio Rapid Assessment for Wetlands as guidance (www.epa.state.oh.us/dsw/401/permitting.aspx).

  Ohio EPA wetland categories are defined in the Ohio Administrative Code (OAC) 3745-1-54 (http://codes.ohio.gov/oac/3745-1 and http://epa.ohio.gov/portals/35/rules/01-54.pdf). They are:

  - Category 3 - wetlands are considered to be the highest quality;
  - Category 2 - wetlands are those of moderately high quality and may be good candidates for wetland enhancement;
  - Category 1 - wetlands are considered low quality wetlands and provide the least public health, habitat or safety services.

- Maintain Hydrology

  Determine the hydrologic inputs to the wetland, whether overland flow, streams, lakes, or springs. These inputs must either be maintained or substituted for other hydrologic inputs. Incorporating wetland hydrologic sources into the setback may be necessary to protect the integrity of the wetland resources.

- Setback Width

  The setbacks width differs with the functional capacity of the wetlands. See the Planning Considerations above for adjustments to the setback width. For most situations, Ohio EPA has concurred with the following guidelines.

  - A minimum of 120 feet surrounding all Ohio EPA Category 3 wetlands, or current equivalent Ohio EPA classification,
  - A minimum of 75 feet surrounding all Ohio EPA Category 2 wetlands, or current equivalent Ohio EPA classification, and
  - A minimum of 25 feet surrounding all Ohio EPA Category 1 wetlands or current equivalent Ohio EPA classification.

  NOTE: Category 1 wetlands often provide minimal habitat, hydrologic and recreational functions. Often times the degradation of these resources is due to the lack of setback, thus establishing setbacks from these resources may promote the restoration of these wetlands.

- Vegetation

  The Wetland Setback should be preserved in a natural state and established prior to any soil-disturbing activities. This area should not be mowed or disturbed in any way. If planting occurs within the setback, only native species should be utilized.

Maintenance

Wetland Setbacks should be inspected regularly to ensure that the Wetland Setbacks are being maintained in a natural state and have not been mowed, treated with herbicide (except as used to control invasive species), or developed. Wetland Setbacks and the wetlands they surround should be placed in a conservation easement to protect these resources in perpetuity. Easements should be regularly monitored and violations of easement agreements addressed in order to insure long-term protection.

References – See Appendix IV, page 104-113

4.7 APPENDIX III – STRUCTURAL BEST MANAGEMENT PRACTICES

Structural BMPs are specifically engineered measures that are designed to reduce and mitigate the impacts of development. The use of the "structural BMPs" is considered the second step in stormwater management design (non-structural BMPs being the first step – Appendix II). As mentioned earlier, the primary objective in stormwater management is to maximize stormwater "prevention" through use of non-structural BMPs. Once prevention has been maximized, some amount of stormwater peaking and volume control will likely remain to be managed. These stormwater management needs should be met with an array of natural-system based structural BMPs which includes a wide variety of practices and devices, from large-scale retention ponds and constructed wetlands, to small-scale underground treatment systems, infiltration facilities, filter strips, bioretention, wet ponds, permeable paving, grass swales, sand filters, detention basins, and manufactured devices.

For more comprehensive information concerning structural BMP placement and construction, refer to Chapter 2 (Post Construction Stormwater Management Practices) in the Ohio Department of Natural Resources Rainwater and Land Development manual (http://epa.ohio.gov/Portals/35/storm/technical_assistance/RLD_11-6-14All.pdf)

The following Structural BMPs include the following information:

1. Description
2. Conditions Where Practice Applies
3. Planning and Design Criteria
4. Maintenance
5. Construction Sequences
6. References and Web Sites

4.7.1 REDUCTION OF IMPERVIOUS AREAS

Description

Impervious area is the largest cause of increased stormwater runoff as a result of development. Any type of surface that does not allow water to penetrate it is considered impervious. Impervious areas do not allow precipitation to infiltrate into the ground or be absorbed by vegetation, thus increasing the quantity of stormwater runoff and all of its associated problems. Impervious areas consist of asphalt or concrete used in roads, parking lots, drive ways, sidewalks and roofs.

Conditions Where Practice Applies

Almost every development project includes the construction of some type of impervious surface, which will contribute to the increase in stormwater runoff. Opportunities to reduce the amount of impervious area exist on practically every project.

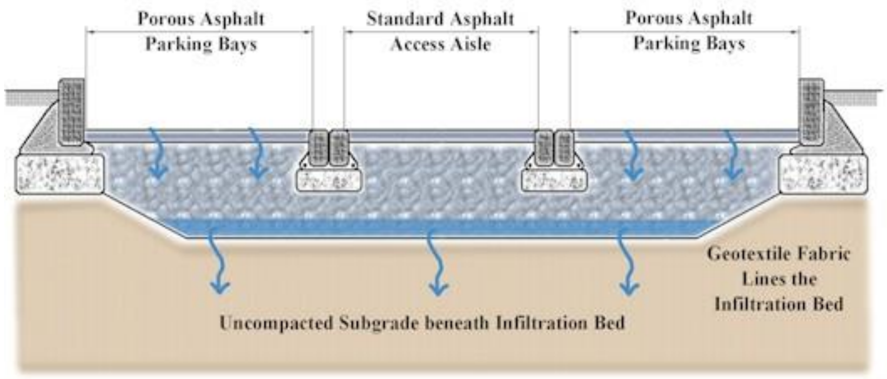
Studies have shown that pervious systems have been very effective in reducing contaminants such as total suspended solids, metals, and oil and grease. When designed, constructed, and maintained according to the following guidelines, pervious pavement with underlying infiltration systems can dramatically reduce both the rate and volume of runoff, recharge the groundwater, and improve water quality.

In northern climates, pervious pavements have less of a tendency to form black ice and often require less plowing. Pervious asphalt and concrete surfaces provide better traction for walking paths in rain or snow conditions.

Planning Considerations

Pervious pavement consists of a permeable surface course underlain by a uniformly-graded stone bed which provides temporary storage for peak rate control and promotes infiltration. The surface course may consist of porous asphalt, porous concrete, or various porous structural pavers laid on uncompacted soil.

A pervious pavement bed consists of a pervious surface course underlain by a stone bed of uniformly graded and clean-washed coarse aggregate, 1-1/2 to 2-1/2 inches in size, with a void space of at least 40%. The pervious pavement may consist of pervious asphalt, pervious concrete, or pervious pavement units. Stormwater drains through the surface, is temporarily held in the voids of the stone bed, and then slowly drains into the underlying, uncompacted soil mantle. The stone bed can be designed with an overflow control structure so that during large storm events peak rates are controlled, and at no time does the water level rise to the pavement level. A layer of geotextile filter fabric separates the aggregate from the underlying soil, preventing the migration of fines into the bed. The bed bottoms should be level and uncompacted. If new fill is required, it should consist of additional stone and not compacted soil.



Although the developers have the ability to incorporate alternative designs that reduce the amount of impervious area in their project, it is the City Engineer that will actually determine what can and will be used. It is in the best interest of communities to allow some alternative design options, especially with Phase II stormwater regulations.

Design Criteria

- The overall site should be evaluated for potential pervious pavement/infiltration areas early in the design process, as effective pervious pavement design requires consideration of grading.

- Orientation of the parking bays along the existing contours will significantly reduce the need for cut and fill.

- Pervious pavement and infiltration beds **should not be placed on areas of recent fill** or compacted fill. Any grade adjust requiring fill should be done using the stone subbase material. Areas of historical fill (>5 years) may be considered for pervious pavement.

- The bed bottom should not be compacted, however the stone subbase should be placed in lifts and lightly rolled according to the specifications.

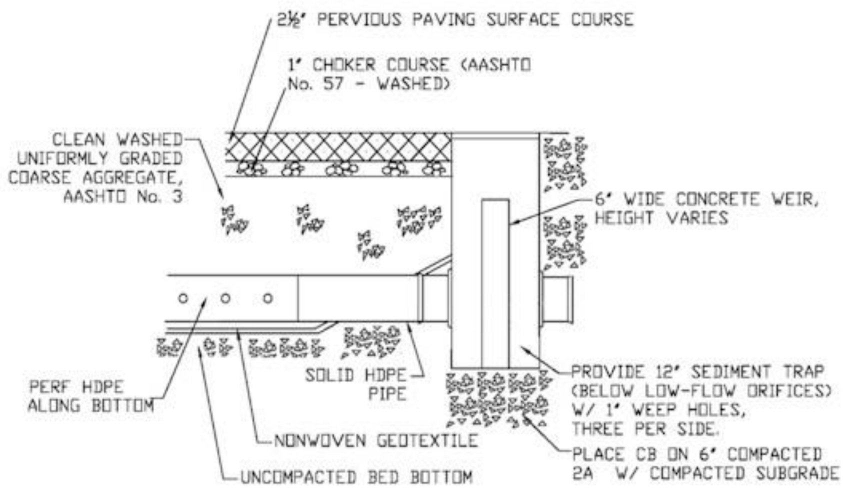
- During construction, the excavated bed may serve as a temporary sediment basin or trap. This will reduce overall site disturbance. The bed should be excavated to within twelve (12) inches of the final bed bottom elevation for use as a sediment trap or basin. Following construction and site stabilization, sediment should be removed and final grades established.

- **Bed bottoms should be level or nearly level**. Sloping bed bottoms will lead to areas of ponding and reduced distribution.

- **All systems should be designed with an overflow system**. Water within the subsurface stone bed should never rise to the level of the pavement surface. Inlet boxes can be used for cost-effective overflow structures.

- While infiltration beds are typically sized to handle the increased volume from a storm, they should also be able to convey and mitigate the peak of the less-frequent, more intense storms (such as the 100-yr). Control in the beds is usually provided in the form of an outlet control structure. A modified inlet box with an internal weir and low-flow orifice is a common type of control structure. The specific design of these structures may vary, depending on factors such as rate and storage requirements, but it always should include positive overflow from the system.

- The subsurface bed and overflow may be designed and evaluated in the same manner as a detention basin to demonstrate the mitigation of peak flow rates. In this manner, the need for a detention basin may be eliminated or reduced in size.



- A weir plate or weir within an inlet or overflow control structure may be used to maximize the water level in the stone bed while providing sufficient cover for overflow pipes.

- Perforated pipes along the bottom of the bed may be used to evenly distribute runoff over the entire bed bottom. Continuously perforated pipes should connect structures (such as cleanouts and inlet boxes). Pipes should lay flat along the bed bottom and provide for uniform distribution of water. Depending on size, these pipes may provide additional storage volume.

- Roof leaders and area inlets may be connected to convey runoff water to the bed. Water quality inserts or sump inlets should be used to prevent the conveyance of sediment and debris into the bed.
- Infiltration areas should be located within the immediate project area in order to control runoff at its source. Expected use and traffic demands should also be considered in pervious pavement placement.

- Control of sediment is critical. Rigorous installation and maintenance of erosion and sediment control measures should be provided to prevent sediment deposition on the pavement surface or within the stone bed. Non-woven geotextile may be folded over the edge of the pavement until the site is stabilized. The Designer should consider the placement of pervious pavement to reduce the likelihood of sediment deposition. Surface sediment should be removed by a vacuum sweeper and should not be power-washed into the bed.

- Infiltration beds may be placed on a slope by benching or terracing parking bays**.** Orienting parking bays along existing contours will reduce site disturbance and cut/fill requirements.

- The underlying infiltration bed is typically 12-36 inches deep and comprised of clean, uniformly graded aggregate with approximately 40% void space. The American Association of State and Transportation Officials (AASHTO) No. 3, which ranges 1.5-2.5 inches in gradation, is often used. Depending on local aggregate availability, both larger and smaller requirements are that the aggregate be uniformly graded, clean washed, and contain a significant void content. The depth of the bed is a function of stormwater storage requirements, frost depth considerations, site grading, and anticipated loading. Infiltration beds are typically sized to mitigate the increased runoff volume from a 2-yr design storm.

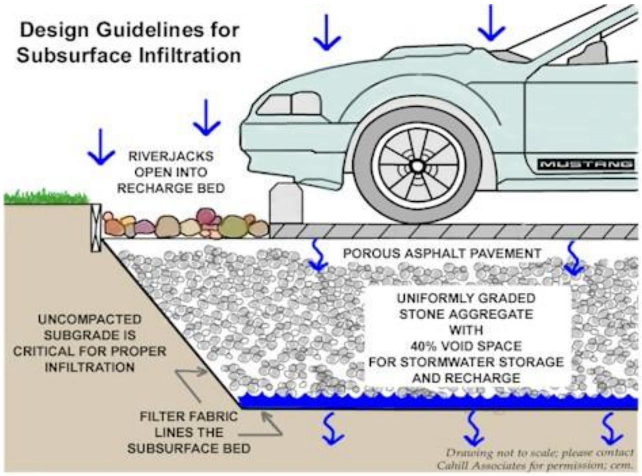
- Most pervious pavement installations are underlain by an aggregate bed; alternative subsurface storage products may also be employed. These include a variety of proprietary, interlocking plastic units that contain much greater storage capacity than aggregate, at an increased cost.

- All pervious pavement installations should have a backup method for water to enter the stone storage bed in the event that the pavement fails or is altered. In uncurbed lots, this backup drainage may consist of an unpaved 2 ft. wide stone edge drain connected directly to the bed. In curbed lots, inlets with water quality devices may be required at low spots. Backup drainage elements will ensure the functionality of the infiltration system, if the pervious pavement is compromised.

- In areas with poorly draining soils, infiltration beds below pervious pavement may be designed to slowly discharge to adjacent wetlands or bioretention areas. Only in extreme cases (i.e. industrial sites with contaminated soils) will the aggregate bed need to be lined to prevent infiltration.

- In those areas where the threat of spills and groundwater contamination is likely, pretreatment systems, such as filters and wetlands, may be required before any infiltration occurs. In hot spot areas, such as truck stops, and fueling stations, the appropriateness of pervious pavement must be carefully considered. A stone infiltration bed located beneath standard pavement, preceded by spill control and water quality treatment, may be more appropriate.

- The use of pervious pavement must be carefully considered in areas where the pavement may be seal coated or paved over due to lack of awareness, such as individual home driveways. In those situations, a system that is not easily altered by the property owner may be more appropriate. An example would include an infiltration system constructed under a conventional driveway. Educational signage at pervious pavement installations may guarantee its prolonged use in some areas.



Construction Sequence

- Due to the nature of construction sites, pervious pavement and other infiltration measures should by installed toward the end of the construction period, if possible. Infiltration beds under pervious pavement may be used as temporary sediment basins or traps provided that they are not excavated to within 12 inches of the designated bed bottom elevation. Once the site is stabilized and sediment storage is no longer required, the bed is excavated to its final grand and the pervious pavement system is installed.

- The existing subgrade under the bed areas should NOT be compacted or subject to excessive construction equipment traffic prior to geotextile and stone bed placement.

- Where erosion of subgrade has caused accumulation of fine materials and/or surface ponding, this material shall be removed with light equipment and the underlying soils scarified to a minimum depth of 6 inches with a York rake (or equivalent) and light tractor. All fine grading shall be done by hand. All bed bottoms should be at a level grade.

- Earthen berms (if used) between infiltration beds should be left in place during excavation. These berms do not require compaction if proven stable during construction.

- Geotextile and bed aggregate should be placed immediately after approval of subgrade preparation. Geotextile should be placed in accordance with manufacturer's standards and recommendations. Adjacent strips of geotextile should overlap a minimum of 16 inches. It should also be secured at least 4 feet outside of bed in order to prevent any runoff or sediment from entering the storage bed. This edge strip should remain in place until all bare soils contiguous to beds are stabilized and vegetated. As the site is fully stabilized, excess geotextile along bed edges can be cut back to bed edge.

- Clean (washed) uniformly graded aggregate is placed in the bed in 8-inch lifts. Each layer should be lightly compacted, with the construction equipment kept off the bed bottom as much as possible. Once bed aggregate is installed to the desired grade, a +/- 1 inch layer of choker base course (AASHTO #No. 57) aggregate should be installed uniformly over the surface in order to provide an even surface for paving.

- The pervious pavement should be installed in accordance with current standards. Further information can be obtained from the appropriate Association.

The full permeability of the pavement surface should be tested by application of clean water at the rate of at least 5 gpm over the surface, using a hose or other distribution devise. All applied water should infiltrate directly without puddle formation or surface runoff.

<u>Maintenance</u>

The primary goal of pervious pavement maintenance is to prevent the pavement surface and/or underlying infiltration bed from being clogged with fine sediments. To keep the system clean throughout the year and prolong its life span, the pavement surface should be vacuumed biannually with a commercial cleaning unit**. Pavement washing systems or compressed air units are not recommended.** All inlet structures within or draining to the infiltration beds should also be cleaned out biannually.

Planted areas adjacent to pervious pavement should be well maintained to prevent soil washout onto the pavement. If any washout does occur it should be cleaned off the pavement immediately to prevent further clogging of the pores. Furthermore, if any bare spots or eroded areas are observed within the planted areas, they should be replanted and/or stabilized at once. Planted areas should be inspected on a semiannual basis. All trash and other litter that is observed during these inspections should be removed.

Superficial dirt does not necessarily clog the pavement voids. However, dirt that is ground in repeatedly by tires can lead to clogging. Therefore, trucks or other heavy vehicles should be prevented from tracking or spilling dirt onto the pavement. Furthermore, all construction or hazardous materials carriers should be prohibited from entering a pervious pavement lot.

Special Maintenance Considerations

- Prevent Clogging of Pavement Surface with Sediment
- Vacuum pavement 2 or 3 times per year
- Maintain planted areas adjacent to pavement

- Immediately clean any soil deposited on pavement
- Do not allow construction staging, soil/mulch storage, etc. on unprotected pavement surface
- Clean inlets draining to the subsurface bed twice per year

- Winter Maintenance

  Winter maintenance for a pervious parking lot may be necessary but is usually less intensive than that required for a standard impervious surface. By its very nature, a pervious pavement system with subsurface aggregate bed has superior snow melting characteristics than standard pavement. The underlying stone bed tends to absorb and retain heat so that freezing rain and snow melt faster on pervious pavement. Therefore, ice and light snow accumulation are generally not as problematic. However, snow will accumulate during heavier storms. Abrasives such as sand or cinders should not be applied on or adjacent to the pervious pavement. Snow plowing is fine, provided it is done carefully (i.e. by setting the blade slightly higher than usual, about an inch). Salt is acceptable for use as a deicer on the pervious pavement, though nontoxic, organic deicers, applied either as blended, magnesium chloride-based liquid products or as pretreated salt, are preferable.

- Repairs

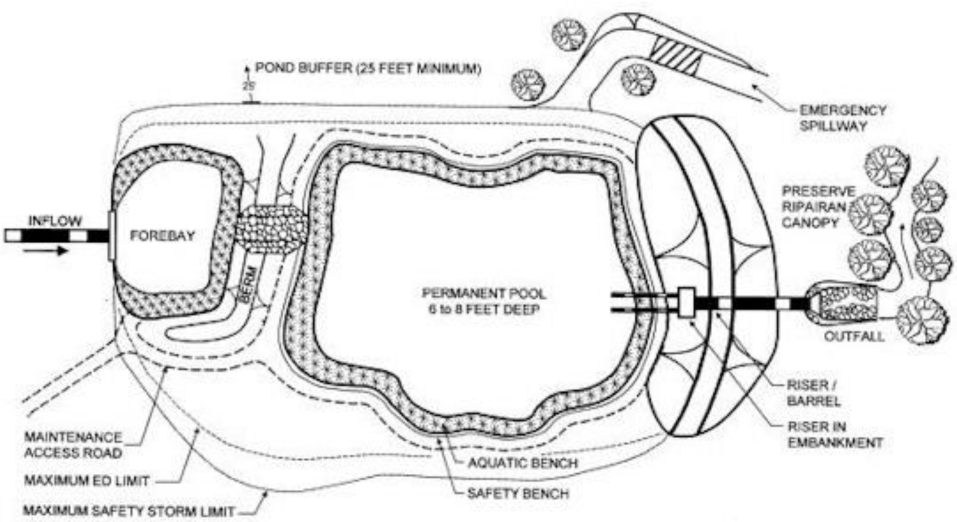
  Potholes in the pervious pavement are unlikely; though settling might occur if a soft spot in the subgrade is not removed during construction. For damaged areas of less than 50 square feet, a declivity could be patched by any means suitable with standard pavement, with the loss of porosity of that area being insignificant. The declivity can also be filled with pervious mix. If an area greater than 50 square feet is in need of repair, approval of patch type should be sought from either the engineer or owner. Under no circumstance should the pavement surface ever be seal coated. Any required repair of drainage structures should be done promptly to ensure continued proper functioning of the system.

References – See Appendix IV, pages 104-113

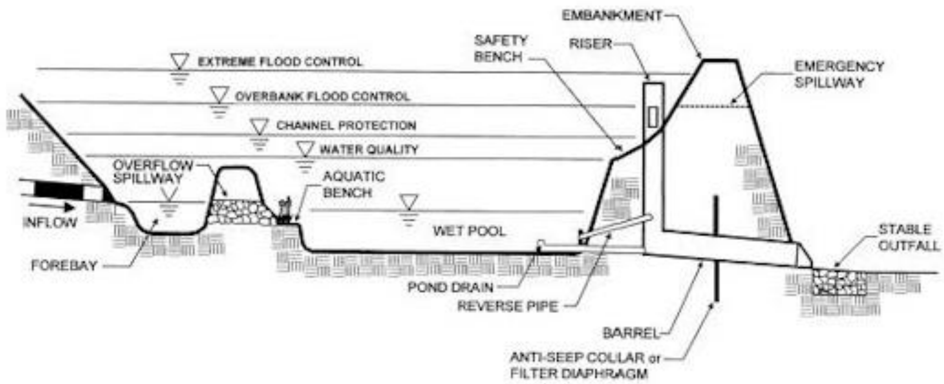
4.7.2 WATER QUALITY PONDS

Description

Water quality ponds are stormwater ponds designed to treat runoff for pollutants and control increases in stream discharge and bedload transport. Water quality ponds may be predominantly dry between storm events, or have a permanent pool or even have wetland features. Water quality ponds remove pollutants by settling, chemical interaction and biological uptake by plants, algae and bacteria. The efficiency of settling suspended solids and the ability to treat dissolved pollutants is improved with the addition of wetlands and permanent pools. Water quality ponds are often designed to provide flood control by including additional detention storage above the volume specified in this practice.



Plan View



Profile

They can also be used effectively in series with other sediment reducing BMPs that reduce the sediment load such as vegetated filter strips, swales, and filters.

Conditions Where Practice Applies

Water quality ponds are applicable to most urbanizing areas where pollutant loads are predominantly particulates and control is needed to address increased erosion potential in downstream channels.

Water quality ponds are appropriate for residential, commercial and industrial areas and are easily incorporated on sites where a stormwater pond is to be constructed to control potential flooding. Even where detention ponds are not necessary for flood control, water quality ponds can be used to address water quality and stream stability concerns.

Water quality ponds are most appropriate for larger sites, greater than 20 acres for wet or wetland ponds or greater than 10 acres for extended detention ponds. Ponds may be beneficial for smaller areas, yet have greater problems sustaining permanent pools, or issues of maintenance such as potential blocking of the outlet (due to small orifices) by trash and debris.

Existing flood control ponds may be retrofitted to meet the water quality and stream stability objectives of these stormwater ponds.

Planning Considerations

Water quality ponds may not be appropriate for ultra-urban areas where adequate space is not available or for heavy industrial areas that require extensive pollution treatment.

Water quality ponds may cause stream warming and may need additional design considerations or may not be appropriate for cold water streams.

Ponds with dams are regulated under the Ohio Revised (ORC) 1521.031: Ohio Water Advisory Council. A dam is exempt from the state's authority (ORC Section 1521.062) if it is 6 feet or less in height regardless of total storage; less than 10 feet in height with not more than 50 acre-feet of storage, or not more than 15 acre-feet of total storage regardless of height. Check with the Ohio Department of Natural Resources, Division of Water, for the most current requirements.

Additional upland practices may be needed to reduce nutrient loads that cause problems common to eutrophic ponds (excess algae, low oxygen levels, and odor).

For wet ponds, soils and site conditions must be appropriate to maintain a permanent pool during dry weather. Permanent pools may be difficult to maintain if the contributing watershed area is less than 20 acres and if the ratio of drainage area to water surface area is less than 6:1.

Suitable soils must be available for constructing the embankment and insuring sufficient impermeability to prevent seepage losses. A trained professional shall conduct an on-site evaluation of the proposed pond site and borrow areas prior to final design to characterize the adequacy of the site and the excavated soils for use as core trench or embankment fill. The evaluation should include a test pit at each abutment, along the centerline of the proposed embankment, the emergency spillway, the borrow area and the pool area. As a general rule, one test pit should be placed for every 10,000 square feet of area examined. All explorations shall be logged using the Unified Soil Classification System.

Treatment goals, watershed characteristics and site constraints should drive designs towards one of 3 main pond configurations:

A. Extended Detention,
B. Wet Extended Detention
C. Wetland Extended Detention.

Pond volume and depth characteristics depend on the type of pond being designed. In all instances, an extended detention volume (portion of the water quality volume, WQv) must be determined and treated.

Design Criteria **- Applicable to Each Pond Configurations**

- Water Quality Volume

The water quality volume (WQv) is the volume of runoff that is treated in a water quality pond. Depending upon the type of pond (dry extended detention, wet or wetland) all or a portion of this volume is stored above wetland or permanent pool features and drained over a 24-48 hour period. Detaining this volume has two stream protection objectives: reducing the pollutants suspended in the runoff and reducing the energy of common storm events responsible for most channel erosion. The water quality volume is calculated using equation 1 below, adapted from Urban Runoff Quality Management (ASCE/WEF, 1998). This is required by the Ohio EPA NPDES general permit for construction activities.

$$WQv\ (ac\text{-}ft.) = C * 0.75 * A / 12 \qquad \text{(Equation 1)}$$

Where:

C = runoff coefficient

A = area draining into the BMP in acres

The runoff coefficient, C, is calculated using the following equation or alternatively values provided in the current Ohio EPA NPDES general permit for construction activities.

$$C = 0.858i^3 - 0.78i^2 + 0.774i + 0.04 \qquad \text{(Equation 2)}$$

Where:

i = watershed imperviousness ratio, the percent imperviousness divided by 100

NOTE: The Ohio EPA NPDES stormwater general permit for construction activities requires that the water quality volume (WQv) be increased by 20% for capacity lost over time due to sediment accumulation.

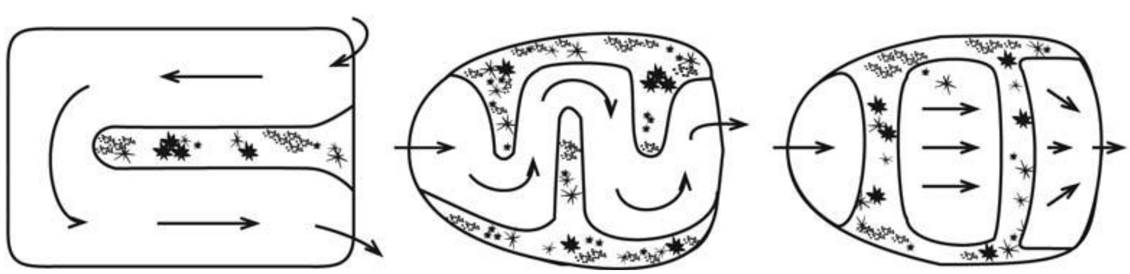
- Pond Configurations

Configure the pond so that water quality treatment is optimized through pond shape and flow length. Improved settling of pollutants occurs as the flow length is maximized. Optimally, designs will avoid the problems of dead storage or incoming water shortcircuiting through the pond and the resuspension of deposited sediments.

Forebays and micropools, pool water at the inlets and outlet of a pond in order to improve the effectiveness and ease of maintenance of water quality ponds. The shape and grade of pond side slopes also strongly influence pond effectiveness and potential safety.

1. Length to Width Ratio

Wedge shaped or ponds that are longer than wide will prevent flow from short-circuiting the main body of water. The ratio of flow length to pond width should be at least 3:1. To increase a pond's flow length, the contours of the pond may be configured to form baffles or an extended flow path. Constructing submerged aquatic benches to form cells will enhance flow routing.

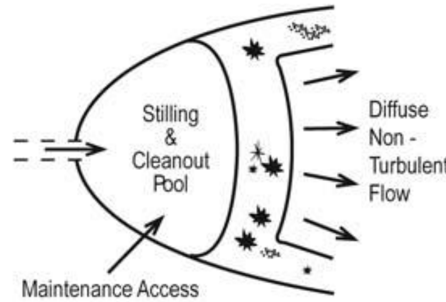


Flow Routing to Enhance Water Quality Treatment

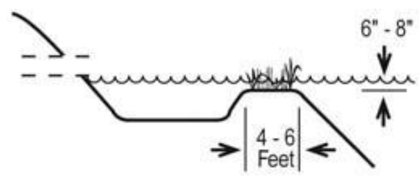
2. Side Slopes

Varying the slope to create benches above and below waterlines increases safety and stability and can create water quality features such as wetland benches in permanent pools. Slopes should not be steeper than 3:1 or shallower than 12:1.

3. Forebay(s)



A forebay is a settling pool located at the inlet to a pond. It is separated from the rest of the pond by a level dike often planted with emergent wetland vegetation. Forebays are primarily used to improve the settling efficiency of a pond but they also reduce maintenance by promoting settling in a confined, easily accessible location.



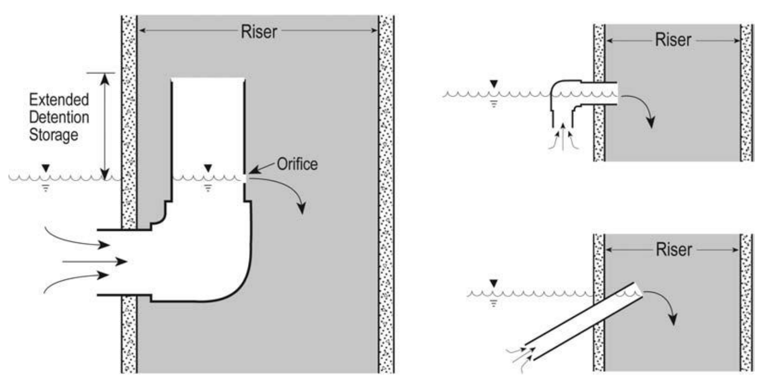
Forebays promote settling by: segmenting or dividing the pond into cells which reduce mixing and promote plug flow; by converting the high velocity concentrated inflow from a pipe to a wide uniform slow flow to the normal pool area; and by dissipating flows through emergent vegetation.

4. Micropool

For wetland and predominantly dry extended detention stormwater ponds, a micropool is recommended in front of the outlet. The micropool allows a reverse slope pipe or other non-clogging outlet to be used. The micropool should be 4-6 feet deep and equal to 10% of the volume of the water quality volume.

5. Non-Clogging Outlet

Extended detention outlets often require small orifices or controls and must be designed to be non-clogging. A reverse flow pipe is one way to configure an outlet to better trap floating pollutants and to be less clogging. Reverse flow pipes draw water from below the water surface to trap floating debris that would otherwise clog the outlet.



Reverse Flow Structures Reduce Clogging and Trap Floating Pollutants

6. Pond Drain

   It is recommended that a drain be installed such that the entire pond can be drained for maintenance or repair purposes.

7. Additional Specifications for Pond Construction

   Embankment ponds must be well constructed and built according to USDA Natural Resources Conservation Service (NRCS) Conservation Practice Standard~~s~~ 378 (Pond) addressing issues such as:

   - Ponds must incorporate emergency spillways designed to safely convey flows exceeding design storm flows.

   - Outlet structures should be built to withstand floatation and incorporate anti-vortex and debris or trash rack devices.

   - Embankments and principal spillway shall utilize adequate soils and compaction, core trenches and anti-seep collars.

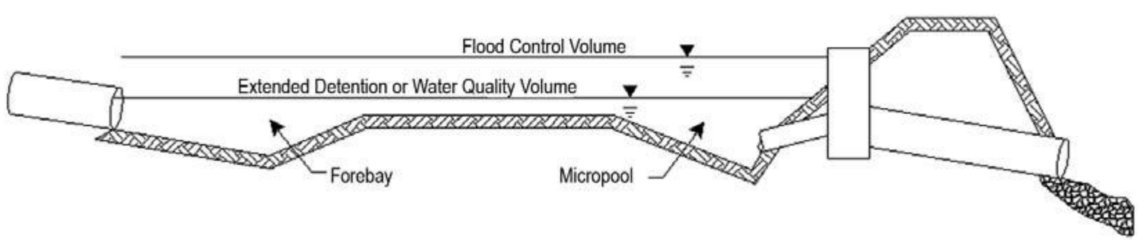
<u>Design Criteria - By Configurations</u>

- <u>Dry Extended Detention Basin</u>

  - Detention Volumes

    The extended detention volume is equal to the water quality volume (WQv) found in equation 1. An additional capacity of 20% must be provided within the water quality volume for sediment accumulation. This additional volume may be utilized in forebays at inlets and in a micropool at the outlet, which will improve the maintenance and efficiency of the pond.

    The City may require additional detention volumes for peak discharge control (flood control).



Storm Water Pond with Extended Detention and Flood Control Volumes

- Outlet Design

  Design the outlet structure (principal spillway) to draw down the extended detention volume over a 48-hour period. The outlet should empty less than 50% of this volume in the first 16 hours.

- Permanent Pool

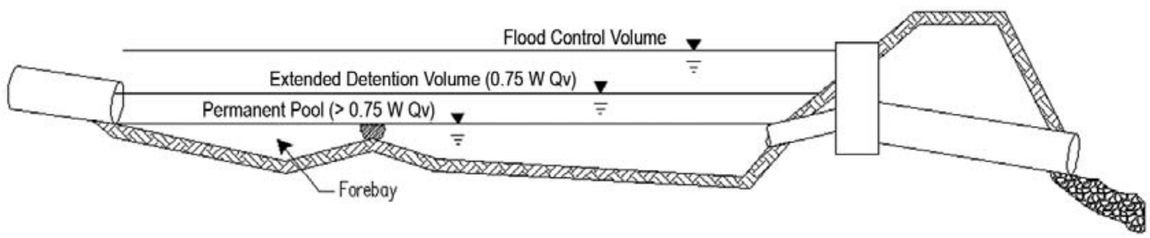
  Dry extended detention basins do not have a permanent pool except for the establishment of forebays at inlets and a micropool at the outlet. While these are not required, they increase the effectiveness of the pond and the ease of maintenance.

- <u>Wet Extended Detention Basin Design Criteria</u>

1. Detention Volumes

   Wet extended detention ponds detain a volume equal to 75% of the WQv found with equation 1 (0.75 WQv) above a permanent pool.

   The City may require additional detention volumes for peak discharge control (flood control).



Wet Storm Water Pond with Extended Detention and Flood Control Volumes

2. Outlet Design

   Design the outlet structure (principal spillway) to draw down the extended detention volume over a 24-hour period. The outlet should empty less than 50% of this volume in the first 8 hours. Peak discharge control (flood control) required by local government can be incorporated into the spillway with additional control devices (e.g. orifices or weirs) above the extended detention outlet.

3. Permanent Pool Volume

   The permanent pool of a wet extended detention pond is equal to three fourths of the WQv (0.75 WQv) found with equation 1 plus an additional volume equal to 20% of the WQv (0.2 WQv) added for sediment accumulation. Thus the original capacity of the permanent pool shall be equal to 0.95 of the water quality volume. This volume may include forebays, cells created within the permanent pool for increasing efficiency.

4. Permanent Pool Depth

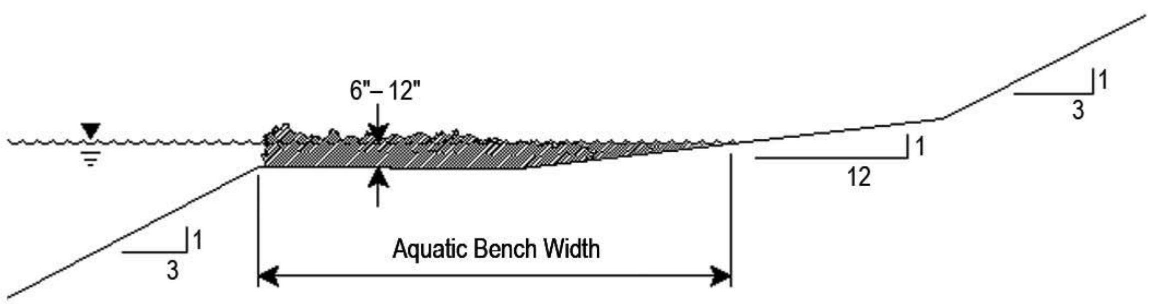
The mean depth of the permanent pool should be between 3 and 6 feet in order to optimize settling of suspended particles. This is calculated by dividing the permanent pool's storage volume by the pool's surface area. A pool that varies in depth will allow diverse conditions for wetland vegetation and portions, which are deep enough for fish. If fish are to be maintained in the pool, approximately 25% of the pool should be at least 6 to 8 feet deep.

Overly shallow pools will have increased problems with algae and the re-suspension of deposited sediments by wind or as runoff enters the pond. Overly deep pools may encourage thermal stratification and anaerobic conditions at the bottom, which allow pollutants (e.g. metals and phosphorus) to be released from sediments.

5. Wetland Benches

Wet extended detention ponds may include wetland environments that greatly enhance water quality treatment by establishing a shallow aquatic bench around the main pool.

When used as one water quality design feature within a wet extended detention pond, wetland vegetation should occupy at least 20% of the wet pool's water surface. It is also recommended that benches be at least 6 feet wide and have depths of 6 to 12 inches on average and not exceed 18 inches.



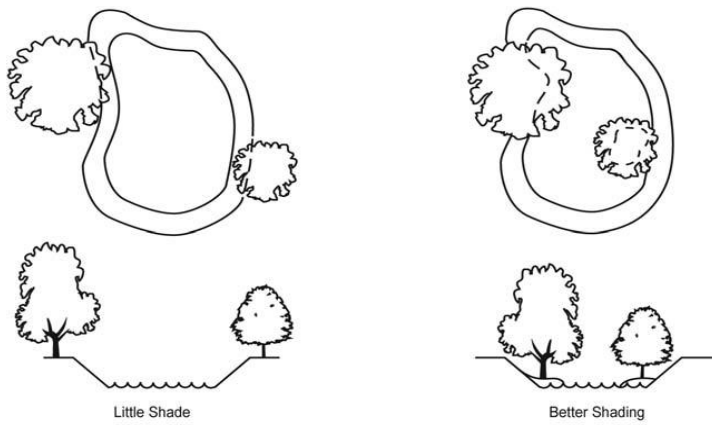
Grading of Side Slope to form a Wetland Bench

6. Reducing Thermal Impacts Through Shading

Pools can act as a heat sink between storm events during the summer months. Water released downstream from the pond can be as much as 10° F warmer than naturally occurring base flow. Large impervious surfaces also warm surface runoff significantly which can be critical to stream systems where fish and other aquatic life are threatened by high summertime water temperatures.

a. Add Shading

Trees planted around the pond, particularly on the south and west sides offer the most protection from the summer sun. Trees planted on islands or peninsulas should also be considered. Because tree roots can damage dams, trees must not be planted on the embankment itself. Wetland vegetation also contributes to shading and reduces thermal impacts.



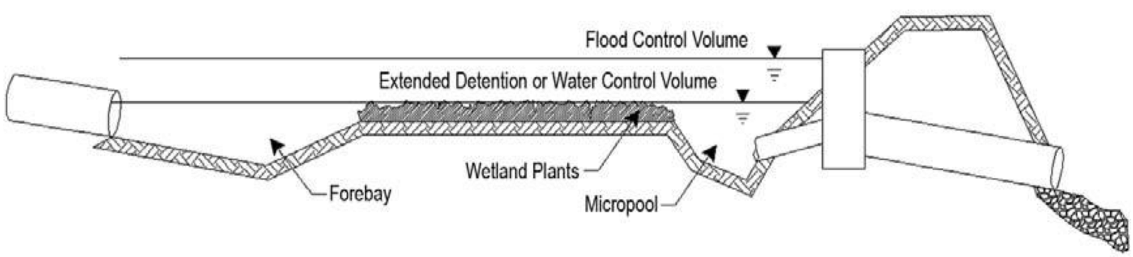
Tree Placement to Shade Ponds and Reduce Thermal Impacts

- <u>Wetland Extended Detention Basin Design Criteria</u>

1. Detention Volumes

Wetland extended detention ponds detain a volume equal to the water quality volume (1.0 WQv) found in equation 1 above the permanent wetland pool.

The City may require additional detention volumes for peak discharge control (flood control).



Wetland Storm Water Pond with Extended Detention and Flood Control Volumes

2. Outlet Design

Design the outlet structure (principal spillway) to draw down the extended detention volume over a 24-hour period. The outlet should empty less than 50% of this volume in the first 8 hours.

Peak discharge control (flood control) required by local government can be incorporated into the spillway with additional control devices (e.g. orifices or weirs) above the extended detention outlet.

3. Permanent Wetland Pool Volume

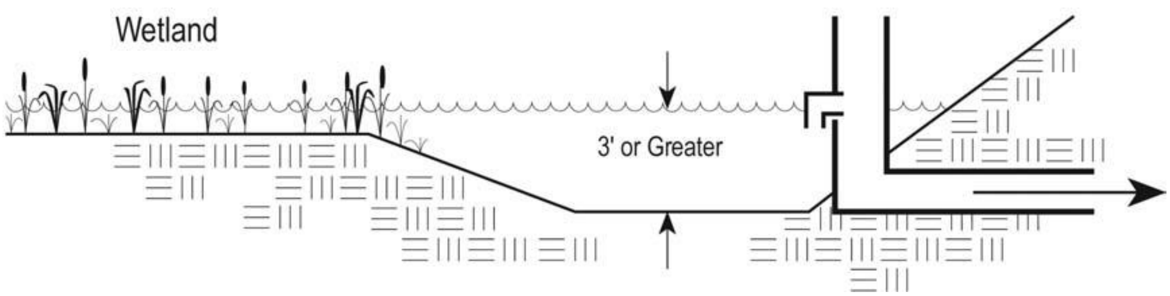
The permanent pool volume is based on the designer's assessment of sufficient runoff and base flow to sustain a wetland pool. The designer should assess the change in storage volume over time based on water entering and leaving the wetland. This water budget should include water entering from precipitation, runoff, base flow, groundwater and any water to be pumped. Water leaving should include evaporation, expected plant transpiration, stormwater outflow, and seepage or percolation.

NOTE: For more comprehensive information refer to the USDA NRCS (2008) Part 650, Engineer Field Handbook (210-VI-NEH-650.13), Chapter 13 "Wetland Restoration, Enhancement or Creation" http://www.pdhonline.com/courses/c689/USDA%20Wetland%20Creation-Planning.pdf.pdf

Add a volume equal to 20% of the water quality volume to the permanent wetland pool volume for accumulation of sediment overtime. This total volume should include forebays, cells and micropools graded within the permanent pool for increasing efficiency.

4. Wetland Depth

Wetland pool depths should generally range between 6-18 inches. The average depth should be between 6 and 12 inches. This depth may vary but must accommodate 1) the depth appropriate for the type of wetland vegetation planted, and 2) adequate volume of runoff stored within the wetland. Wetland diversity and stability will be improved if a variety of depths are created with complex subsurface contours and irregular shapes to provide more edge effect.



Micropool: Open Water Around Outlet Structure of Wetland

A micropool, that is a deep area, greater than 3 feet, should be created at the outlet structure so that vegetation and sediment buildup do not interfere with outflow from the basin.

5. Establishing Wetland Vegetation

Six to eight species of wetland plants should be planted. Species that have worked well in constructed urban wetlands include: common three square, arrowhead, soft stem bulrush, wild rice, pickerelweed, sweetflag, smartweeds, spike rush, soft rush, and a number of other sedges.

Vegetation may be established one or a combination of the following methods: planting nursery stock (plants or rhizomes), mulching with soils from an existing wetland or allowing volunteer establishment. Using only volunteer establishment is discouraged since it often leads to mono-typical stands of invasive or undesirable species.

a. Planting Layout

Initial planting should cover at least 30% of the wetland area, concentrated in several portions of the pond and have densities of four to five plants/square yard. Planting clusters of single species will improve the quality and diversity plantings. Plants should be planned for their appropriate depth within the permanent wetland pool.

b. Grading or Disking the Basin

The basin substrate should be soft enough to permit relatively easy insertion of the plants into the soil. If the basin has been recently graded or excavated, the soil should be sufficiently soft. However, if the basin soil is compacted or hard subsoil is encountered, planting will be difficult.

c. Flood and Drain Prior to Planting

If nursery stock will be used, it is recommended that the wetland area be flooded for a period of time (6-9 months, USEPA) prior to draining and planting.

d. Treatment of Plant Materials

For growing plants, keep the roots moist at all times, and keep the plants out of direct sunlight as much as possible. Vegetation should be planted as soon as possible to avoid damage during on-site storage. Dormant plant material should be stored under conditions similar to those under which the material was stored at the nursery.

When planting container plants dig holes about one third bigger to allow root systems an un-compacted area in which to develop.

e. Mulching with Wetland Soils

If an area is mulched with soil from an existing wetland, plants should be allowed to germinate and grow for a period prior to fully inundating the wetland pool. Care should be taken not to allow the newly germinated plants to dry out.

6. Transition from temporary sediment control basin to permanent stormwater quality pond: often permanent stormwater management ponds are used for sediment control during construction. In most cases, these facilities will need dewatering and sediment removal in order to insure that the pond has the appropriate volume for permanent stormwater design. This includes removal of temporary risers used for sediment control and reseeding bare soil or establishing wetland vegetation in designated areas within the pond.

Maintenance of Water Quality Ponds

While maintenance is inevitable, the amount of maintenance required and its cost can vary considerably depending on the initial design of a pond. A number of design features are helpful in this regard:

1. Sediment Storage

   Reduce the frequency of sediment cleanout easily by increasing the volume available for sediment storage. Increasing the permanent pool volume by 20% or according to the predicted sediment loads is recommended. Ponds used for sediment control during construction should be cleaned out when the site is stabilized, as the cost of cleanout will be considerably less expensive during construction than in the future.

2. On-Site Disposal

   Provide an area on-site for future sediment disposal. A disposal site should be designated during site design.

3. Forebay

   Trapping most sediment in a confined, easily accessible forebay can reduce maintenance costs.

4. Maintenance Easements

   Maintenance easements must be established to allow access to the pond, particularly to the forebays, embankment, outlet structure and sediment disposal areas.

5. Disposal of Pollutants

   Trapped sediment is usually clean enough for on-site use. The large volume of sediment poses the most common disposal problem. Sediments may also have high concentrations of hydrocarbons, nutrients and heavy metals. Soil tests should be done if the pond has received spills, is in a highly industrial area, or if the watershed has intensive traffic.

   Sediment should be spoiled in areas, which will keep pollutants bound in the sediment (e.g., metals and phosphorous). To avoid these pollutants from becoming soluble, acid and anaerobic conditions, such as wetlands, should be avoided.

NOTE: Typical maintenance activities chart for water quality ponds is presented in the Ohio Department of Natural Resources Rainwater and Land Development Manual, Chapter 2.

References – See Appendix IV, page 104-113.

4.7.3 INFILTRATION TRENCH

Description

An infiltration trench is a rock-filled trench that receives stormwater runoff, allowing it to infiltrate into the ground. These structures provide temporary underground storage in the form of a trench or other storage chamber filled with uniform graded stone. Infiltration trenches are used in conjunction with sediment removal practice so that most suspended solids are removed before passing runoff into the infiltration trench. This is typically accomplished by passing runoff through a forebay (see section 4.6.2 - water quality ponds), a grass filter strip or a water quality swale prior to the trench.

Infiltration is the single most efficient post-construction stormwater practice, providing several benefits other control practices don't. Most notably, infiltration tends to reverse the hydrologic consequences of urban development by reducing peak discharge and increasing base flow to local streams. Unfortunately, infiltration trenches must be very carefully constructed to ensure they will continue to function, and they often have high long-term maintenance requirements. Infiltration practices also are limited by site constraints, particularly soils, which must be within a narrow range of permeability.

Conditions Where Practice Applies

- Smaller Sites

  Infiltration trenches are generally not considered practical for sites larger than 5 acres. Used in small areas they offer flexibility in incorporating water quality treatment into a site's drainage system. They may be used prior to runoff entering the site's drainage system, such as along parking lot perimeters. They can be located in small areas, which cannot readily accommodate wet ponds or similar facilities.

- Soil Hydraulic Conductivity

  Hydraulic conductivity describes the ability of water to move through a soil. Hydraulic conductivity should be at least 0.52 inches per hour but not more than 2.4 inches per hour for infiltration trenches. These rates represent average or saturated soil conditions, not dry conditions. Rates slower than the minimum will lead to trench sizes that are unreasonably large and are more prone to failure. Higher infiltration rates will not provide adequate runoff treatment or protection against ground water contamination. Higher hydraulic conductivity will not provide adequate runoff treatment and protection against groundwater contamination. Trenches should not be constructed on undisturbed soils that have been filled. On-site evaluation of soil parameters related to hydraulic conductivity and groundwater by a trained professional is recommended.

- Industrial or Other Areas of Potential Ground Water Contamination

  This practice should not be used in heavy industrial developments, areas with chemical storage, pesticide storage or fueling stations.

- Stable Slope

  Trenches should not be used in slip prone areas where they may cause slope instability.

- Hydrologic Recharge

  Infiltration practices help reduce runoff and may help support recharge of groundwater and baseflow to streams. This practice may be a particularly desirable option when the receiving stream is a cold water habitat.

Planning Considerations

- Sediment Clogging

  The principle threat to infiltration trenches and a common reason for their failure is sediment clogging and sealing off of the permeable soil layer. An effective sediment trapping system is an essential part of all infiltration trench designs. Vegetated swales, buffer strips or sediment settling ponds should be planned so that most sediment is removed from runoff prior to reaching the infiltration trench. Additionally infiltration trenches may not be installed until disturbance from construction has ended and soils are stabilized.

- Groundwater Protection

  Precautions must be taken to guard against the facility introducing contaminants into water supply aquifers. Excessively permeable soils will not effectively stop pollutants and should not be used for infiltration practices Infiltration trenches should be used with caution in well-head protection areas, i.e., areas of the state where the public water supply comes from ground water. At a minimum, infiltration structures should not be located within 100 feet of an active water supply well. A minimum vertical separation of 3 feet between the bottom of the infiltration trench and the seasonal high water elevation of the ground water must be maintained, although larger separations are recommended where achievable.

- Considerations for Cold Climates

The design volume of the infiltration trench may need to be increased in order to treat snowmelt. In addition, if the practice is used to treat roadside runoff, it may be desirable to divert flow around the trench in winter to prevent infiltration of chlorides from road salt. Finally, a minimum setback of 20 feet from road subgrade is required to ensure that the practice does not cause frost heaving.

Design Criteria

NOTE: Water Quality Volume (WQv) information and formula located on page 60 and 61.

- Diversion

Storm water runoff should be directed to the infiltration trench via dispersed sheet flow wherever possible. A grass filter strip of at least 25 feet must precede the infiltration trench in these situations. Where runoff is directed to the infiltration trench as concentrated flow (via a swale, storm sewer or other discrete conveyance), the infiltration trench must be designed “off-line” such that flows in excess of the Water Quality Volume (WQv) are diverted around the infiltration trench.

In addition, a diversion that allows the trench to be bypassed when the pretreatment system becomes clogged or otherwise fails should be included in the design. This can be accomplished by providing a drain valve.

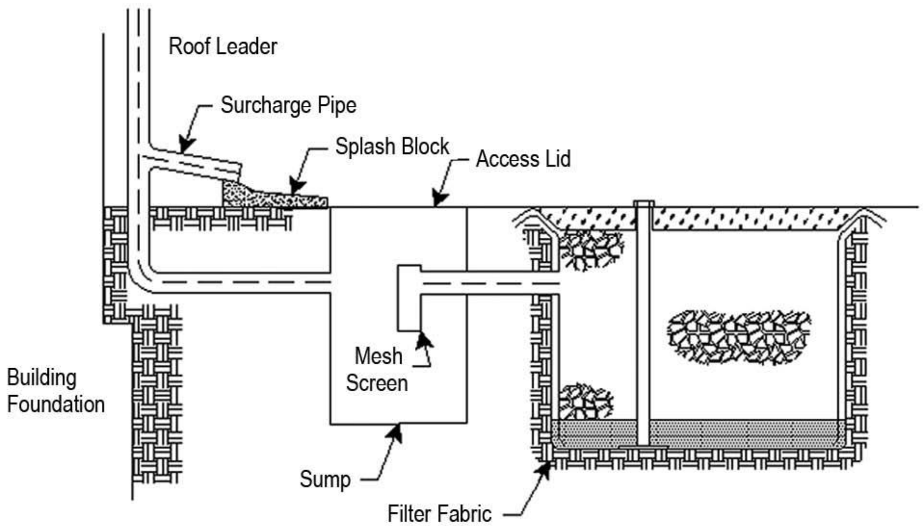
- Soil Hydraulic conductivity

Soil infiltration rates within the trench must be between 0.52 and 2.4 inches per hour. The soil should have no greater than 20 percent clay content and less than 40 percent silt/clay content.

Site-specific soil tests should be performed to confirm that the hydraulic conductivity falls within the required range. A certified Soil Scientist or other trained professional shall perform one test hole per 5000 feet, with a minimum of two borings within the planned facility location. This evaluation shall include an evaluation of the normal and seasonal high groundwater levels.

- Pretreatment

The potential for failure of infiltration practices due to clogging by sediments is high. Failure will result if sediment is not trapped before runoff enters the trench. Thus, it is imperative that the facility design includes a durable, maintainable pretreatment system for removing sediment from stormwater before the trench. This can be accomplished by installing a plunge pool. Where infiltration trenches are used to treat rooftop runoff with drainage areas of 1 acre or less, pretreatment can be accomplished by providing an underground trap with a permanent pool between the downspout and the infiltration trench. The trap must be accessible, but sealed tightly so that it does not become a breeding ground for mosquitoes.



Underground pretreatment facility and infiltration trench for treating rooftop runoff.

- Size of Pretreatment Facility

  The size of the pretreatment facility is based on the infiltration rate of the soil in which the infiltration trench is built. For soils with infiltration rates of 2.0 inches per hour or less, the pretreatment facility shall be sized to contain 25% of the WQv. For infiltration rates greater than 2.0 inches per hour, the pretreatment facility shall be sized to contain 50% of the WQv.

- Exit Velocity from Pretreatment Facility

  The velocity of runoff as it exits from the pretreatment device must be non-erosive.

- Drain Time Requirements

  The practice is to be designed to infiltrate the WQv through the bottom floor of the structure in 24 to 48 hours. Drain times in excess of 72 hours should be avoided to prevent mosquito-breeding habitat from forming. Flows in excess of the WQv are to be diverted around the trench.

- Dimensions

  The dimensions of the storage reservoir (infiltration trench) are made by fitting the length, width and depth into a configuration, which satisfies drain time and storage volume requirements. The trench dimensions shall be sized by accepted engineering methods such as those outlined below:

1. Determine Initial Storage Depth

   The bottom of the infiltration trench must be deeper than 2 feet to avoid freezing and shallow enough to leave at least 3 feet between the seasonal high-water table or bedrock and the trench bottom. Soil morphology also must be considered in determining the dimensions of the storage reservoir to utilize the optimum horizons or strata. The presence of a thin, slowly permeable soil horizon may require a trench depth which completely penetrates it to more permeable underlying material. Long trenches may need to be curved parallel to the topographic contour in order to keep the trench bottom elevation within the optimum depth in the soil profile.

2. Determine Area of Trench Bottom

   The bottom of the trench is to be completely flat so as to allow runoff to infiltrate through the entire surface.

$$A_{min} = \frac{WQv}{Porosity*(E*T)}$$

Where: *Amin* = Minimum area of the bottom of the trench (ft2);
WQv = Water Quality Volume (ft3); (Trench volume less stone volume).
E = Exfiltration Rate (ft./hr.); (Soil infiltration rate at trench bottom)
T = Drain Time (hr.) (Must be 24 to 48 hrs. per Ohio EPA requirements)

   The excavated volume of the trench is the WQv divided by porosity or the void space of the stone.

3. Determine Length and Width

   A long, narrow trench is less affected by water table mounding. If depth to seasonal high-water table or bedrock is within 5 feet of the trench bottom, it is advisable to design the trench as long and narrow as possible. Otherwise, the configuration of the trench is not restricted and is only limited by site design constraints.

4. Stone

   The infiltration trench is filled with clean, washed aggregate. Stone with a diameter of between 1 and 3 inches should be used.

5. Geotextile

   The sides and top of the trench must be lined with a non-woven geotextile to restrict the amount of sediment entering the structure. The top layer of the geotextile should be covered by 6-to-12 inches of smaller sized gravel (0.75-inch diameter). This top layer of gravel and geotextile must be replaceable. The bottom of the trench must NOT be covered with geotextile to prevent clogging with sediment. The geotextile should meet the following specifications:

SPECIFICATIONS	CRITERIA
Material	ASTM D-3776
Weight, oz./yd2	4
Grab tensile strength, lbs./min (ASTM D4632)	90
Elongation at break, 5 (ASTM D4632)	30
Toughness, lbs./min	6000

6. Bottom Sand Filter

   The bottom of the trench should be covered with a clean layer of sand, approximately 6 inches deep.

7. Observation Well

   An observation well, consisting of a perforated vertical 6-inch diameter PVC pipe with lockable cap should be installed in the trench to monitor performance. The original depth of the well must be marked on the top of the well.

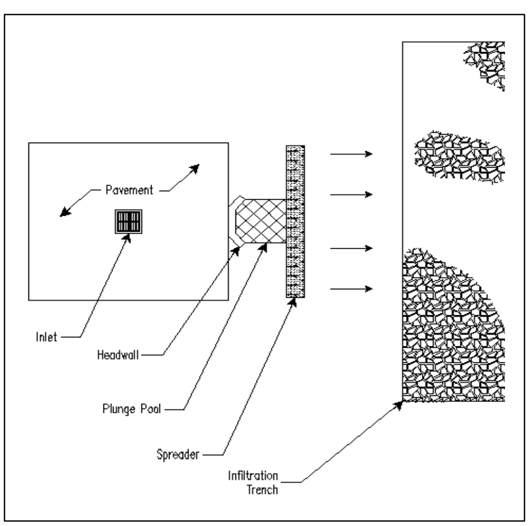
8. Overflow

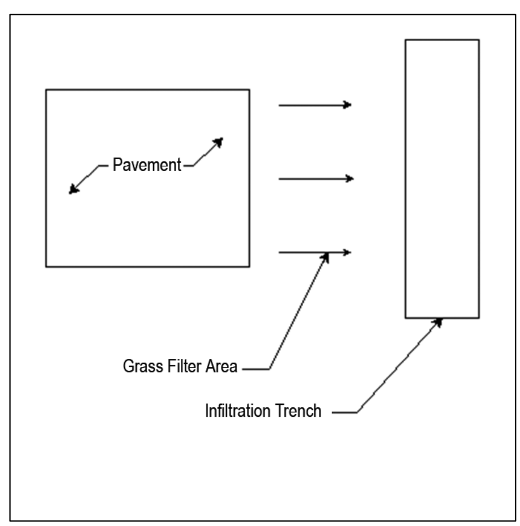
   Infiltration trenches, like all stormwater facilities, must be designed to handle storms, which exceed their storage capacity without damage. Discharges must be non-erosive and overflow must always pass around the infiltration trench without being restricted by sediment filters.

   For example, the infiltration trenches that accept concentrated runoff from a subsurface pipe must have an overflow structure that collects overflow from within the structure rather than forcing runoff up and out through the geotextile cover.

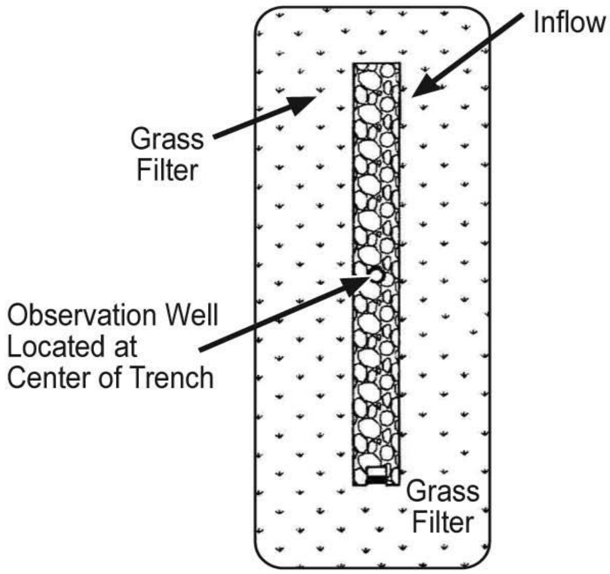
9. Construction Sediment

   Due to their sensitivity to sediment, infiltration trenches should not receive runoff from disturbed areas of the site. It is advisable to construct the infiltration trench only after the contributing drainage area has been stabilized.





Typical Infiltration Trench with Plunge Pool



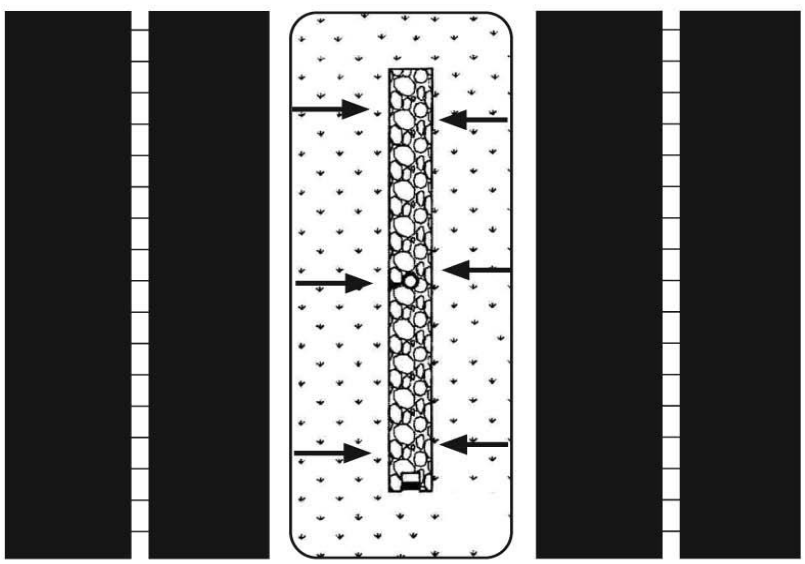


Illustration of a median strip trench design

Infiltration trenches have a high rate of failure. In one study in Prince George's County, Maryland (Galli, 1992), less than half of the trenches investigated were still functioning properly and less than one third still functioned properly after 5 years. However, many of these structures did not incorporate pretreatment of runoff. Thus, it is critical to ensure that proper pretreatment of runoff has been provided.

Maintenance

The following regular maintenance and inspection protocol is recommended:

SCHEDULE	ACTIVITY
Twice per year	Check observation wells following 3 days of dry weather. Failure to percolate within this time period indicates clogging. Inspect pretreatment devices and diversion structures for sediment build-up and structural overflow.
Standard maintenance	Remove sediment and oil/grease from pretreatment devices as well as overflow structure.
Upon failure	Total rehabilitation of the trench should be conducted to maintain storage capacity within 67% of the design treatment volume and 72-hour exfiltration rate limit. Trench walls should be excavated to expose clean soil.
Annually	Trim adjacent trees to assure that drip-line does not extend over the surface of the infiltration trench.

Typical Maintenance for Infiltration Practice

References – See Appendix IV, page 104-113

4.7.4 SAND AND ORGANIC FILTERS

Above-ground Austin Sand Filter and sand filtration chamber

Description

Sand filters utilize a sedimentation chamber and a filtration chamber to treat stormwater. The first chamber (sedimentation) removes large particles from stormwater by allowing them to settle out of suspension, while the second chamber (filtration) removes finer particles by filtering stormwater through a bed composed of sand or a combination of sand and organic material overlying a drain system.

Sand filters provide good treatment for pollutants except nitrates. Since these facilities attenuate the peak flows of common storm events, they are expected to reduce the potential for downstream channel erosion.

Conditions Where Practice Applies

Sand and organic filters are most often implemented on ultra-urban sites dominated by impervious area or where space is a consideration. Therefore, sand filters, if maintained frequently enough to prevent clogging, are effective at treating stormwater "hot spots" with atypically high particulate loads, such as commercial parking lots, fueling stations, auto recycling facilities, industrial rooftops, commercial nurseries, outdoor loading/unloading facilities, and vehicle or equipment washing facilities.

Sand filters are appropriate on sites where contamination of groundwater may be a concern. In most instances, sand filters are constructed with impermeable basin or chamber bottoms that help to collect, treat, and release runoff to a storm drainage system or directly to surface water with no contact between runoff and groundwater. Sand filters can be used in areas where a permanent pool cannot be maintained for a wet pond. Sand filters should not receive runoff from active construction areas and are not appropriate for continuously disturbed areas that could cause premature clogging of the sand/media bed.

The two most common types of sand filters used in the United States, the Austin Sand Filter and the Delaware Perimeter Sand Filter.

Planning Considerations

- Size and Condition of Contributing Drainage Area

  Sand filters are best suited to treat drainage areas of up to 25 acres for Austin aboveground sand filters and up to 1 acre for Delaware perimeter or underground units.

- Slopes

  Sand filters can be used on sites with up to 6 percent slope. Austin aboveground sand filters require an elevation drop (head) of about 4 to 8 feet to allow runoff to flow through the system, while Delaware Perimeter Sand Filters typically require only 2 feet of head. The top of the filter bed must be completely level and stormwater must enter the filtration chamber as sheet flow.

- Climate

  The filter bed and internal conveyance structures may freeze in aboveground and perimeter sand filters unless the filter bed is placed below the frost line. Alternative conveyance systems such as a weir system between the sediment chamber and the filter bed may prevent the filter bed from freezing in colder climates.

Design Criteria

This manual provides the design criteria for two common configurations of sand filters: the Austin Aboveground Sand Filter and the Delaware Perimeter Sand Filter.

NOTE: Other manuals should be consulted for other design variations.

- Design Steps

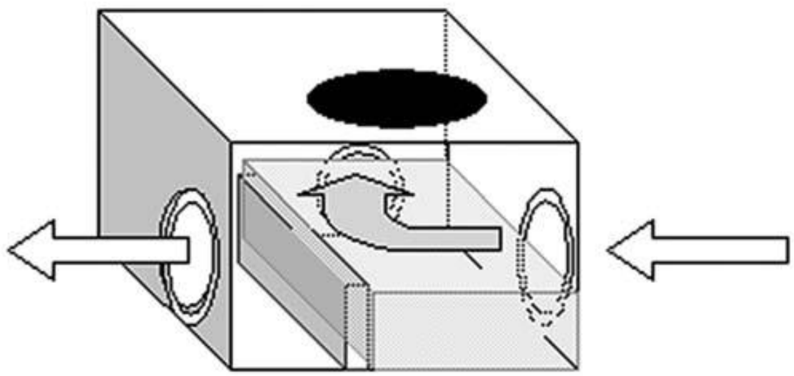
  Sand filters are usually constructed inside a concrete shell or built directly into the terrain over an impermeable liner. Where possible, the filter bed should be constructed below the frost line to prevent freezing. Although most Austin Sand Filters are open, they have been installed underground in parking areas, along the perimeter of parking lots, and in medians or landscaped areas.

  1. Determine overall treatment Volume (WQv)

     See Section 4.7.2 (Equations 1 & 2)

  2. Divert Flows Exceeding Treatment Volume

In most cases flows into the sand filter are limited to the water quality volume (WQv). Therefore other measures may be necessary to meet flood control detention requirements either (1) by diverting all runoff exceeding the water quality volume to separate facilities or (2) by increasing the size of the sedimentation basin and placing a second outlet sized to meet flood control requirements above the stage of the water quality volume. The figure below shows a device that utilizes a weir to divert the water quality volume to a sand filter.



A weir inside the junction box of the storm sewer system diverts initial flows to sand filter.

3. Designing the Sedimentation Chamber (Basin)

The sedimentation chamber is the first stage of treatment within a sand filter. The chamber provides pretreatment of runoff by settling out coarser particles from runoff in order to prevent clogging and to reduce regular maintenance of the sand filter.

- The Austin Sand Filter – Sedimentation Chamber

  The sedimentation chamber within an Austin Sand Filter is designed to completely empty between storms. This requires a somewhat larger size in order to minimize re-suspension of settled material, but also minimizes potential mosquito breeding conditions that exist within Delaware Perimeter Sand Filters and other designs that retain water between storms.

  - Basin Dimensions

    The volume of the sedimentation basin equals the WQv plus an additional 20% of the WQv for sediment storage. The water depth in the sedimentation basin when full should be at least 2 feet and no greater than 10 feet. The minimum surface area of the sedimentation basin is determined by using the equation:

$$As = (1.2 * WQv)/(ds + freeboard) \qquad \text{(Equation 3)}$$

Where:

As = Minimum surface area of sedimentation chamber (cubic feet)
WQv = Water Quality Volume (cubic feet)
ds = Basin depth (feet)

freeboard = 0.5 feet

The sedimentation chamber should be configured so that it has a minimum length-to-width ratio of 2:1 between inlet(s) and the outlet, otherwise baffles may be necessary within the sedimentation chamber. A fixed vertical sediment depth marker should be installed in the sedimentation basin to indicate when 20% of the basin volume has been lost because of sediment accumulation.

- Sedimentation Chamber Inlet

The WQv should be discharged uniformly into the sedimentation chamber at a velocity of no more than 2 ft./sec in order to maintain near quiescent conditions. Energy dissipation devices may be necessary in order to reduce inlet velocity to 2 ft./sec or less.

- Sedimentation Chamber Outlet

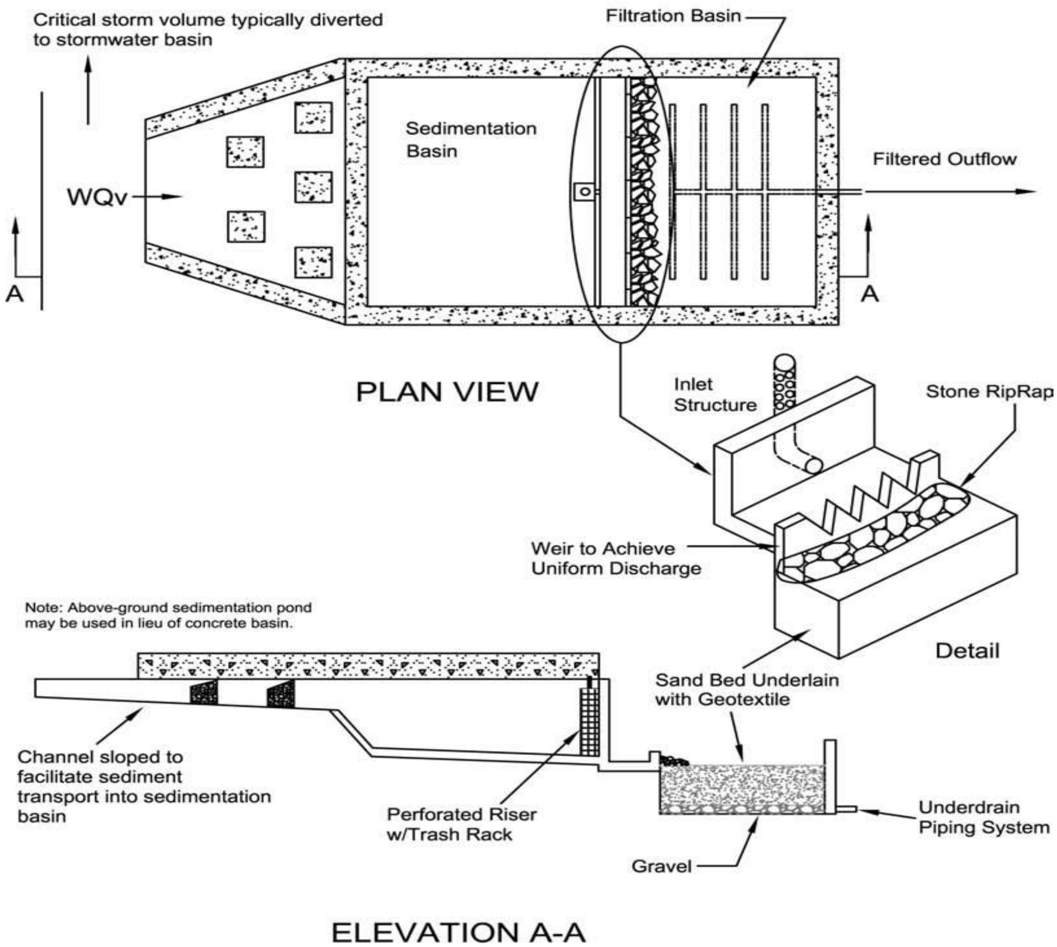
The outlet of the sedimentation basin conveys the WQv into the filtration chamber. The outlet structure should consist of a weir or a perforated riser pipe with a trash rack discharging to a weir acting as the inlet to the filtration chamber.

ADDITIONAL REQUIREMENTS: The surface area of the cell will generally be between 5 and 10 percent of the contributing drainage area.

- Liners

For sedimentation basins built directly on the terrain of the site, they must be built on an impermeable liner, particularly in areas where groundwater protection is of primary importance. The liner may consist of either compacted clay with a hydraulic conductivity of 1 x 10-6 cm/sec or less, or nonwoven geotextile fabric meeting the specifications of American Standard Test Methods (ASTM) D-751 and ASTM D-1682 and a minimum US Standard Sieve size of 80.

Austin Sand Filter
(Not to Scale)



- The Delaware Perimeter Sand Filter – Sedimentation Chamber

  The sedimentation basin within the Delaware Perimeter Sand Filter system is usually a narrow 24" deep trough parallel to; and the same length and width as, the filtration basin, separated by a weir that runs the entire basin width with an elevation equal to the elevation of the top of sand in the filtration basin. This weir results in a permanent pool 24 inches deep, the depth of the filtration bed, within the sedimentation basin.

  - Sedimentation Chamber Surface Area

    To meet Ohio EPA permit requirements, the WQv must fit within the volume of the sedimentation basin and the filtration basin between the top of the filter media and an overflow weir designed to divert flows in excess of the WQv to conveyance and/or detention facilities sized to meet local drainage criteria. The following equation may be used to calculate the surface area of the sedimentation basin:

$$A_s = WQv/2h - A_f \qquad \text{(Equation 4)}$$

Where:

A_s = Surface area of the sedimentation basin (square feet)
WQ_v = Water quality volume (cubic feet)
$2h$ = Maximum allowable depth of water over the filter (feet)
A_f = Surface area of the filtration basin (square feet)

The surface area of the sedimentation basin and the filtration basin are usually equal in a Delaware Perimeter Sand Filter, allowing the following equation to be used to determine the maximum allowable depth of water over the filter:

$$2h = WQv / 2{*}A_f \qquad \text{(Equation 5)}$$

Solve this equation simultaneously with Equation 5 to calculating the surface area of the filter bed.

- Establishing Basin Width and Length

  Once the area of each chamber is calculated, the dimensions of the facility must be established. Although typical sediment trenches and filter trenches are 18 to 30 inches wide, site constraints dictate the width. In addition, other factors such as available grate widths also may dictate final widths. Standard grate width is 26 inches.

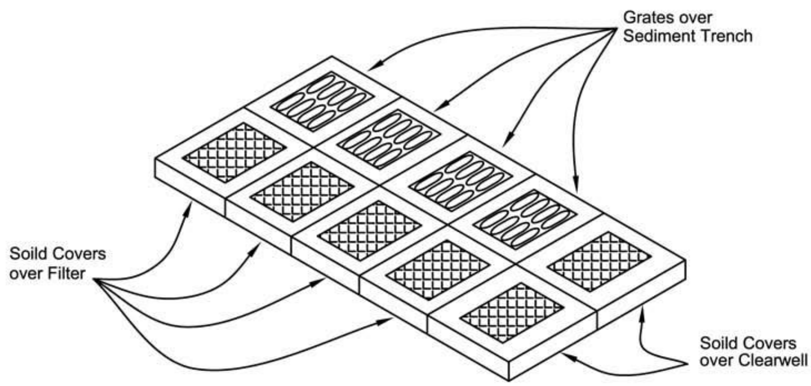
- Floatable Control

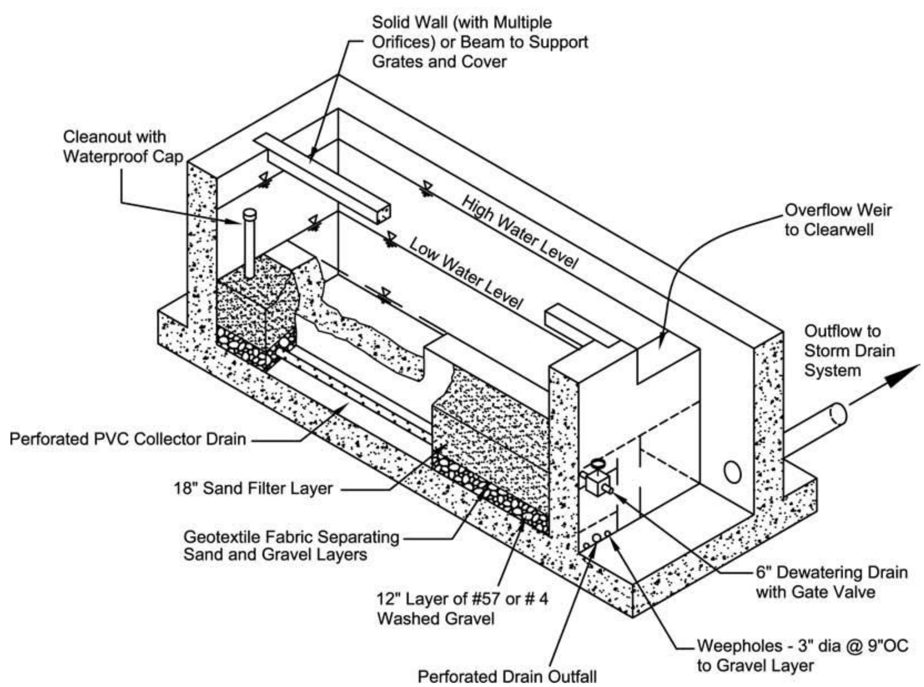
  If installing a Delaware Sand Filter in a situation where floatables or hydrocarbons are a concern, long-term maintenance plans should reflect the increased maintenance needs of the sand filter. In addition, large storm overflow weirs should be equipped with a 10-gauge aluminum hood or commercially available catch basin trap. The hood or trap covers should extend a minimum of 1 foot into the permanent pool.

- Dewatering Drain

  A 6-inch diameter dewatering drain with gate valve should be installed at the top of filter bed elevation through the partition separating it from the clearwell chamber.

Delaware Sand Filter
(Not to Scale)





4. Designing the Filtration Chamber

   Once the WQv passes through the sedimentation chamber, it enters the filtration chamber where the stormwater passes through a sand filter for treatment. Surface area is the primary design parameter.

   a. Filter Surface Area - The filter surface area is calculated using the following formula:

$$A_f = \frac{WQv * d_f}{k * (h + df) * t_f} \qquad \text{(Equation 7)}$$

Where:

A_f = Filter surface area (feet2)

d_f = Sand bed depth (feet)

k = Coefficient of permeability for sand filter (feet/day)

= 3.5 ft./day for clean concrete sand (0.02” to 0.04” diameter) satisfying AASHTO M-6 or ASTM C-33

h = One-half the maximum allowable water depth over filter (feet)

t_f = Time required for runoff volume to pass through filter (days) or 1.67 days (40 hours) per Ohio EPA requirement

b. Filter Basin Inlet

Storm water must be spread uniformly across the surface of the filter media. To assure a uniform flow, stormwater must enter the filtration chamber using flow spreaders, weirs or multiple orifice openings, and the receiving end of the sand filter protected (splash pad, riprap, etc.) such that erosion of the sand media does not occur.

- Sand Bed

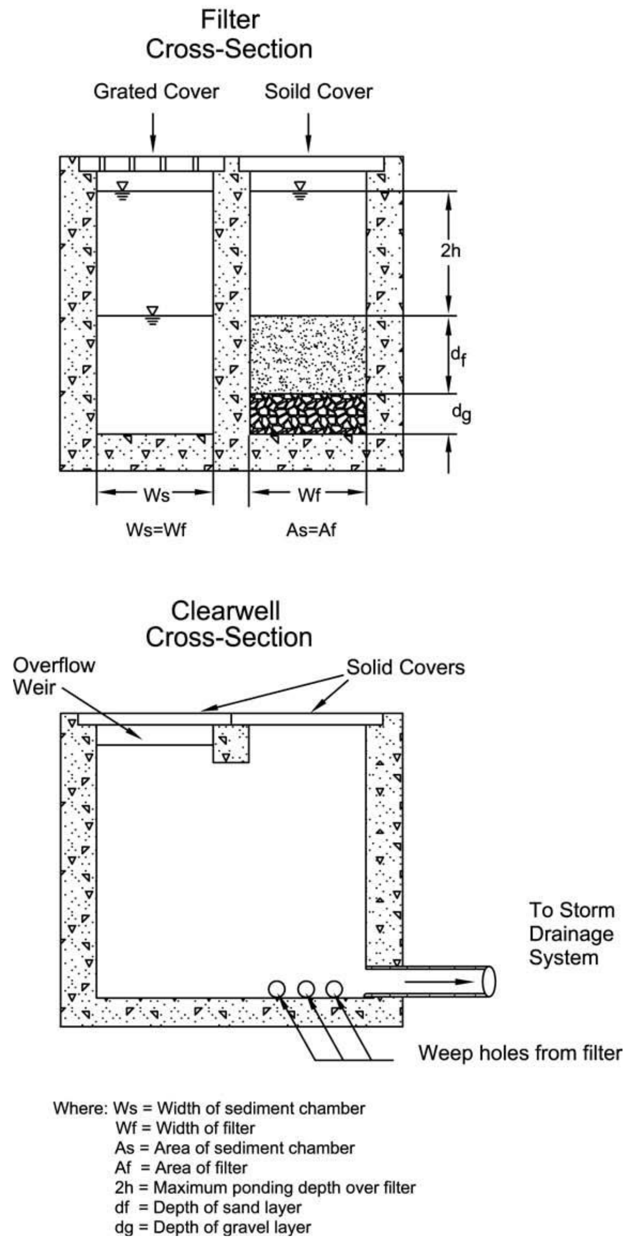
The sand filter is constructed with at least 18 inches of sand overlying at least 6 inches of very coarse gravel (0.5 to 2 inch diameter). The sand and gravel media shall be separated by a permeable geotextile fabric meeting ASTM D-751 and ASTM D-1682, and the gravel layer shall be placed on drainage matting made of geotextile fabric meeting ASTM D-2434, ASTM D-1682, and ASTM D-1117.

- Underdrain and Outlet Requirements

The underdrain piping consists of 4 inch diameter perforated PVC pipe (Schedule 40 PVC or greater), configured as a main collector pipe and, for Austin Sand Filters, two or more lateral branch pipes placed no more than 10 ft. apart or 5 ft. from the basin wall. Perforations should be 3/8 inch in diameter, with at least 6 holes per row and a maximum spacing between rows of perforations of no more than 6 inches. Each underdrain pipe should be wrapped in a geotextile fabric meeting ASTM D-751 and ASTM D-1682, with a minimum of 2 inches of gravel covering the top surface of the PVC pipe. Each pipe must have a minimum slope of 1% (1/8 inch per foot), and each individual underdrain pipe shall have a cleanout access location.

- Weepholes

Weepholes between the filter chamber and the shell may be provided as a backup in case of underdrain pipe clogging. If used, weepholes should be 3 inches in diameter with a minimum spacing of 9 inches center to center. The openings on the filter side of the dividing wall should be covered to the width of the trench with 12-inch high plastic hardware cloth of 1/4-inch mesh or galvanized steel wire, minimum wire diameter 0.03-inch, number 4 mesh hardware cloth anchored firmly to the dividing wall structure and folded 6 inches back under the bottom stone.



Delaware Sand Filter
Cross sections

Maintenance of Sand Filters

Filter systems require frequent maintenance. Two design considerations that can help reduce maintenance problems are:

1. Providing access to the filtering system
2. Addressing confined space issues for underground systems

Where observation wells and grates are used, lifting rings or threaded sockets should be provided to allow for easy removal by lifting equipment. Access for the lifting equipment must be provided. Any long-term maintenance plan for sand and organic filters should include regular inspections for each of the following items:

Schedule	Activity
Monthly	Debris Removal Check for clogging and sediment accumulation on the filter surface – remove and replace areas where clogging is occurring or likely If sediment chamber is more than half full of sediment, clean out Vegetation Control for surface systems (if applicable) • Mowing • Fertilization • Repair erosion
Semi-Annual	Check for cracks and leakage Inspect, repair grates Replenish media
Annual and/or after major storms	Remove accumulated sediment from sedimentation chamber Rake and/or remove sediment from surface of filter bed Inspect spillways and repair if necessary

Typical maintenance activities

References – See Appendix IV, pages 104-113.

4.7.5 GRASS FILTER STRIPS

Description

Grass filter strips, also known as vegetated filter strips, treat the water quality of small sheet flows from developed areas. They are uniform strips of dense turf or meadow grasses with minimum slope, best suited to accept diffuse flows from roads and highways, roof downspouts, and very small parking lots, usually prior to runoff being collected by swales, ditches or storm drains. They are also an ideal component of stream buffers or as pretreatment to a structural practice.

Dense turf creates a thick porous mat, which slows runoff velocity from small flows causing deposition and filtration of particulates. Other pollutant removal mechanisms are nutrient uptake, adsorption and infiltration. Grass filter strips are generally not very effective for treating soluble pollutants. Their overall effectiveness is highly variable depending on slope, the quality of turf, and flow rates. It is critically important to maintain sheet flow through the filter strip; otherwise the practice provides little to no treatment.

Conditions Where Practice Applies

Grass filter strips are an adaptable practice that often can be incorporated throughout a development site, allowing multiple use from turf areas. Grass filter strips, should not be used as the primary control practice to provide water quality treatment for a development site, particularly hot spots such as gas stations and junkyards, but can be used as a supplemental practice or as pretreatment when combined with another structural treatment practice.

Natural meadow areas also may be used for grass filter strips. Grass filter strips are most often located in landscaping areas around building and parking lot perimeters, in greenbelts or along conservation easements, and median strips in parking lots and streets. The site's topography must allow shallow slopes and sheet flow runoff through the filter strip.

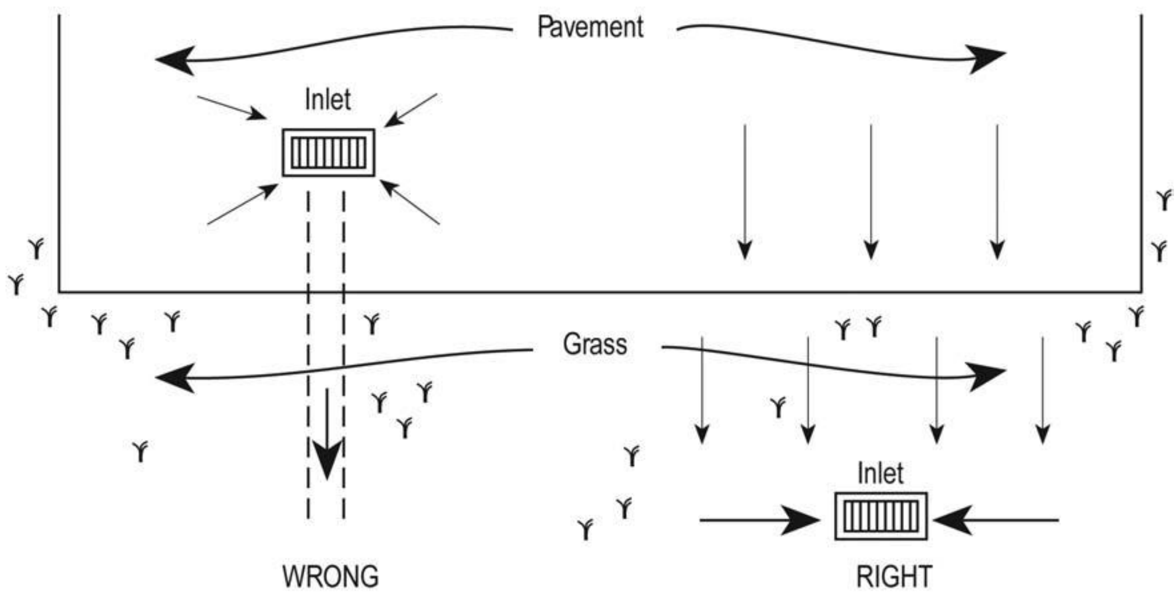
Filter strips are a suitable practice to protect cold-water habitats as they typically do not warm runoff.

Filter strips are impractical in ultra-urban settings because they consume a large amount of space when compared to other practices. Filter strips typically consume an equal width to the impervious drainage area they treat.

Planning Considerations

- Grass Filter Strips at the Source vs. Buffer Strips at the Resource

  Grass filter strips are used as close as possible to the source of the runoff. They are integrated throughout a development site such as along the edges of parking lots. Buffer strips, on the other hand, are used adjacent to perennial and intermittent stream channels. Grass filter strips are planted to turf while buffer strips have diverse forest vegetation. Grass filter and buffer strips both treat sheet flow runoff but buffer strips also provide many additional functions important to the riparian system: shading, bank stability, leaf litter and detritus.



Runoff routed through grass filter strip before entering drainage system

Design Criteria

- Siting Criteria

  The filter strip should about the contributing drainage area. If placed abutting a parking lot, devices that channelize flows into the filter, such as curb cuts and gutters should be avoided. In order to minimize soil compaction and to maintain quality dense vegetation, filter strips should not be located in areas expected to receive heavy pedestrian or vehicular traffic once the site is developed.

- Drainage Area

The limiting design factor for grass filter strips is not the drainage area to the practice, but rather the length of flow leading to it. The length of flow cannot exceed the length at which sheet flow concentrates. As a rule of thumb, sheet flow from impervious surfaces will concentrate within a maximum of 75 feet, and 150 feet from pervious surfaces (Center for Watershed Protection, 1996). Thus, as a rule of thumb, a filter strip can treat 1 acre of impervious area per 580-foot length and 1 acre of pervious area per 290-foot length.

- Slope

The slope of a grass filter strip should be as flat as possible. However, if standing water may create a nuisance, slopes should be sufficient to provide positive drainage. To avoid runoff converging into concentrated flows, slopes must be less than 5%. Filter strips that are 1% slope or flatter should be avoided unless they are built on very sandy or gravely soils. The top and toe of the slope should be as flat as possible to encourage sheet flow and prevent erosion.

- Slope Length

A higher level of pollutant removal is achieved the longer the slope length (the distance water flows through a filter strip). Grass filter strips must have a minimum slope length of 25 feet, but should be designed to provide a slope length based on their slope within the ranges noted in the table below:

Slope of Filter Strip	75% Particulate Trap Efficiency	90% Particulate Trap Efficiency
1%	25 ft.	50 ft.
2%	30 ft.	120 ft.
3%	40 ft.	135 ft.
4%	60 ft.	170 ft.
5%	75 ft.	210 ft.

- Ground Water

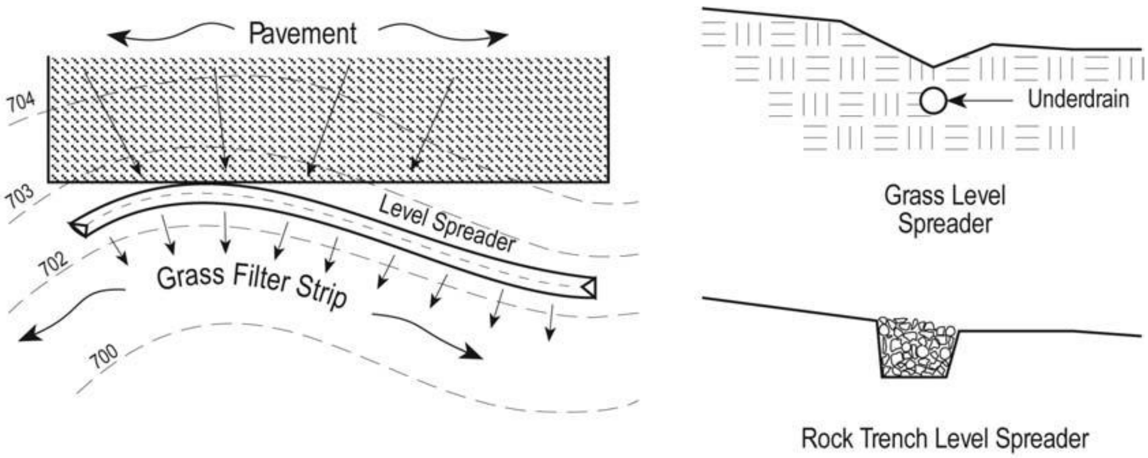
Filter strips should be separated from ground water by at least 2 to 4 feet to prevent contamination and to assure that the filter strip does not remain wet between storms.

- Soils

Filter strips will be less effective as the clay fraction of the soil increases, since this limits the infiltration of runoff associated with proper treatment. Filter strips are not suitable in very poor soils that cannot sustain a grass cover.

- Assuring Sheet Flow

  To assure that runoff remains as sheet flow through the filter strip, a grass or rock trench level spreader shall be used at the top of the slope. The level spreader must have a minimum depth and a minimum width of 1 foot. The level spreader shall be placed on a level contour. In addition to assuring sheet flow, the level spreader acts as a pretreatment device to settle out some sediment particles.



Grass filter strip with level spreader to distribute flow

- Establishing Vegetation

  Dense vegetation is critical to effective filter strips. Poor stands of vegetation may even result in a grass filter strip eroding and becoming a source of pollution. Soil preparation and planting is deserving of special attention. When selecting vegetation for grass filter strips, select species that can withstand relatively high velocity flows and both wet and dry periods.

  Some common grasses suitable for use in Ohio include perennial ryegrass, tall fescue, red fescue and kentucky bluegrass as well as canada wildrye, chinese silvergrass, orchardgrass, smooth brome, switchgrass, timothy and western wheatgrass. Filter strips can even provide a convenient area for snow storage and treatment. If used for this purpose, salt-tolerant vegetation such as creeping bentgrass should be selected.

  Seeding of the filter strip should be completed no later than September 30th to assure sufficient vegetation by October 31st. Vegetation should be inspected within 30 days of seeding to assure that an adequate stand of vegetation has established. If an adequate stand has not been established by October 31st, temporary measures must be installed to divert stormwater flows around the filter strip until adequate vegetation and stabilization occurs. No stormwater flows should be directed to a filter strip with established vegetation until the contributing drainage area has been stabilized.

- Pedestrian and Vehicular Traffic

  Heavy use should be avoided to minimize soil compaction and maintain quality dense vegetation.

Maintenance

- Only a minimum amount of maintenance should be necessary to ensure continued functioning of grass filter strips.

- The most significant concern is gully formation from unexpected concentrated flows. If rills and gullies occur, they must be repaired and stabilized with seed or sod. Measures must be taken to eliminate the concentrated flow.

- Filter strips should be inspected annually to assure that the level spreader is not clogged and to remove built-up sediment.

- Grass within the filter strip should be maintained as lawn. Grass height should be about 3 to 4 inches. Vegetation must be kept healthy.

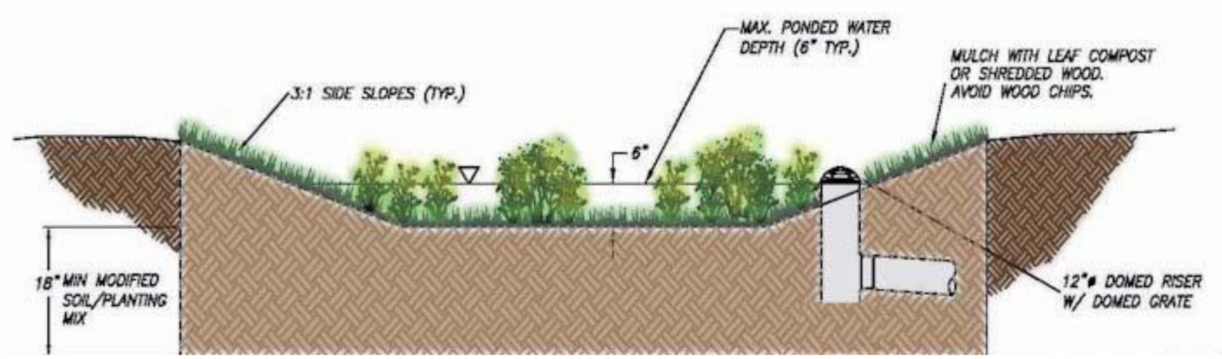
References – See Appendix IV, page 104-113.

4.7.6 BIORETENTION/RAIN GARDENS

Description

Bioretention practices are stormwater basins that utilize a soil media, mulch and vegetation to treat runoff and improve water quality for small drainage areas. Bioretention practices provide effective treatment for many runoff quality problems including reduction of total suspended solids, heavy metals, organic compounds, bacteria and nutrients (phosphorous and nitrogen) by promoting settling, adsorption, microbial breakdown, and nutrient assimilation by plants.

A bioretention area consists of a depression that allows shallow ponding of runoff and gradual percolation through a soil media, after which it either infiltrates through undisturbed soils or enters the storm sewer system through an underdrain system. Bioretention practices are sized for common storm events (the water quality volume) whereas runoff volumes from larger events are typically designed to bypass these practices.



Properly designed bioretention techniques mimic natural ecosystems through species diversity, density and distribution of vegetation, and the use of native species, resulting in a system that is resistant to insects, disease, pollution, and climatic stresses.

Bioretention/Raingardens function to:

- Reduce runoff volume
- Filter pollutants, through both soil particles (which trap pollutants) and plant material (which take up pollutants)
- Recharge groundwater by infiltration
- Reduce stormwater temperature impacts
- Enhance evapotranspiration
- Enhance aesthetics
- Provide habitat

Condition Where Practice Applies

Bioretention can be integrated into a site with a high degree of flexibility and can balance nicely with other structural management systems, including porous asphalt parking lots, infiltration trenches, as well as non-structural stormwater BMPs previously described in Appendix II of this manual.

Applicable For:

- Limited contributing drainage areas, generally less than 2 acres.

- Broad water quality treatment, including temperature, suspended solids, metals and to a lesser degree, nutrients.

- Various land uses including highly impervious areas such as roadways, commercial areas, or parking areas, especially in traditionally landscaped areas such as cul-de-sacs or parking islands.

- Sites with soils of sufficient hydraulic conductivity or a suitable outlet for an underdrain system to fully drain the practice in a period of 40 to 72 hours.

- Sites with sufficient fall between inflow point and outlet for underdrain, (generally 5 feet). Shallower facilities are expected to reduce the effectiveness of treatment.

- Sites where the primary treatment volume is limited to the water quality volume. Bioretention practices have limited ability to manage large volumes of stormwater.

Not Applicable For:

- Continuous groundwater flow will prevent the basin from draining between storm events.

- Groundwater pollution potential is high due to high pollution loads, high groundwater table or extremely permeable soils.

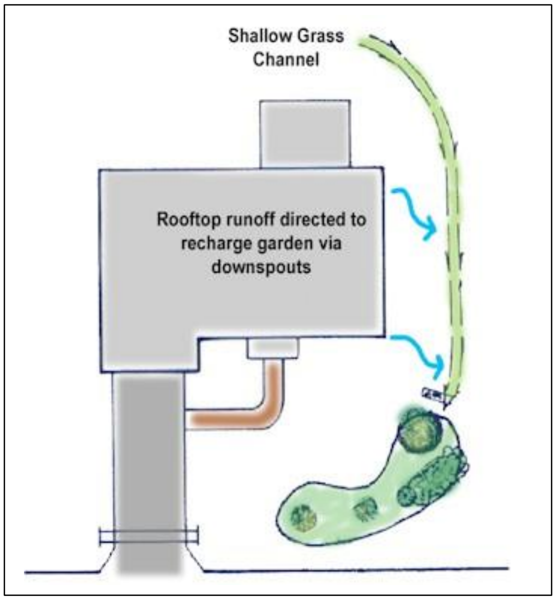
Applications

Positive Overflow: Inlet

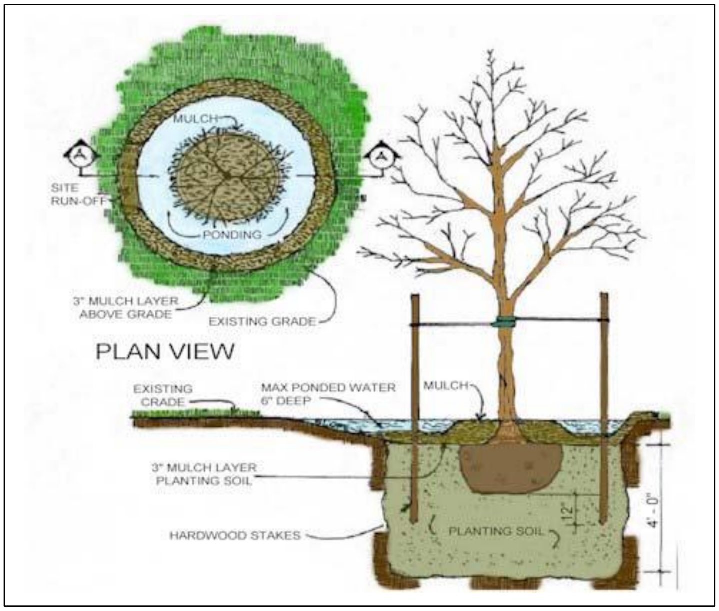
Flow Entrance: Curbs and Curb Cuts

Positive Overflow: Domed Riser

Flow Entrance: Trench Drain



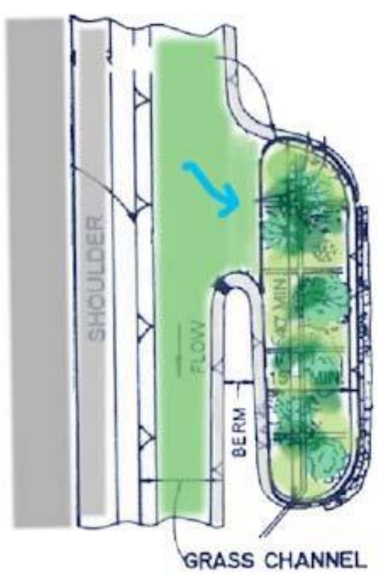
Residential On-Lot



Residential On-Lot

Tree and Shrub Pits

Stormwater management technique that intercepts runoff and provides shallow ponding in a dished mulched area around the tree or shrub. Extend the mulched area to the tree drip line.



Roads and Highways

Roads and Highways

Curbed Parking Lot Perimeter Bioretention

Parking Lots

Roof Leader Connection from Adjacent Buildings

Planning Considerations

Bioretention/Rain Gardens are flexible in design and can vary in complexity according to water quality objectives and runoff volume requirements. Though bioretention/rain gardens are structural BMPs, the initial siting of bioretention areas should respect the Integrating Site Design Procedures previously described in Appendix I and integrated with the preventive non-structural BMPs (Appendix II).

It is important to note that bioretention areas are not to be confused with constructed wetlands or wet ponds which permanently pond water. Bioretention is best suited for areas with at least moderate infiltration rates (more than 0.1 inches per hour). In extreme situations where permeability is less than 0.1 inches per hour, special variants may apply, including under drains, or even constructed wetlands.

Rain Gardens are often very useful in retrofit projects and can be integrated into already developed lots and sites. An important concern for all rain garden applications is their long-term protection and maintenance, especially if undertaken in multiple residential lots where individual homeowners provide maintenance. In such situations, it is important to provide some sort of management that insures their long-term functioning (deed restrictions, covenants, and so forth).

1. Sizing criteria

   - Surface area is dependent upon storage volume requirements but should generally not exceed a maximum loading ratio of 5:1 (impervious drainage area to infiltration area).

     NOTE: The Ohio Department of Natural Resources Rainwater and Land Development manual recommends that the surface area of the cell be between 5 and 10 percent of the contributing drainage area (Chapter 2).

   - Surface side slopes should be gradual. For most areas, maximum 3:1 side slopes are recommended, however where space is limited, 2:1 side slopes may be acceptable.

   - Surface ponding depth should not exceed 6 inches in most cases and should empty within 72 hours.

- Ponding area should provide sufficient surface area to meet required storage volume without exceeding the design ponding depth. The subsurface storage/infiltration bed is used to supplement surface storage where feasible.

- Planting soil depth should generally be at least 18” where only herbaceous plant species will be utilized. If trees and woody shrubs will be used, soil media depth may be increased, depending on the species.

2. Planting soil should be a loam soil capable of supporting a healthy vegetative cover. Soils should be amended with a composted organic material. A typical organic amended soil is combined with 20-30% organic material (compost), and 70-80% soil base (preferably topsoil). Planting soil should be approximately 4 inches deeper than the bottom of the largest root ball.

3. Volume storage soils should also have a pH of between 5.2 and 7.0 (better pollutant adsorption and microbial activity), a clay content less than 10% (a small amount of clay is beneficial to adsorb pollutants and retain water), be free of toxic substances and unwanted plant material. Organic matter can be added to the soil to increase water holding capacity (tests should be conducted to determine volume storage capacity of amended soils).

4. Proper plant selection is essential for bioretention areas to be effective. Typically, native floodplain plant species are best suited to the variable environmental conditions encountered. If shrubs and trees are included in the bioretention area (which is recommended), at least three species of shrub and tree should be planted at a rate of approximately 700 shrubs and 300 trees per acre (shrub to tree ratio should be 2:1 to 3:1). An experienced landscape architect is recommended to design native plant layout.

5. Planting periods will vary, but in general trees and shrubs should be planted from mid-March through the end of June, or mid-September through mid-November.

6. A maximum of 2 to 3 inches of shredded mulch or leaf compost (or other comparable product) should be uniformly applied immediately after shrubs and trees are planted to prevent erosion, enhance metal removals, and simulate leaf litter in a natural forest system. Wood chips should be avoided as they tend to float during inundation periods. Mulch / compost layer should not exceed 3” in depth so as not to restrict oxygen flow to roots.

7. Must be designed carefully in areas with steeper slopes and should be aligned parallel to contours to minimize earthwork.

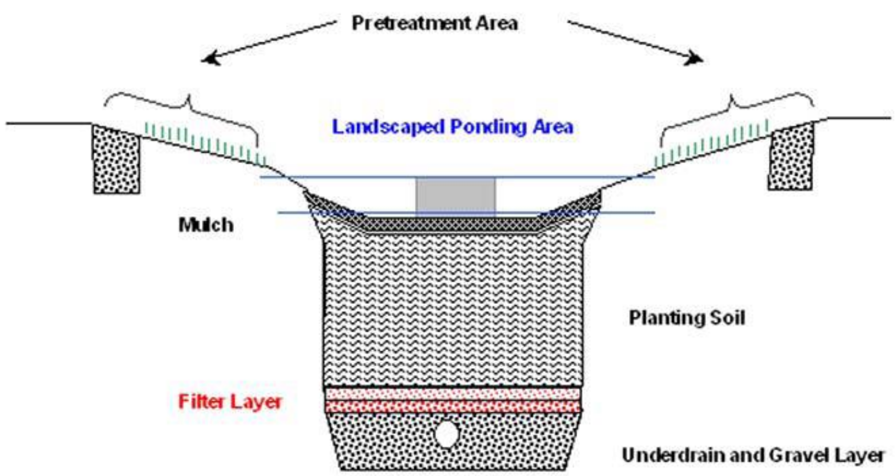
8. Under drains should not be used except where in-situ soils fail to drain surface water to meet the standard criteria.

    - Suitable Soils for Infiltration or with a Designed Underdrain System

The bioretention practice must be designed so that the runoff storage capacity will be drained between 40 and 72 hours either through infiltration into the existing soils under the facility, through an underdrain system, or through a combination of in-situ soils and an underdrain system.

NOTE: Facilities designed without an underdrain system shall have a qualified professional certify that in-situ soils are appropriate for infiltration. This certification shall include a description of the soil depth and horizons that correspond to the design elevations of the bioretention practice.

Design Criteria



General Components of Bioretention

- Pretreatment Area

  Pretreatment consists of dissipating energy and capturing excessive sediment or other pollutants before runoff enters the practice. A level stone trench at the edge of pavement, perpendicular to flow and a grassed area are typical options for pretreatment. Where flow is concentrated, a grassed swale, stabilized flow entrances or forebay may be necessary. Depending upon the potential of pollution sources, some sites may need an apparatus for capturing litter or oils and grease.

- Landscaped Pond Area

  The depth of ponding should generally be less than 6 inches, but may be designed up to 12 inches provided ponding will not damage plant materials or nearby structures and there is adequate drainage. The depth of ponding is controlled by the height of the overflow structure or berm containing runoff. This area provides a substantial portion of the storage capacity of a bioretention facility.

- Mulch

  A minimum of 3 inches of coarse shredded hardwood mulch is provided around plants and over the planting soil. Besides protecting the area from erosion, the mulch creates an organic atmosphere conducive to filtering, capturing and degrading pollutants and promoting biological growth. Pine mulches and fine or chipped hardwood mulches may not be used since they tend to float and move, and may block drainage systems, or leave the area with high flows.

- Planting Soil

The planting soil filters and detains runoff in the available void space and provides a media for plant and biological growth. Much of the pollutant removal occurs in this zone due to settling, filtering, microbial activity, ion exchange, adsorption and plant uptake. The planting soil or created soil mix shall be between 2.5 feet and 4 feet in depth (settled). The higher depth of the range may be necessary to accommodate the root ball of trees planted in bioretention facilities. Soils and soil mixes must be certified by a qualified laboratory (1 test per 100 yd^3 of soil) and have the following attributes:

- Texture class: sandy loam or loamy sand. Having no less than 72% sand and no greater than 10% clay considering only the mineral fraction of the soil.
- pH range: 5.2 - 7.0
- Soluble Salts: 500 ppm maximum.
- Organic matter: 5-20%.
- Phosphorus: soil p-index should be between 15 and 40.
- Sand added to meet textural class or the composition below shall be clean and meet AASHTO M-6 or ASTM C-33 with a grain size of 0.02-0.04” inches.

NOTE: If the planting soil layer is the main limiting factor determining how fast water will drain through the bioretention practice, then the drain time for the entire facility should be calculated using either actual values derived from testing or the predicted coefficient of permeability or hydraulic conductivity for the soil texture. The coefficient of permeability or hydraulic conductivity for the above soils is predicted to be between 1.5 to 2.6 inches/hour.

- Gravel Layer and Underdrain System

A gravel bed consisting of # 57 washed stone shall be provided as a drainage medium and bedding material for underdrain pipes or as a water storage area above soils suitable for infiltration. The gravel layer shall generally be 8-12” thick with a minimum of 3-in. of gravel provided above and below underdrain pipes, although utilizing this layer for water storage may increase its thickness.

Underdrains shall be a perforated pipe capable of withstanding the expected load above it and exceeding the drainage capacity of the planting soil layer. The following requirements apply to underdrains:

- The underdrain system shall be placed at a minimum 0.5 % slope.
- Underdrain pipes shall be a minimum 4-inch diameter perforated pipe.

- Underdrains are placed within a layer of # 57 washed gravel, having a minimum of 3- inch of gravel above and 3- inch below the pipe.

- Underdrains shall be placed depending upon the purpose of the gravel layer:
  a. The underdrain is typically placed in the middle of the gravel layer in order to provide bedding material.
  b. To promote infiltration into in-situ soils or to create an anaerobic zone for denitrification, the underdrain is placed near the top of a gravel bed. Gravel depth is determined by water storage needed to infiltrate the entire water quality volume into the soil or the volume of water targeted for anaerobic treatment.

- Underdrain pipes shall end with a cap, or an elbow with a vertical pipe providing observation and/or cleanout at the elevated end of the pipe. Observation/cleanout pipes shall consist of a minimum 4 inch diameter vertical non-perforated PVC pipe extending to the surface of the practice and sealed with a removable watertight cap.

- Underdrains shall drain to an existing drainage system or other suitable stable outlet having positive drainage.

- Overflow and Routing

  Bioretention facilities shall have a non-erodible means of discharging flow exceeding the capacity of the practice. Commonly this will be an overflow pipe or drop inlet set at the maximum ponding elevation. Off-line facilities collect runoff and then are bypassed by major storm plows. Consideration for tailwater from the receiving system shall be made.

- Planting Materials

  Species planted in bioretention practices should be adapted to the region, pollution tolerant, and able to survive the variable moisture conditions. Most plants should be facultative (found equally in wetland or upland conditions) though some species found in either environment may be acceptable. Native and non-invasive plants shall be used.

  Select plants, which in a mature condition will be appropriate to the depth of soil and the underdrain system. For examples, trees may be selected if the planting soil can accommodate the root ball of the selected trees. Trees and large shrubs will require staking to prevent being dislodged by wind. A qualified landscape architect, botanist, or native plant dealer will be helpful to design a planting plan.

<u>Design Checklist</u>

Refer to Ohio Department of Natural Resources Rainwater and Land Development manual, Chapter 2.

Maintenance

Proper functioning of a bioretention practice is dependent on the planting soil continuing to drain, and the plant survival. Most maintenance activities influence these goals. Maintaining the pretreatment area and minimizing erosion will extend the life of the planting soil. Bioretention areas are a landscaped feature of a site and regular attention to the plants is necessary. Take measures to insure winter snow plowing does not pile snow on the landscaped ponding area.

Over time (3-10 years); clogging of the planting soil or filter layer with fines particles may occur. This is expected and can be corrected by replacing a portion of the planting soil or replacing all the planting soil and the filter layer until better permeability is achieved.

Activity	Schedule
Water Plants	As necessary during first growing season
Prune and weed plants for appearance	As needed
Inspect & replace poorly suited or diseased plants	As needed
Check for erosion or deposition in pretreatment areas; clean out and repair damaged areas	Semi-annually
Inspect facility for salt damage	Monthly
Remove litter and debris	Monthly
Add additional mulch	Annually
Test soil and adjust as necessary to maintain in 5.2-7.0 pH range	Biannually
Check planting soil and filter layer for clogging, replacing portions necessary	2-10 years

Suggested Minimum Maintenance Activities

References – See Appendix IV, pages 104-113.

4.8 APPENDIX IV – BEST MANAGEMENT PRACTICES (NON-STRUCTURAL AND STRUCTURAL)

References

For a more thorough understanding of best management practices, it is encouraged to review this appendix. It contains more comprehensive descriptions and specifications of each non-structural and structural BMPs. References cited were last inspected and confirmed in March 2017.

This information is in various forms.

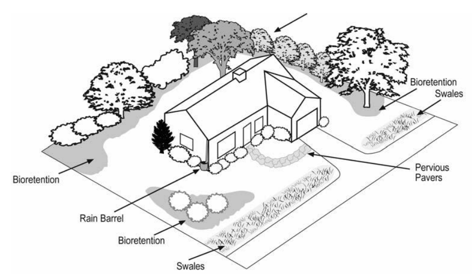
- Manuals
- Books
- Journals and Research Papers
- Web Sites

This information originates from various sources.

- Individual Field Experts
- National Associations
- Universities
- Federal, State and Local Governments
- Federal, State and Local Organizations

4.8.1 NON-STRUCTURAL BEST MANAGEMENT PRACTICES

1. Low Impact Development



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Web Site References

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- The Community Planning Program:
  Cleveland State University
  2121 Euclide Avenue, UR 26B
  Cleveland, Ohio 44115-2214
  Telephone (216) 687-5477
  email: k.date@csuohio.edu

  http://www.countrysideprogram.org/main_frameset.html

"The Countryside Program Resource Manual" or "Conservation Development Resource Manual" by the Community Planning Program, Ms. Kiby Date, author. Can be obtained by contacting Ms. Date at: telephone (216) 687-5477; email: k.date@csuohio.edu

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- Global Challenges Research Team. Colorado State University. Resources, GCRT Publications, books and articles, popular press http://cd.colostate.edu/resources

- "Conservation Subdivisions – A Better Way for Every Beautiful Place in America Slated for Development" http://www.landchoices.org/conservationsubs.htm

- Smart Communities Network – Creating Energy Smart Communities http://www.sustainable.org/environment/energy

- Conduct an internet search for "Example Layouts for Conservation Subdivisions" to get additional information

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CHAPTER 5. RAINFALL

5.l Rainfall Intensity-Duration-Frequency

A tabulation of rainfall intensities for the 1-, 2-, 5-, 10-, 25-, 50-, and 100-year recurrence intervals, and for durations ranging from 10 through 200 minutes, has been developed for Oxford and is shown in Exhibit V-1. This data supersedes the works of D.L. Yamell and E.W. Steel (who developed the steel precipitation formulas). The data was developed from the latest precipitation-frequency data contained in the U.S. Department of Commerce Technical Memorandum NWS HYDRO-35 and Technical Paper No. 40. Intensities for durations not shown shall be calculated by linear interpolation from intensities for the next smaller and next larger durations included.

5.2 Example - Rainfall Intensity

Determine the 10- and 100-year rainfall intensities from a watershed having a time of concentration equal to 16 minutes.

Use Exhibit V-1, locate a duration of 16.0 minutes, and read:
10-year rainfall intensity = 4.46 inches per hour
100-yeer rainfall intensity = 6.35 inches per hour

5.3 Rainfall Distribution by Time

Total rainfall amounts for Oxford are presented in Table 5-1 for selected rainfall durations and recurrence intervals. The 24-hour rainfall amounts are to be used with the Soil Conservation Service, Technical Release No. 55 methods.

Table 5-1

Total Rainfall Amounts

Recurrence Interval (Years)	Total Rainfall for Duration of: l Hour (Inches)	6 Hours (Inches)	12 Hours (Inches)	24 Hours (Inches)
l	1. 14	1. 80	2.16	2. 64
2	1. 36	2. 16	2. 52	2. 88
5	1. 77	2. 64	3.00	3.60
10	2. 03	3. 12	3. 60	4.08
25	2. 42	3. 48	4.08	4.80
100	3. 00	4. 32	4.92	5. 76

EXHIBIT V-1
DESIGN RAINFALL INTENSITIES

Duration - {Minute}	Rainfall Intensity (In/Hr) For Recurrence Interval of						
	1 Yr	2 Yr	5 Yr	10 Yr	25 Yr	50 Yr.	100 Yr
10.0	3.07	4.08	4.85	5.45	6. 30	7.02	7.69
10.5	3.01	4.00	4.78	5.38	6.15	6.85	7.50
11.0	2.95	3.92	4.68	5.26	6.02	6.75	7.39
11.5	2.90	3.83	4.58	5.18	5.95	6.18	7. 23
12.0	2.85	3.77	4.48	5.08	5. 84	6.57	7.17
12.5	2.80	3.70	4.40	5.00	5.75	6.46	7.00
13.0	2.75	3.63	4.33	4.94	5.65	6.35	6.92
13.5	2.70	3.57	4.26	4.83	5.58	6.20	6.80
14.0	2.65	3.50	4.20	4.78	5.48	6.08	6.70
14.5	2.61	3.45	4.13	4.68	5.40	6. 01	6.60
15.0	2.57	3.40	4.07	4.60	5.35	5.95	6.50
15.5	2.53	3.35	4.00	4.53	5.24	5.85	6.40
16.0	2.49	3.30	3.95	4.46	5.18	5.77	6.35
16.5	2.45	3.23	3.90	4.40	5.10	5.65	6.27
17.0	2.41	3.17	3.85	4.35	5.02	5.60	6.20
17.5	2.37	3.10	3.79	4.26	4.97	5.53	6.08
18.0	2.34	3.05	3.73	4.21	4.90	5.43	6.00
18.5	2.31	3.01	3.67	4.16	4.82	5.36	5.95
19.0	2.28	2.98	3.62	4.09	4.77	5.29	5.86
19.5	2.25	2.95	3.57	4.02	4.72	5.23	5.78
20.0	2.22	2.89	3.52	4.00	4.64	5.18	5.73
21.0	2.17	2.82	3.42	3.89	4.54	5.03	5.58
22.0	2.12	2.75	3.33	3.80	4.42	4.95	5.45
23.0	2.07	2.67	3.25	3.70	4.33	4.81	5.34
24.0	2.02	2.59	3.17	3.60	4.22	4.71	5.21
25.0	1.98	2.52	3.09	3.53	4.14	4.60	5.08
26.0	1.93	2.46	3.02	3.44	4.02	4.52	5.00
27.0	1.88	2.40	2.95	3.38	3.97	4.41	4.90
28.0	1.84	2.33	2.89	3.28	3.86	4.34	4.80
29.0	1.80	2.28	2.83	3.22	3.80	4.25	4.72
30.0	1.76	2.22	2.77	3.15	3.73	4.16	4. 61
32.0	1.71	2.14	2.65	3.03	3.59	4.00	4.44
34.0	1.66	2.05	2.55	2.93	3.45	3.87	4.29

Exhibit V-1 (Continued)
DESIGN RAINFALL INTENSITIES

Duration (Minute)	Rainfall Intensity (In/Hr) For Recurrence Interval of						
	l Yr	2 Yr	5 Yr	10 Yr	25 Yr	50 Yr	100 Yr
36 0	l. 60	1.98	2.46	2.83	3.36	3.75	4.17
38.0	l. 55	l.90	2.38	2.74	3.23	3.62	4.02
40.0	l. 50	l.82	2.30	2.66	3.14	3.52	3.92
42.0	l.45	l.77	2.23	2.57	3.02	3.40	3.79
44.0	1.41	1.72	2.17	2.50	2.95	3.30	3.68
46.0	l.37	l.67	2.10	2.42	2.87	3.21	3.58
48.0	l.33	1.62	2.04	2.36	2.80	3.12	3.46
50.0	1.30	l.56	1.98	2.30	2.72	3.04	3.39
52.0	1.27	1.51	l.93	2.24	2.66	2.99	3.30
54.0	l.24	1.47	1.88	2.20	2.59	2.90	3.21
56.0	l.21	1.42	1.84	2.13	2.52	2.84	3.13
58.0	1.18	1.39	1.80	2.08	2.48	2.78	3.03
60.0	1.15	1.36	1.75	2.03	2.42	2.71	3.00
65.0	1.08	1.29	1.66	l.92	2.28	2.55	2.80
70.0	l.02	l.22	l.58	l.82	2.16	2.40	2.65
75.0	0.98	1.16	l.50	1.74	2.04	2.30	2.52
80.0	0.94	1.10	1.42	1.67	1.96	2.20	2.40
85.0	0.90	l.05	1.36	1.59	l.88	2.10	2.29
90.0	0.86	l.00	1.30	1.52	l.79	2.00	2.20
95.0	0.83	0.97	1.25	1.47	1.71	l. 91	2.10
100.0	0.80	0.93	1.20	l.40	l.65	l.84	2.01
110.0	0.75	0.86	1.12	1.31	l.52	1.71	1.88
120.0	0.70	0.81	l.04	l.22	1.43	l.60	1.75
130.0	0.66	0.76	0.97	l.15	l.33	l.50	1.65
140.0	0.62	0.72	0.92	l.09	l.27	1.41	1.55
150.0	0.59	0.68	0.87	l.02	l.20	1.33	1.47
160.0	0.56	0.65	0.83	0.98	1.13	1.27	1.40
170.0	0.54	0.62	0.80	0.94	1.08	1.21	l.33
180.0	0.51	0.60	0.77	0.89	1.02	1.15	1.27
190.0	0.49	0.57	0.74	0.85	0.99	1.10	l.21
200.0	0.47	0.55	0.11	0.82	0.95	1.05	l.17

CHAPTER 6. STORMWATER RUNOFF

6.1 Rational Method (Preferred Method for Drainage Areas less than 200 Acres)

The basic formula for the Rational Method is: Q = CiA

Where Q is the peak rate of runoff in cubic feet per second, C is the runoff coefficient, "i" is the average intensity of rainfall in inches per hour for the time of concentration (T_c) for a selected frequency of occurrence or return period, and A is the drainage area in acres.

6. 1. l Adopted Runoff Coefficients

Table 6-1 lists the runoff coefficients adopted for use in the Rational Method for stormwater drainage in Oxford. These are based on average land use patterns and hydrologic soil group C.

Table 6-1
Runoff Coefficients
For the Rational Method

Land Use	Runoff Coefficient
Residential	0.5
Multi-family	0.6
Commercial and Business Districts	0.85
Industrial Districts	0.75
Open Space (parks, golf courses, cemeteries, meadows, grass, woods, lawns, etc.)	0.3
Impervious Areas (parking lots, roads, rooftops)	0.9
Steep wooded hillside slope > 10 percent	0.5

6. l. 2 Composite Runoff Coefficients

If the runoff coefficient varies over a subarea, a composite coefficient can be calculated as an average, weighted by area of the various runoff coefficients.

6. 1. 3 Time of Concentration

The minimum time of concentration used shall be 10 minutes.

The time of concentration is the estimated time required for runoff to flow from the most remote part of the drainage area under consideration to the point under consideration. It consists of the total of time for overland sheet flow, open channel flow, and pipe flow. Overland sheet flow time for overland flow from the most remote part of the drainage area until a dry channel is present (contours forming a U shape) or up to 300 feet in length may be estimated from the chart (Exhibit 11-1). The time of flow in shallow concentrated flow from overland sheet flow until a channel is show to carry an intermittent or perennial stream (a stream symbol indicated on a topographic map) may be estimated by applying the chart (Exhibit 11-2). The time of flow in natural channels, open channels, or pipes may be estimated by applying the Manning Formula (Exhibit VI-2).

Care should be taken to avoid excessive time of concentration caused by long overland sheet flow time. To insure that the peak rate of runoff at a particular location is correct, the peak discharge shall be calculated twice – once including the overland sheet flow area and time and once omitting the overland sheet flow area and time. The larger peak discharge shall be used.

6. 1. 4 Example - Rational Method

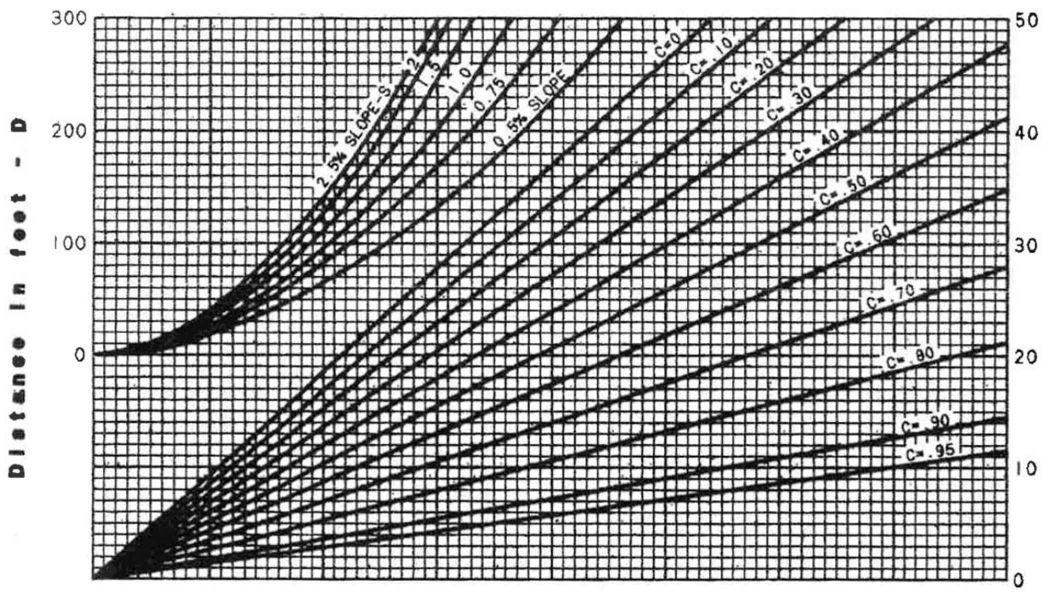
Determine the 10-year discharge from a 10-acre watershed assuming a runoff coefficient of 0.3 and a time of concentration of 12.0 minutes.

Step l. Use Exhibit V-1, locate a duration of 12.0 minutes and read: 10-year rainfall intensity = 5.08 inches per hour.

Step 2. Calculate the 10-year discharge Q = CiA = 0.3 x 5.08 x 10 = 15.2 cubic feet per second (cfs).

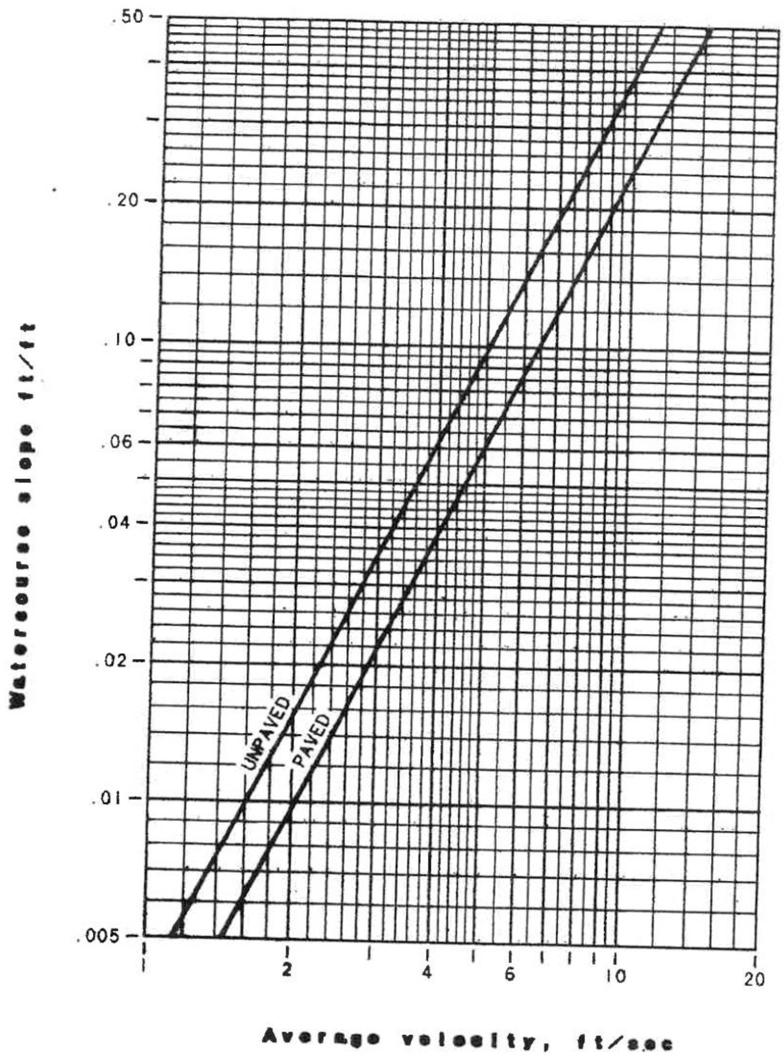
6. 2 Other Methods

For areas between 200 and 640 acres, the preferred hydrograph method of calculation is the Soil Conservation Service, Technical Release No. 55 Graphical Peak Discharge method. For areas greater than 640 acres, the preferred hydrograph method of calculation is the Soil Conservation Service, Technical Release No. 20 method.



OVERLAND SHEET FLOW

Exhibit II-1



SHALLOW CONCENTRATED FLOW

Exhibit II-2

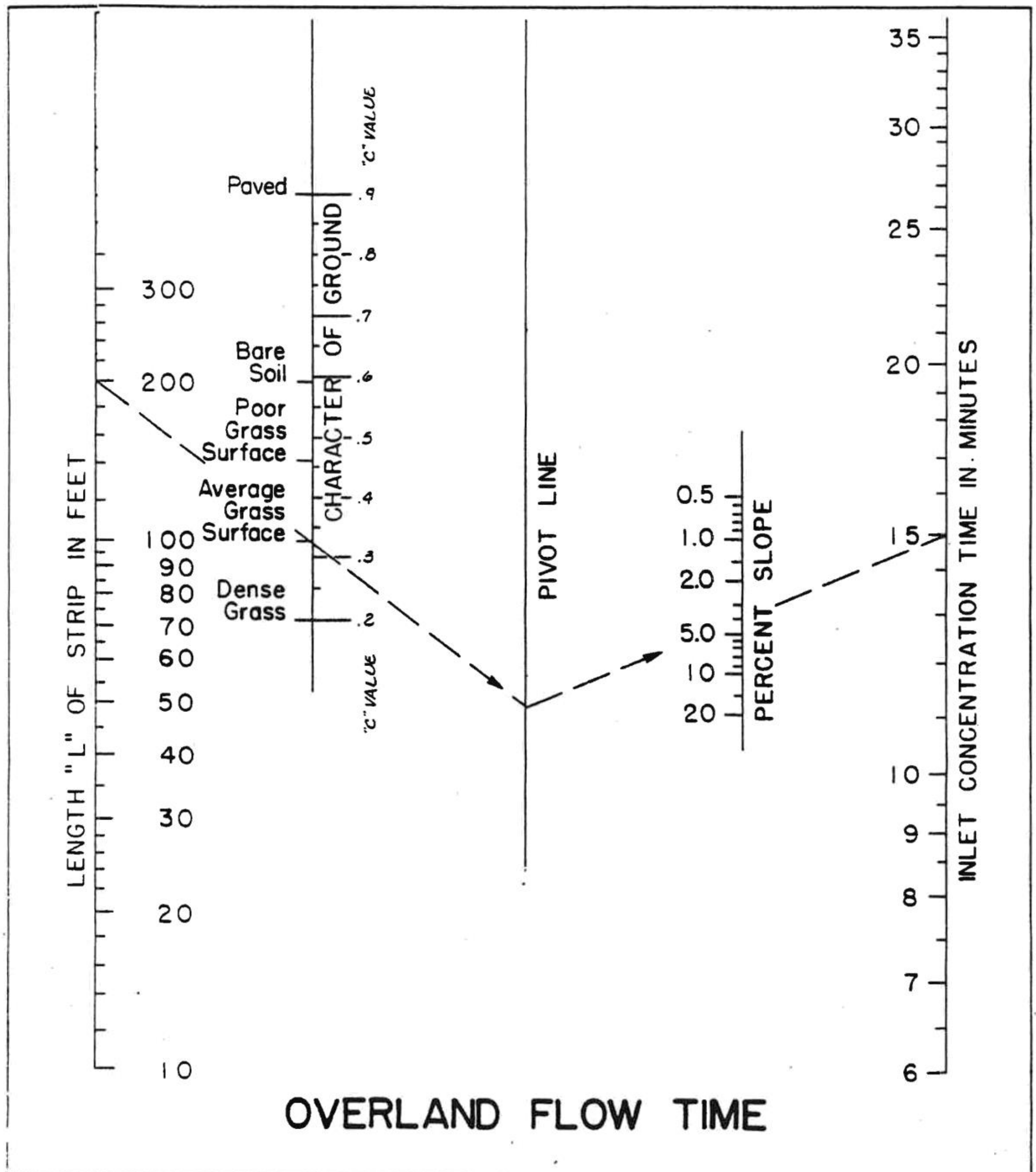
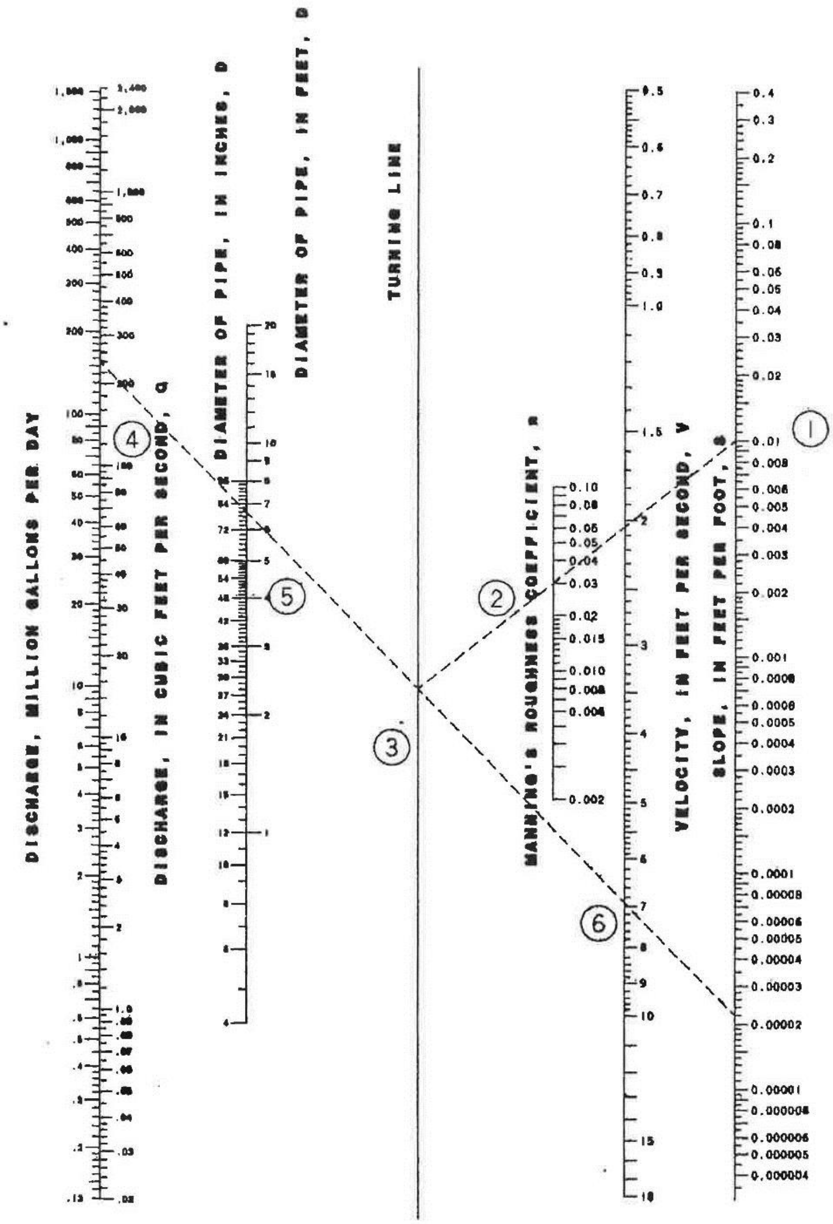

LENGTH "L" OF STRIP IN FEET
300
200
100
90
80
70
60
50
40
30
20
10
Paved
Bare Soil
Poor Grass Surface
Average Grass Surface
Dense Grass
CHARACTER OF GROUND
"C" VALUE
.9
.8
.7
.6
.5
.4
.3
.2
PIVOT LINE
0.5
1.0
2.0
5.0
10
20
PERCENT SLOPE
35
30
25
20
15
10
9
8
7
6
INLET CONCENTRATION TIME IN MINUTES
OVERLAND FLOW TIME

Exhibit VI-1



NOMOGRAPH FOR SOLUTION OF THE MANNING FORMULA

$$Q = AV = A\,\frac{1.49}{n}\,r^{2/3}\,s^{1/2}$$

Exhibit VI-2

STORMWATER RUNOFF

GRAPHICAL PEAK DISCHARGE COMPUTATIONS

PROJECT ________________ DESIGNER ________________ DATE __________

1) DATA: WATERSHED CONDITION = ________________ (PRESENT OR FUTURE) TYPE II STORM

DRAINAGE AREA (DA) ______________ ACRES.

Hydrologic Soil Group	Land Use Description Include Treatment, Practice & Condition	CN Exhibit (3)		Area (acres)	Area (%) (4)	Product (3) x (4) (5)
			Totals =		100	

CN (weighted) = $\frac{total\ col.\ (5)}{total\ col.\ (4)}$ [________] = ____________ = use CN = [ ]

Ponding and Swampy areas (PND) = ____________ acres = __________ % of DA

Time of Concentration (TC) = ____________ minutes __________ hours

		1st Storm	2nd Storm	3rd Storm	
2)	Rainfall Frequency (F)				Yrs.
	Rainfall Depth (P) From Table 5-1				inches
3)	Initial Abstraction (Ia) $Ia = 0.2\ [\frac{1000}{weighted\ CN} - 10]$				
4)	(Ia)/(P)				
5)	Unit Peak Discharge Use TC = Ia/P				CFS/Square Mile-inch
6)	Runoff Depth (Q) Use P = CN				inches
7)	Ponding and Swampy Area Adjustment Factor Use % PND				
8)	Adjusted Pack Discharge [a_g] Drainage area x step 5 x (step 6 x step 7) / 640				cfs
9)	Total Runoff Volume Step 6 x Drainage Area / 12				acre-feet

Exhibit T6-1

CHAPTER 7. OPEN CHANNELS

7.l Selection of Shape

In general, open channels are not permitted by the City of Oxford. If site conditions are such that open channels would be beneficial, the City Engineer must be notified. In no case will open channels be allowed without prior permission from the City Engineer.

Open channels are usually designed with sections of regular geometric shapes. The trapezoid is the most common shape for channels with unlined earth banks, for it provides side slopes for stability. The rectangle and triangle are special cases of the trapezoid. Since the rectangle has vertical sides, it is commonly used for channels built of stable materials, such as lined masonry, rocks, metal, or timber. The triangular section is used only for small ditches and roadside gutters.

7.2 Design Criteria

7.2.1 Design Storm

Roadside ditches shall be designed for the 10-year storm. All other open channels, except major channels as defined herein, shall be designed for the 25-year storm. Major channels shall be designed for the 100-year storm. Four Mile Creek is the only major channel.

7.2.2 Bankful Depth of Flow

For subcritical flow, the bankful depth shall be equal to or greater than the design flow depth. For supercritical flow design, the channel shall be sized so that the bankful depth is equal to or greater than the critical depth for the design flow. A primary criterion for determining which state of flow exists is the depth of flow. If the flow depth (actual or as computed with the Manning equation) is deeper than the critical depth for the given discharge and channel shape, then subcritical flow exists. If the flow depth is less than critical depth, then supercritical flow exists. If the flow depth equals the critical depth, then critical flow exists. The depth of flow (discharge computation on open channel worksheet) shall be computed for the 100-year frequency storm for all open channels except roadside ditches and major channels.

7.2.3 Channel Linings

For channels with subcritical flow, channel bottoms shall be sodded and channel side slopes which are flatter than 3:1 may be sodded or seeded. The City recommends using side slopes of 3:1 before a steeper side slope is used. The open channel shall be reviewed and approved by the City Engineer. Channel side slopes between 3:1 and 2:1 shall be sodded. Channel side slopes of 2:1 or steeper shall be lined with concrete, riprap, gabions, brick, asphalt, or other erosion resistant lining. For channels with supercritical flow, the bottom and sides of the channel shall be concrete lined.

7.2.4 Minimum Bottom Slope

The recommended minimum channel bottom slope shall be 0.50 percent for paved or lined channels and l.00 percent for grass or sod lined channels.

7.3 Design for Steady Uniform Flow

To calculate steady uniform flow in an open channel, the mean velocity (V) can be calculated by the Manning equation: $V = (l.49\ r^{2/3}\ s^{1/2})/(n)$, where V is the mean velocity in fps, n is Manning's coefficient of roughness, S is the slope of the channel in feet per foot, and r is the hydraulic radius of the channel in feet. The hydraulic radius is calculated as a cross sectional area divided by wp, the wetted perimeter.

The discharge (Q) is then calculated: Q = VA, where Q is the discharge in cfs, V is the mean velocity in fps, and A is the cross section area of flow in square feet.

General formulas for determining elements for various channel shapes are given in Exhibit VII-1.

7.3.1 Flow Depth and Velocity

To calculate flow depth and velocity using Manning Formula, Table 7-1 of area times the two-thirds power of the hydraulic radius for various trapezoidal channels is he1pful. The usefulness is apparent when the Manning Formula is rearranged to:

$Ar^{2/3} = (nQ)/(1.49\ s^{1/2})$

Knowing the discharge Q, Manning's coefficient of roughness n, and the channel slope S, $Ar^{2/3}$ can be easily computed. Then, by looking in Table 7-1, a channel can be chosen. It can be seen by the table that any channel can meet the design flow, but at different depths of flow. The table is a quick method to determine if a particular trapezoidal channel will flow at a desirable depth.

7.3.2 Coefficient of Roughness. (n)

The computed discharge for any given channel will only be as reliable as the estimated value of n used in making the computation. The type of channel, degree of maintenance, seasonal requirements, season of year design storm occurs, and other considerations should be studied and evaluated before selecting the value of n. In Exhibit VII-2, values for n have been tabulated to help the designer choose an appropriate value.

Because of the erosion effects velocity has on the channel, the following is a general guide to determine when and what type of channel linings are required: for velocity below 2.5 fps, no special requirements; for velocity between 2.5 and 4.0 fps, seeded or sodded channels; and for velocity greater than 4.0 fps, special channel protection materials.

7.3.3 Summary of Design Procedures

The following summarizes general procedures for the design of open channels using the formatted form T7-l.

Step 1. Fill in frequency Q, n, S, and V_{max} in columns l, 2, 3, 4, and 12.

Step 2. Quantify value of $Ar^{2/3}$ for Discharge (Q) and Velocity (V), column 5: $Ar^{2/3} = (nQ)/(l.49\ S^{1/2})$

Step 3. Calculate minimum area of channel (A_{min}) column 6 that will flow within limit set by V_{max} • A_{min} = Q (column 2)/V_{max} (column 12).

Step 4. Using Table 7-1, select channel configuration of bottom width = b (column 7) and side slope = c (column 7).

Step 5. Find df (column 8) by interpolating from Table 7-1, using either $Ar^{2/3}$ (column 5) or A_{min} (column 6), whichever gives the larger df.

Step 6. Calculate channel flow area A (column 9) from equation given on Exhibit VII-1

Step 7. Calculate top width of flow T (column 10), using equation from Exhibit VII-1.

Step 8. Calculate channel velocity V (column 11) from area derived in Step 6 and discharge by V=Q/A. check that this channel velocity (column 11) does not exceed maximum permissible velocity (column 12). If V (Column 11) ≤ V_{max} (column 12), continue; if not, choose a different n or s and restart at Steph 1, or choose a different channel cross-section and restart at Step 4.

Step 9. Calculate Z for critical flow $Z=Q/g^{½}$ (column 13)

Step 10. Calculate $Z/b^{2.5}$ (column 14).

Step 11. Using Exhibit VII-3, find d_c/b (column 15).

Step 12. Multiply d_c/b x b to get d_c (column 16).

Step l3. Using d_c, calculate V_c, (column 17), $V_c = (Q)/[\ (b+cd_c)d_c]$

Step 14. Compare the critical flow depth and velocity values equal to the channel depth and velocity values:

If column 16 (d_c) < column 8 (d_f);
and column 17 (V_c) > column 11 (v) flow is subcritical

If column 16 (d_c) > column 8 (d_f)
and column 17 (V_c) < column 11 (v) flow is supercritical

If column 16 (d_c) = column 8 (d_f)
and column 17 (Vc) = column 11 (v) flow is critical

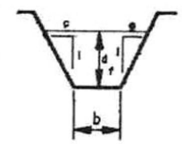
Step 15. When an acceptable channel design for discharge and velocity has been selected with regard to discharge, capacity, and critical flow considerations, then the total channel depth as required by the design criteria is determined as:

a. for subcritical flow channel depth $\geq d_f$, or

b. for supercritical flow channel depth $\geq d_c$.

d_f	b=2, c=2		b=2, c=3		b=2, c=4		b=3, c=2		b=3, c=3		b=3, c=4	
	$Ar^{2/3}$	A	$Ar^{2/3}$	A	$Ar^{2/3}$	A	$Ar^{2/3}$	A	$Ar^{2/3}$	A	$Ar^{2/3}$	A
0.5	0.75	1.50	0.85	1.75	0.95	2.00	1.05	2.00	1.15	2.25	1.24	2.50
0.8	1.85	2.88	2.21	3.52	2.56	4.16	2.50	3.68	2.85	4.32	3.19	4.96
1.0	2.90	4.00	3.56	5.00	4.20	6.00	3.83	5.00	4.47	6.00	5.10	7.00
1.1	3.53	4.62	4.38	5.83	5.21	7.04	4.60	5.72	5.44	6.93	6.26	8.14
1.2	4.23	5.28	5.30	6.72	6.35	8.16	5.47	6.48	6.53	7.92	7.56	9.36
1.3	5.00	5.98	6.33	7.67	7.63	9.36	6.41	7.28	7.73	8.97	9.01	10.66
1.4	5.86	6.72	7.48	8.68	9.06	10.64	7.44	8.12	9.05	10.08	10.61	12.04
1.5	6.79	7.50	8.74	9.75	10.64	12.00	8.56	9.00	10.49	11.25	12.38	13.50
1.6	7.81	8.32	10.13	10.88	12.38	13.44	9.77	9.92	12.07	12.48	14.32	15.04
1.7	8.91	9.18	11.64	12.07	14.29	14.96	11.07	10.88	13.78	13.77	16.43	16.66
1.8	10.10	10.08	13.28	13.32	16.37	16.56	12.47	11.88	15.63	15.12	18.71	18.36
1.9	11.38	11.02	15.05	14.63	18.63	18.24	13.97	12.92	17.62	16.53	21.19	20.14
2.0	12.76	12.00	16.97	16.00	21.07	20.00	15.56	14.00	19.76	18.00	23.85	22.00
2.1	14.23	13.02	19.03	17.43	23.70	21.84	17.27	15.12	22.05	19.53	26.71	23.94
2.2	15.81	14.08	21.23	18.92	26.53	23.76	19.07	16.28	24.49	21.12	29.77	25.96
2.3	17.48	15.18	23.59	20.47	29.55	25.76	20.99	17.48	27.09	22.77	33.04	28.06
2.4	19.26	16.32	26.10	22.08	32.78	27.84	23.01	18.72	29.85	24.48	36.51	30.24
2.5	21.14	17.50	28.77	23.75	36.22	30.00	25.15	20.00	32.78	26.25	40.21	32.50
2.6	23.13	18.72	31.61	25.48	39.87	32.24	27.41	21.32	35.88	28.08	44.13	34.84
2.7	25.24	19.98	34.61	27.27	43.75	34.56	29.78	22.68	39.15	29.97	48.28	37.26
2.8	27.45	21.28	37.78	29.12	47.85	36.96	32.27	24.08	42.59	31.92	52.65	39.76
2.9	29.79	22.62	41.21	31.03	52.18	39.44	34.88	25.52	46.22	33.93	57.27	42.34
3.0	32.24	24.00	44.64	33.00	56.75	42.00	37.62	27.00	50.03	36.00	62.13	45.00

TRAPEZOIDAL CHANNELS HYDRAULIC CHARACTERISTICS



$$Ar^{2/3} = \frac{n\,Q}{1.49\sqrt{s}}$$

$r = A/wp$

Table 7-1

Step 16. Compute the anticipated depth of flow in the design channel for the 100-year frequency storm.

7. 3. 4 Example - Roadside Ditch Design

Find the design channel depth for a trapezoidal roadside ditch that has a 2-foot bottom (b = 2), 4:1 side slopes (c = 4), a slope of 0.02 feet per foot (S = 0.02), and an excavated, straight alignment, lined with grass sides and a sod bottom where Manning's roughness coefficient is 0.025 (n = 0.025), a maximum permissible velocity of 4 fps (V_{max} = 4), and a 10-year discharge of 15 cfs (Q = 15).

Step l. Complete columns 1, 2, 3, 4, and 12.

Step 2. Compute $Ar^{2/3} = (nq)/(l.49\ s^{1/2}) = (0.025 \times 15)/(1.49 \times 0.020^{1/2}) = 1.\ 78$

Step 3. Determine $A_{min} = Q/V_{max} = 15/4 = 3.75$ square feet

Step 4. Channel configuration is bottom width b = 2 and side slope c = 4.

Step 5. Use Table 7-1, with $Ar^{2/3}$ = l. 78 and A_{min} = 3. 75, and find the largest d_f values closest to either $Ar^{2/3}$ or A_{min}

$Ar^{2/3}$	d_f	Calculate d_f for $Ar^{2/3}$ = 1.78
0. 95	0.5	interpolation d_f = 0.5 = [(1.78-0.95)/
4.21	1.0	(4.21-1.78)] (1.0-0.5)=0.67 feet

A	d_f	Calculate d_f for A_{min} = 3.75. By
2.00	0.5	interpolation d_f = 0.5 = [(3.75 – 2.00)/
6.00	1.0	(6.00-3.75)] (1.0-0.5) = 0.89

Use largest d_f of 0.89 versus 0.6 7.

Step 6. Calculate channel flow area = $A = (b + cd_f)\ d_f = (2 + 4 \times 0.89)\ 0.89 = 4.95$ square feet.

Step 7. Calculate top width of flow = $T = b + 2\ cd_f = 2 + 2 \times 4 \times 0.89 = 9.12$ feet.

Step 8. Calculate channel velocity = V = Q/A = 15/4.95 = 3.03 fps

- For velocity check, $V \leq V_{max}$ = 3.03 fps < 4 fps; therefore, design is acceptable for velocity.

Step 9. Calculate Z for critical flow 1 = $Q/\ g^{1/2} = 15/32.2^{1/2} = 2.64$

Step 10. Calculate $Z/b^{2.5} = 2.64/2^{2.5} = 0.47$

Step 11. Use Exhibit VII-3 with $Z/b^{2.5}$ = 0.47 and c = 4 and read dc/b = 0.38

Step 12. Compute $d_c = d_c/b \times b = 0.38 \times 2 = 0.76$ feet

Step 13. Compute $V_c = Q/([\ b + cd_c]\ d_c)$: $15/([\ 2 + 4 \times 0.76]\ 0.76) = 3.92$ fps

Step 14. Compare calculated d_f and V to calculated d_c and V_c.

$d_f = 0.89 > d_c = 0.76$

and $V = 3.03 < V_c = 3.92$ Therefore, flow is subcritical

Step 15. Design channel depth for subcritical flow shall be 0.89 feet or greater.

7. 4 Floodway Delineation and Regulation

The Federal Emergency Management Agency (FEMA) has published a Flood Insurance Rate Map for the City of Oxford. This map contains the flood boundary for areas of special flood hazards. Where such data exists, it should be utilized in stormwater facility design.

EXHIBIT VII-1

OPEN CHANNEL
SYMBOLS, EQUATION, ANO GEOMETRIC FORMULA

Symbol	Units	Description
A	sq. ft.	Area of cross section of flow
b	ft.	Bottom width of trapezoidal channel
c		Side slope of channel, c:l
d_c	ft.	Critical depth
d_f	ft.	Depth of flow
g	ft/sec^2	Acceleration of gravity = 32.2
n		Manning roughness coefficient
Q	cfs	Rate of discharge
r	ft.	Hydraulic radius = A/wp
s	ft./ ft.	Slope of channel
S_c	ft./ft.	Critical slope
T	ft.	Top width of water surfacing in a channel
V	fps	Mean velocity of flow
V_c	fps	Critical velocity
wp	ft.	Wetted perimeter – length of line of contact between the flowing water and the channel
Z		Section factor for critical flow

Equations

$v = \frac{1.49}{n} r^{2/3} s^{1/2}$ $Q = AV$ $Q = \frac{1.49}{n} A r^{2/3} s^{1/2}$ $Z = Q/g^{1/2}$

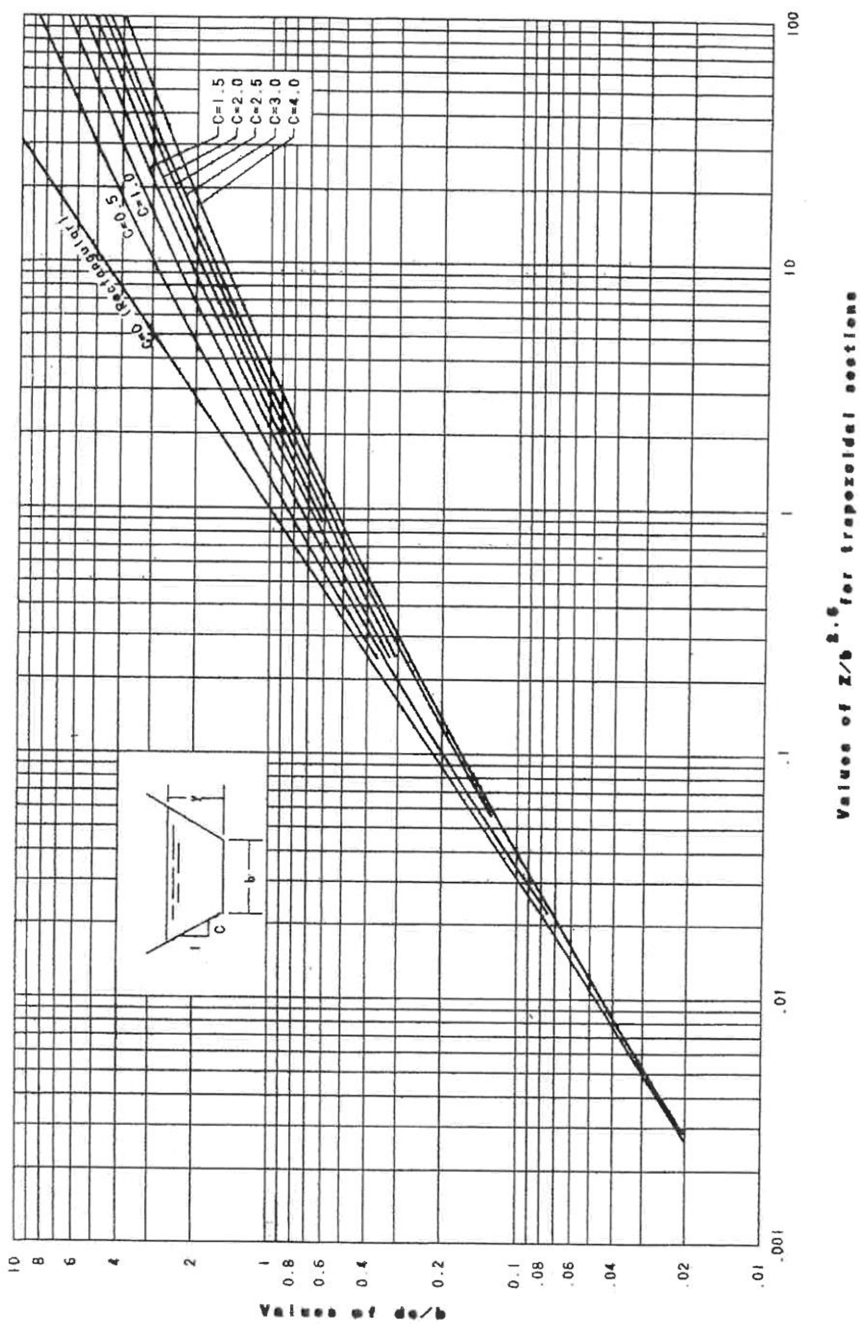
Geometric formula

Trapezoidal	Rectangle	Triangle
$A = (b + cd_f)\, df$	$A = bd_f$	$A = cd_f^2$
$wp = b + 2d_f -(1 + c^2)^{1/2}$	$w = b + 2d_f$	$wp = 2d_f (l + c^2)^{1/2}$
$T = b + 2\, cd_f$	$T = b$	$T = 2\, Cd_f$
$r = \frac{(b+cd_f)\, d_f}{b+2d_f (l + c^2)^{1/2}}$	$r = \frac{bdf}{b + 2d_f}$	$r = \frac{cd_f}{2 (l + c^2)^{1/2}}$

EXHIBIT VIl-2

MANNING ROUGHNESS COEFFICIENTS

1.	Open Channels Lined (Straight Alignment)	0.015
	A. Concrete	
	B. Concrete, bottom, sides, as indicated	
	l. Stone in mortar	0.020
	2. Riprap	0.025
	C. Gravel bottom, sides as indicated	
	l. Concrete	0.020
	2. Rip rap	0.028
	D. Brick	0.017
	E. Asphalt	0.015
II.	Open Channels, Excavated (Straight Alignment, Natural Lining)	
	A. Earth, fairly uniform section	
	l. Grass, some weeds	0.025
	2. Dense weeds	0.035
	3. Sides clean, gravel bottom	0.030
	B. Rock	
	l. Based on design section	0.035
	2. Based on actual mean section	
	a. Smooth and uniform	0.040
	b. Jagged and irregular	0.045
	C. Channels not maintained, weeds and brush	
	l. Dense weeds, high as flow depth	0.100
	2. Clean bottom, brush on sides	0.080
	3. - Dense brush, high stage	0.120



CURVES FOR DETERMINING CRITICAL DEPTH

Exhibit VII-3

OPEN CHANNEL COMPUTATIONS

PROJECT ____________ DESIGNER ____________ DATE ________

	DISCHARGE											CRITICAL FLOW					
1 FREQUENCY	2 Q	3 n	4 s	5 $Ar^{2/3}$	6 Amin	7 b, c	8 d_f	9 A	10 T	11 V	12 Vmax	13 Z	14 $Z/b^{2.5}$	15 d_c/b	16 d_c	17 V_c	18 TYPE OF FLOW
	CFS		FT/FT		SQ FT		FT	SQ FT	FT	FPS	FPS				FT	FPS	

Form T7-1

CHAPTER 8. STREETS AND INLETS

8.1 Design Criteria

The design criteria for streets and inlets include minimum standards for design storms, streets with curb and gutter, gutter inlet on continuous grade, combination inlet on sag or sump, maximum street spread and streets with side ditch swales.

8.1.1 Design Storms

For street and inlet design the design storm is the 10 year rainfall. After initially designing the streets and inlets for the design storm, a check shall be made to ensure that a 25-year rainfall does not exceed the maximum depth of flow (Article 8.2.2).

Final design shall indicate water surface elevations for the design storm. In addition, the 100-year water surface elevation for all streets and inlets shall be shown.

8.1.2 Streets with Curb and Gutter

The design roughness coefficient "n" value shall be 0.015 for paved streets. The minimum gutter slope shall be 0.50 percent. All street resurfacing shall be done to maintain a recommended minimum flow depth of 5 3/4 inches at the face of the curb.

Depth of flow shall not exceed the top of curb for the design storm. In addition, the 100-year water surface elevations shall not exceed 10-inch depth above the curb for local and collector streets and shall not exceed 6-inch depth at crown for arterial streets. In order for the depth of flow not to exceed the specified limit, especially for the 100-year rainfall, an open channel or storm sewer system may be required to convey some of the flow to a major channel. Where a drainageway is located outside a street right-of-way, easements shall be provided. In determining the required capacity of surface channels and storm sewer system, the street storm inlets and conduit provided shall be assumed to be carrying not more than one-half their design capacity.

8.1.3 Gutter Inlets: Continuous Grade

Gutter inlets shall have a local depression of 3/4 inch below the normal gutter flow line. Gutter inlets shall be located at all points where the maximum pavement spread or maximum flow depth is reached. No flow is permitted to cross street intersections for the initial design storm. Maximum inlet spacing on a continuous grade shall be 300 feet. Gutter inlets shall not be closer than 3 feet to the point of the drop curb to a driveway or handicap ramp.

8.l.4 Combination lnlets: Sag or Sump

Combination inlets shall be provided at all sag or sump locations. When combination inlets are used, the grate capacity alone shall be considered the capacity of the inlet. The curb opening serves as a relief in the event the grate is clogged.

Combination inlets with grate and curb opening shall have a local depression of 3/4 inches below the gutter flow line.

Recommended inlet locations are at the points of vertical curvature on each side of the sag at an elevation which is 0.2 feet higher than the flow point and at least one inlet at the low point. Combination inlets shall not be closer than 3 feet to the point of the drop curb to a driveway or handicap ramp.

8.l.5 Maximum Street Spread

The following are maximum spread of the 10-year rainfall design storm onto the pavement.

For two-lane streets, maximum spread is 6 feet from the face of the curb.

For four-lane streets, maximum spread is 8 feet from the face of the curb.

The more restrictive condition for either maximum street spread or depth of flow (Article 8.2.2) shall control.

8.l.6 Streets with Side Ditch Swales

Side ditch swales shall be designed in accordance with the general procedures stated in Chapter 7, “Open Channels” of this manual. The minimum channel bottom slope shall be l.00 percent for grass or sod lined channels and 0.50 percent for paved or lined channels.

8.2 General Design Procedures

A generalized design approach to inlet spacing is as follows:

Step l. Locate the first inlet at the point where the maximum gutter capacity is reached based on the 10-year design storm.

Step 2. Determine the inlet capacity Q and percent carryover (gutter flow) to the next inlet (Exhibit Vlll-1). As a general rule, the carryover flaw should be no greater than 15 percent and the picked up flow no less than 85 percent.

Step 3. Locate the next inlet downstream at that point where the gutter capacity is again reached including the gutter flow (carryover) from the upstream inlet. Note that inlets so placed may or may not be located directly across from each other on each side of the street. The individual inlet spacing depends on the configuration of the tributary drainage area and the percent of carryover from the upstream inlet.

Step 4. Continue locating inlets at maximum gutter capacity points on continuous grades until a street intersection or a low point (sag) in the street profile is reached.

Step 5. At street intersections, inlet locations vary, depending on the respective street grades and pedestrian convenience. In general, inlets should be located at the upstream curb turnouts adjacent to crosswalks.

Step 6. Inlets located at the sags of vertical curves are designed for a capacity adequate to intercept 100 percent gutter flow. The following design procedures are included to outline a uniform approach to the determination of gutter carrying capacity, and capacity of inlets.

8.2.l Gutter Capacity

Step 1. Draw the street cross section and determine the maximum depth of flow and the permissible pavement spread.

Step 2. Determine the gutter slope in feet per foot, and "z," the reciprocal of the cross slope.

Step 3. Calculate the theoretical gutter (triangular channel) carrying capacity by using the modified Manning's formula:

$$Q = (0.56\ Z\ S^{1/2} d^{8/3})/n$$

where Z is the reciprocal of the cross slope (T /d), n is Manning's coefficient of roughness, S is the longitudinal slope of the gutter in feel per foot, d is the depth of flow in the gutter at the deepest point in feet, and T is the top width of water surface in the gutter in feet. A nomograph for the solution of this formula is shown on Exhibit VIIl-2. The nomograph may be used for all gutter configurations.

8.2.2 Capacity of a Grate Inlet or Combination Inlet on Continuous Grade

Step 1. Determine the gutter flow at the inlet location (Qa).
Step 2. Determine the gutter flow depth at the curb (d) and the spread of water on the roadway.
Step 3. Calculate the width, depth (d') and amount (Qa') of flow outside of the grate.
Step 4. Determine the flaw over the end of the grate as QE = Qa - Qa'.
Step 5. Calculate flow over the side of the grate using the following steps:

a. Using the depth (d') and the depression (a) of the grate, enter Chart A of Exhibit VIII-1 and read Qa'/La.
b. Compute the 100 percent pickup length, La = Qa'/(Qa'/La)

c. Compute the ratio L/La where L is the distance along the outside edge of the grate. If this ratio is greater than or equal to 1.0, 100 percent of the flow is being intercepted, flow over the side of the grate is Qa' and continue with step 6 below. If the ratio is less than 1.0, only a portion of the flow is being intercepted over the side of the grate. The amount intercepted is calculated beginning with step d.

d. Determine the ratio a/d'.

e. Using L/la and a/d' enter Chart B of Exhibit VIII-1 and read Q'/Qa', the ratio of intercepted flow to total flow outside of grate.

f. Calculate the total flow intercepted over the outside edge of the grate, Q' = Qa' x (Q'/Qa').

Step 6. Determine the total flow intercepted Q = (Qa - Qa') + Q'.

Step 7. Calculate the carryover flow to the next inlet, Qa - Q.

Step 8. Calculate the percent of intercepted flow (% pickup), (Q/Qa) x 100.

Step 9. If the intercepted flow is less than 85 percent, try a different inlet location or type of gutter inlet.

8.2.3 Example - Capacity of a Grate Inlet on Continuous Grade

Find the discharge intercepted by the single gutter grate inlet. The inlet has the following characteristics: (1) local depression of 3/4 inch; (Z) width of grate of 1.4 feet; (J) length of grate of 2.5 feet; (4) perimeter of grate of 4.6 feet; and (5) total clear opening area of grate of 1.6 square feet. The inlet is located on a four-lane street on a continuous longitudinal slope of 3 percent. The pavement cross slope is 2.5 percent and has a roughness coefficient value of 0.015. The gutter flow at the inlet location is 1.5 cfs.

Step 1. Gutter flow at the inlet location is 1.5 cfs.

Step 2. Use Exhibit VIIl-2 with Z/n = (1/0.025)/0.015 = 2667, S = 0.03 ft/ft and Qa = 1.5 cfs read d = 0.15 ft.

Calculate spread of water = d/cross slope = 0.15/0.025 = 6 ft.

Check maximum street spread 6 ft < 8 ft.

Step 3. Calculate width, depth (d'), and flaw (Qa') outside of the grate width = spread - width of grate = 6 - 1.4 = 4.6 ft. Depth (d') = width x crass slope = 4.6 x 0.025 = 0.115 ft. Use Exhibit VIIl-2 with S = 0.03 ft/ft d' = 0.115 feet and Z/n = 266 7. Read Qa' = 0.8 cfs.

Step 4. Calculate the flow over the end of the grate QE = Qa - Qa' = 1.5 – 0.8 = 0.7 cfs (flow at inlet location - flaw outside of grate).

Step 5a. Use Exhibit VIIl-1 Chart A with d' = O.115 ft and a = 0.0625 ft and read Qa'/La = 0.047.

Step 5b. Calculate 100 percent pickup length (La). La = Qa'/(Qa'/La) = 0.8/0.047 = 17.02 ft.

Step 5c. Calculate ratio of length of grate L/La = 2.5/17.02 = 0.15 < 1.0 only portion of flow is intercepted.

Step 5d. Calculate ratio of local depression a/d' = 0.0625/0.115 = 0.54

Step 5e. Use Exhibit VIII-1 Chart B with L/La = 0.15 and a/d' = 0.54 and read Q'/Qa' = 0.27.

Step 5f. Calculate flow over the side of the grate Q' = (Qa')(Q'/Qa') = (0.8) (0.27) = 0.22 cfs.

Step 6. Calculate total flow intercepted Q = (Qa - Qa') + Q' = (1.5 - 0.8) + 0.22 cfs = 0.92 cfs.
Step 7. Calculate carryover flow = Qa - Q = 1.5 - 0.92 = 0.58
Step 8. Calculate percent of intercepted flow = (Q / Q a) x l00 = (0.92/1.5) x 100 = 61
Step 9. Check that intercept flow picks up 85 percent of flow in gutter. (l.5)(0.85) = 1.28 cfs > 0.92 cfs. Therefore, change location of inlet or try a double gutter inlet.

8.2.4 Capacity of Grate Inlet or Combination Inlet in Sag or Sump (Water Ponded on Grate)

The following general procedures are stated for a combination grate inlet. The same procedures would apply to a grate only inlet; however, in consideration of possible clogging of the grate it is recommended the design perimeter and the design area of the grate be one-half of the effective perimeter (P) and effective area (A) determined below.

Step l. Calculate the total inflow (Q) to the inlet.
Step 2. Determine the effective perimeter of the grate opening (P) in feet ignoring the bars and omitting any side of the grate over which water does not enter; e.g., side against face of curb.
Step 3. Calculate the discharge per foot of perimeter (Q/P). Q is the total gutter discharge f rem each side of the grate.
Step 4. Determine the total clear opening area (A), excluding the area of the bars.
Step 5. Calculate the discharge per square foot of effective area (Q/A).
Step 6. Enter Exhibit VIII-3 with the values of Q/P and Q/A and reed the required head (H) in feet using the appropriate weir or orifice curve.
Step 7. Compare the two head values from Curve A and Curve B to determine the type of flow; i.e., weir flow or orifice flow.
Step 8. If the required head (H) is between 0.4 and 1.4 feet, the actual head may be anywhere in this head range. Use the value that gives the more conservative result (highest H).
Step 9. Compare the value of H determined in the preceding steps of the maximum allowable gutter depth (d) including local depression (a).
a. H > (d + a) indicates that the allowable ponding limits are exceeded and that additional inlets are required.
b. H < (d + a) indicates the inlet has ample grate capacity and the maximum allowable ponding limits will not be exceeded.

8.2.5 Capacity of Combination Inlet on Continuous Grade
Step 1. Determine the length (L) of the inlet opening and the depth of local flow line depression (a) at the inlet.
Step 2. Calculate the design gutter discharge (Q_a) for the initial design storm as stated in the preceding Article 8.3.1, including carryover from previous inlets. ·
Step 3. Determine the gutter flow depth (d) at design Q_a for the particular street section using Exhibit VIIl-2.
Step 4. Enter Chart A of Exhibit Vlll-1 with depth of flow in gutter (d) and local depression (a) and determine the interception per foot of inlet opening (Q_a /L_a).

Step 5. Calculate the length, $^{L}a = {}^{Q}a({}^{Q}a/{}^{L}a)$. If length ^{L}a is less than actual inlet length L, 100 percent of the flow is being intercepted. If L_a is greater than L, determine the percentage intercepted following Steps 6 through 10.

Step 6. Calculate the ratio of actual inlet length (L) in feet to length of inlet required to intercept 100 percent of gutter flow (L_a). The ratio is expressed as (L/L_a). Also, calculate the ratio a/d.

Step 7. Enter Chart B of Exhibit VIll-1 with the ratios calculated in Step 6 and determine Q/Q_a (the ratio of total flow intercepted by the inlet to gutter flow).

Step 8. Calculate the total intercepted flow, $Q = Q/Q_a$ x Qa.

Step 9. The carryover flow to the next inlet is Q_a - Q.

Step 10. Calculate the percent of intercepted flow (percent pickup) = Q/Q_a x 100.

Step 11. If the intercepted flow is less than 85 percent, try a different inlet location.

8.2.6 Capacity of Gutter Inlet or Combination Inlet at Street Intersections

Inlets are usually placed immediately upstream from pedestrian crosswalks and street intersections and should intercept 100 percent of the gutter flow. The ponded water depth at such low points of street intersections is determined in terms of curb opening height (Exhibit VIIl-4) as follows:

Step l. Calculate the inflow (Q) to the inlet.

Step 2. Determine the vertical height of curb opening (h) at the curb face, including local depression (a).

Step 3. Calculate the required capacity of the inlet per foot of length of opening, Q/L in cfs/foot.

Step 4. Determine the ratio of ponded water depth (H) to vertical curb opening height (h), H/h, using Exhibit VllI-4.

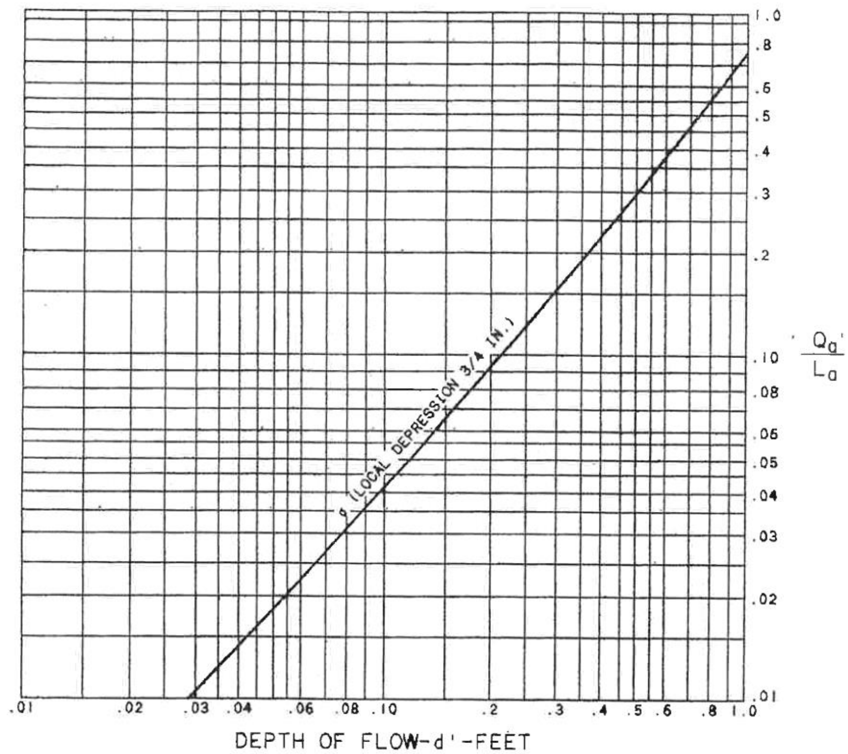
Step 5. Calculate the ponded water depth, H = H/h x h (in feet).

Step 6. The ponded water depth (H) is compared to the maximum allowable depth of flow in the gutter including local depression (a).

a. If H is less than (d + a) using the same units of depth, the curb opening inlet is intercepting 100 percent of the initial design storm discharge.
b. If H is greater than (d + a), the physical design criteria are exceeded and adjustments in design are necessary.

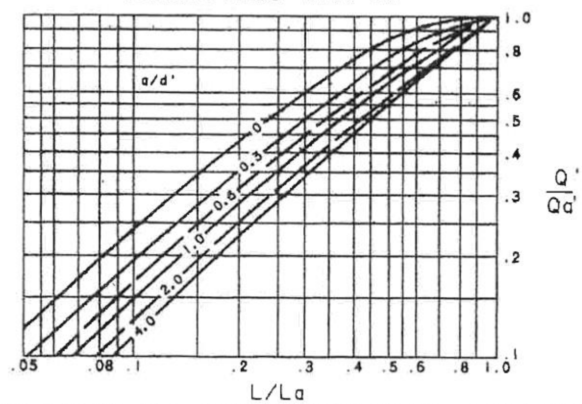
DISCHARGE PER FOOT OF LENGTH OF CURB OPENING INLETS WHEN INTERCEPTING 100% OF GUTTER FLOW

CHART A



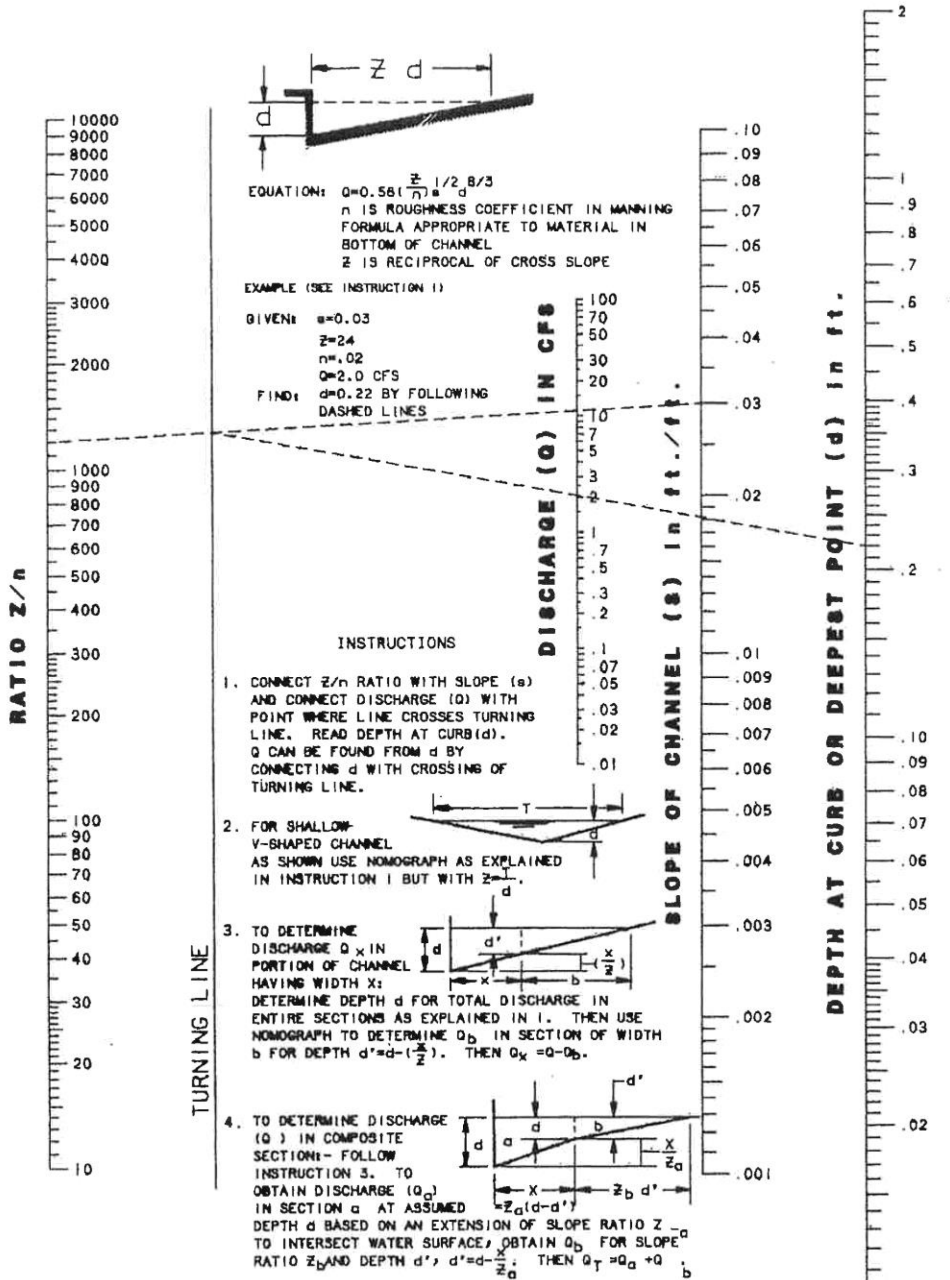
PARTIAL INTERCEPTION RATIO FOR INLETS OF LENGTH LESS THAN La

CHART B



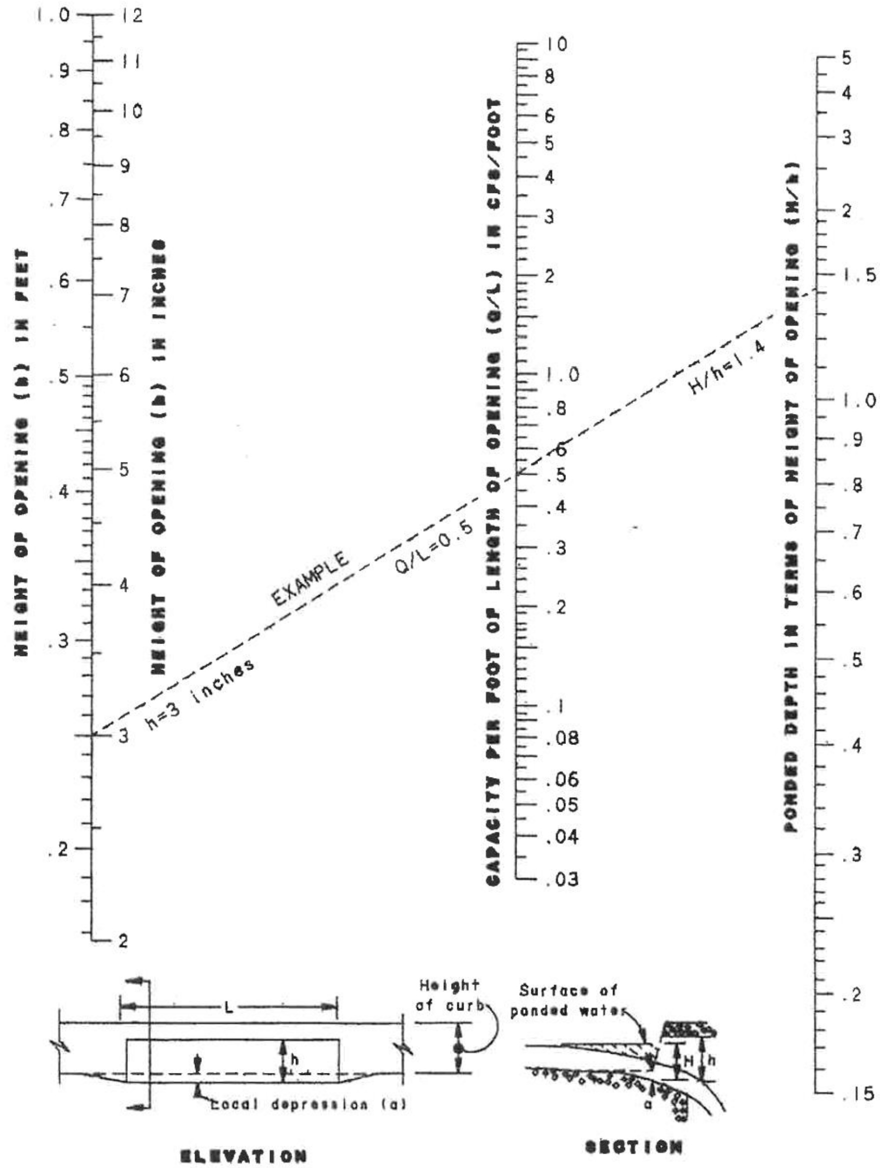
CAPACITY OF CURB OPENING INLETS ON CONTINUOUS GRADE

Exhibit VIII-1



NOMOGRAPH FOR FLOW IN TRIANGULAR CHANNELS

Exhibit VIII-2



CAPACITY OF CURB OPENING INLET AT LOW POINT IN GRADE (STREET INTERSECTION)

Exhibit VIII-4

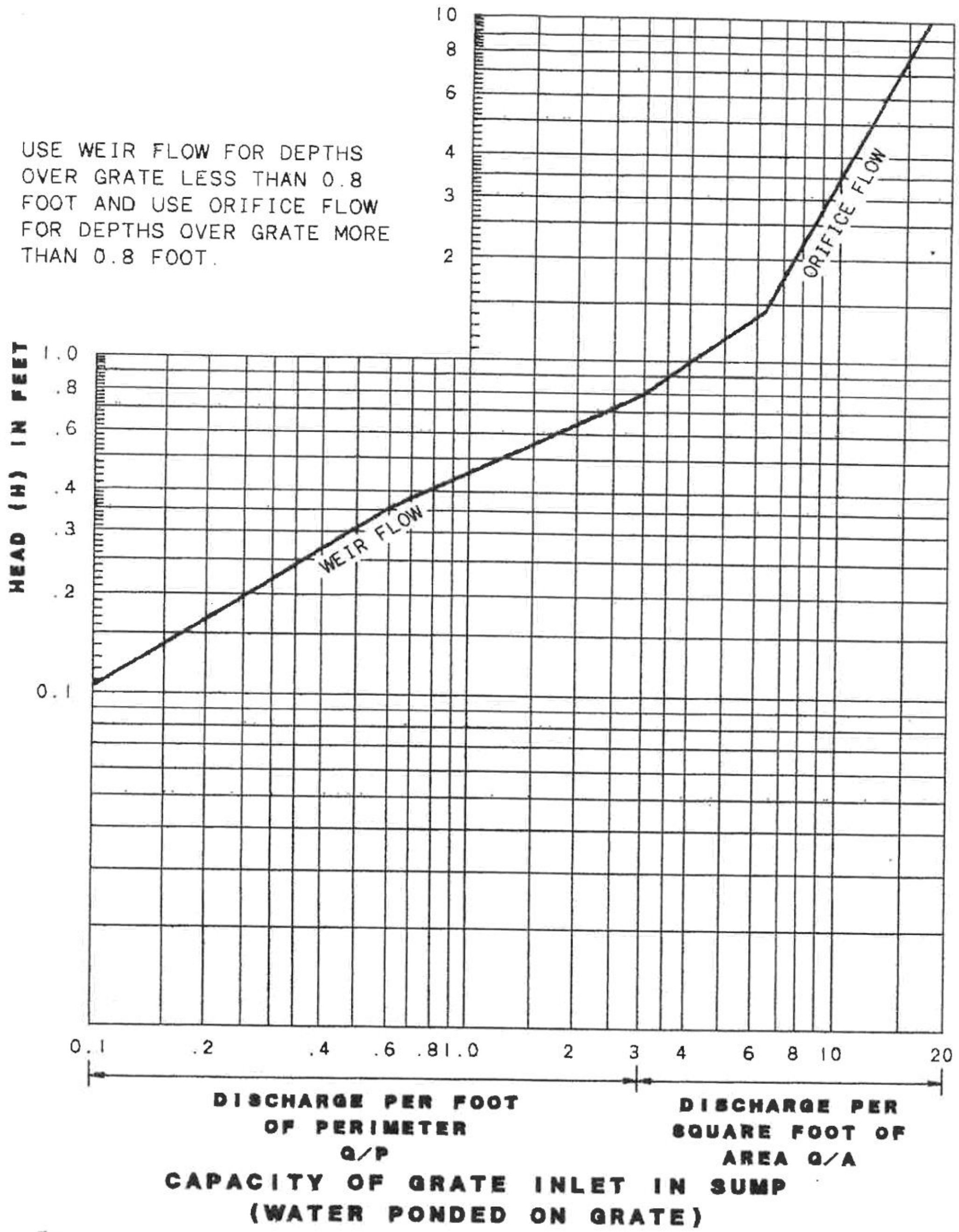


Exhibit VIII-3

PAVEMENT DRAINAGE COMPUTATIONS

PROJECT ______________________ DESIGNER ______________________ DATE ____________

DISCHARGE										GUTTER FLOW				GRATE OPENINGS INLETS					CURB OPENING INLETS									CHECK
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	27	28	29
INLET STATION	UPSTREAM STATION	LENGTH	WIDTH	A	C	CA	TIME	YEAR FREQUENCY I	Qo	GUTTER SLOPE (S)	CROSS SLOPE (Z)	DEPTH AT CURB (d)	SPREAD	TYPE OF INLET	WIDTH OF FLOW OUTSIDE OF GRATE	DEPTH OUTSIDE EDGE OF GRATE (d')	FLOW OUTSIDE OF GRATE (Q'o)	FLOW AT END OF GRATE (Qo-Q'o)	Qo/Lo CURB OPENING Q'o/Lo GRATE OPENING	100% PICKUP LENGTH (Lo)	L/Lo	o/d CURB OPENING o/d' GRATE OPENING	Q/Qo CURB OPENING Q'/Q'o GRATE OPENING	FLOW OVER SIDE OF GRATE (Q')	TOTAL FLOW INTERCEPTED (Q)	CARRY OVER FLOW	% PICKUP	INLET OK
		FT	FT	ACRES		ACRES	MIN	IN/HR	CFS	FT/FT	FT/FT	FT	FT		FT	FT	CFS	CFS		FT				CFS	CFS	CFS		

Form T8-1

CHAPTER 9. STORM SEWERS

9.1 Design Criteria

9.1.l Design Frequency

Storm sewer sizing shall be based on the just full capacity for a 10-year frequency rainfall. After initial sizing, a hydraulic grade line (HGL) check shall be made for a 25-year frequency rainfall. If the check shows water flowing out of the system, then the system needs to be revised to contain the rainfall. Final design shall indicate water surface elevations for the design storm. In addition, 100-year water surface elevations for all storm sewers shall be shown on the storm sewer profile.

9.l.2 Depth

The minimum cover for storm sewers in or within the right-of-way of streets with curb and gutter shall be the deeper of (a) l foot (clearance) from the bottom of the curb or underdrain to the top of the conduit; or (b) 2 feet below the bottom of the roadway base. A minimum cover of 2 feet of unfinished ground surface, or as recommended by manufacturer or as required for structural adequacy, is recommended at all other locations.

9.1.3 Velocity

A minimum velocity of 2.5 feet per second (fps) is recommended to insure self cleaning. The maximum allowable velocity shall be 12 fps unless special materials are included for protection against scouring.

9.l.4 Time of Concentration

The minimum inlet time of concentration for storm sewers shall be 10 minutes.

9.l.5 Design Discharge Method

The Rational Method or the Soil Conservation Service method may be used for drainage areas less than 200 acres to determine peak discharge. For areas between 200 and 640 acres, the Graphical Peak Discharge method of calculations shall be used as presented in Soil Conservation Service, Technical Release No. 55. For areas greater than 640 acres, the hydrograph method of calculation shall be used as presented in Soil Conservation Service, Technical Release No. 20.

9.l.6 Hydraulic Design

The hydaulic design of storm sewers shall be based on the Manning Equation:

$$V = (l.49\ r^{2/3}\ S^{1/2})/(n).$$

9.l.7 Roughness Coefficients

Table 9-1 lists the Manning roughness coefficients (n) to be used for different conduit materials.

Table 9-1
Manning Roughnness Coefficients

Closed Conduit Material	Manning "n"
Concrete, vitrified clay or bituminous lined corrugated metal	.013
Concrete (monolithic)	
Smooth forms	.013
Rough forms	.017
Corrugated metal pipe	
(1/2 inch x 2 3/4 inch corrugations)	
Plain	.024
Paved invert	.022

9. l. 8 Manhole Spacing

Manholes should be located at junctions of conduits, at changes in conduit direction, at changes in slope, and at changes in pipe size. Maximum manhole spacing should be 300 feet for storm sewers with diameters up to and including 36 inches and 500 feet for storm sewers larger than 36 inches.

9. 1. 9 Conduit Size

The minimum conduit size shall be 12 inches in diameter. In no case will storm sewers being used as private property detention basins which use conduit size less than 12 inches in diameter be allowed without permission from the City Engineer.

9.l.10 Hydraulics at Structures

The inverts of curb inlets, manholes, and other structures shall be rounded and sloped to minimize turbulence and collection of debris.

9.1.11 Location of Sewers

Location of sewers in street right-of-way shall be as approved by the City Engineer.

9.2 General Design Procedures

The following general design procedures provide a uniform approach to storm sewer design. The procedure as outlined is for a storm sewer system serving an urban area with curbed streets. With minor modifications, it can apply as well to streets with side ditch swales.

The general procedures for street and inlet design, and a generalized approach to inlet spacing are discussed in the preceding chapter of the manual (Chapter 8). Street and inlet design is a basic part of the storm sewer drainage system. Maximum use should be made of the street gutter capacity to transport storm water runoff to inlets, and thereby reduce the size of the storm sewers.

The following basic data is required:

l. Map of drainage area for which the storm sewer system is to serve (Subdivision plan supplemented by United States Geological Survey [USGS] maps or Butler County topographic maps for off-site area, if required).

2. Typical street cross sections and profiles.

3. Pavement Drainage Computations (use form T9-l provided).

4. Soil maps and data.

5. Outfall Elevation (from field measurement).

6. Rainfall intensity-duration-frequency curves or tabulation (Exhibit V-1).

Step 1. Determine proposed curb inlet locations based on gutter capacity (Article 8.3).

Calculate the initial storm sewer pipe size starting at the most upstream inlet location and working downstream as follows.

Step 2. Calculate the initial storm, 10-year frequency, total runoff (Q) ta the storm sewer inlet.

Step 3. Estimate the slope of the storm sewer to the next manhole and using Exhibit II-3 with flow, pipe roughness, and pipe slope determine the standard size storm sewer pipe diameter required. For this size, read flawing full capacity and the corresponding pipe velocity.

Step 4. Check that flowing full discharge is greater than total runoff discharge and that the pipe velocity meets the design criteria velocity.

Step 5. Calculate the flow travel time between the two manholes. Travel time equals pipe length/pipe velocity (L/V). For each successive downstream manhole, the time of concentration used should be the greater of the preceding manhole's time of concentration plus the flow travel time between the two manholes or the time of concentration of the intermediate area between the two manholes.

Step 6. Calculate the manhole bottom elevation which equals manhole elevation minus pipe length times pipe slope and check depth meets the design criteria.

Step 7. Go back to Step 2 and repeat Steps 2 through 6 for each length of storm sewer throughout the system until initial sizing of all of the storm sewer pipes has been completed. Calculate the hydraulic gradient for the 25-year frequency rainfall starting at the storm sewer system outlet and working upstream as follows:

Step 8. The control elevation (hydraulic gradient elevation) at the system outlet can be taken as the conduit crown for a freely discharging sewer or as the pool elevation for a submerged outlet.

Step 9. Determine the 25-year rainfall intensity at the outlet. This intensity will be used throughout the storm sewer system so long as the system is under pressure. If the system is not under pressure then the intensity would change at that manhole and would be used so long as the system is not under pressure.

Step 10. Calculate the 25-year frequency total runoff at the storm sewer inlet.

Step 11. Using Exhibit II-3 with flow, pipe size, and pipe roughness determine the friction slope to the next inlet.

Step 12. Calculate head loss to next inlet which equals friction slope times pipe length.

Step 13. Determine the hydraulic gradient elevation at the next inlet which equals hydraulic gradient elevation of inlet plus head loss. This hydraulic gradient elevation must be lower than the inlet gutter elevation. If it is not, the pipe must be resized. Go to Step 2 and begin calculations again. For the next pipe upstream, the HGL is assumed to be at the crown of the conduit at the downstream end of that conduit. Ordinarily, the hydraulic gradient will be above the top of the pipe causing the system to operate under pressure. If, however, any run in the system does not flow full (pipe slope steeper than friction slope), the hydraulic gradient slope will follow the friction slope until it reaches normal depth of flow in the steep run. From that point, it will coincide with normal depth of flow until it reaches a run flatter than the friction slope for the run.

Step 14. Go back to Step 9 and repeat Steps 8 through 11 for each length of storm sewer throughout the system.

Step 15. The hydraulic effects of the 100-year storm on the drainage system are determined for compliance with the physical design criteria presented herein.

Step 16. The final design is drawn on prepared plan and profile sheets.

9.3 Major Storm Considerations

The 25- and 100-year storm runoff is routed through the drainage system to determine if the combined capacity of the street and storm sewer system is sufficient to maintain surface flows within permissible limits. The maximum allowable flow depth of a storm is stated in Article 8.2.2. The capacity of the storm sewer conduit at any given point for the 25- and 100-year storm is assumed to be one-half of the design storm capacity for determining the required capacity of surface channels as stated in Article 8.2.2. If the 25- and 100-year storm runoff exceeds the combined capacity of the street and storm sewer drainage system, revision in the design is required. Where a drainageway is located outside a street right-of-way, easements shall be provided.

STORM SEWER COMPUTATIONS

PROJECT ______________ DESIGNER ______________ DATE ________

DISCHARGE											STORM SEWER SIZE											HYDRAULIC GRADIENT						
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	27	28	29
INLET LOCATION (DESIGN POINT)	RUNOFF COEFFICIENT C	DRAINAGE AREA A	CA	ΣCA	INLET OR CONDUIT TRAVEL TIME	TIME OF CONCENTRATION T_c	RAINFALL INTENSITY __ YEAR FREQUENCY I	RUNOFF IΣCA	OTHER CONTROLLED RUNOFF	TOTAL RUNOFF, Q	PIPE LINE DESIGNATION	PIPE DIAMETER	LENGTH, L	SLOPE	GUTTER AT INLET OR COVER ELEV.	INLET OR MANHOLE BOTTOM	PIPE COVER	MEETS COVER DESIGN CRITERIA	JUST FULL CAPACITY	VELOCITY	MEETS VELOCITY DESIGN CRITERIA	RAINFALL INTENSITY __ YEAR FREQUENCY I	TOTAL RUNOFF Q	SLOPE	HEAD LOSS	ELEVATION OF HYDRAULIC GRADIENT	CROWN PIPE	PRESSURE FLOW
		ACRES			MIN.	MIN.	IN/HR	CFS	CFS	CFS		IN	FT	FT/FT			FT		CFS	FPS		IN/HR	CFS	FT/FT	FT			

Form T9-1

CHAPTER 10. CULVERTS

10.l Design Criteria

10.l.l Design Storm

All prefabricated structures including concrete pipe, vitrified sewer pipe, corrugated metal pipe, prefabricated box culverts, etc., shall be considered culverts. Culverts under driveways shall be designed for the 10-year storm. All other culverts, except culverts that cross a major channel or are located in the floodplain of a major channel, shall be designed for the 25-year storm. Culverts that cross a major channel or are located in the floodplain of a major channel shall be designed for the 100-year storm. Final design shall indicate headwater elevations for the design storm and 100-year rainfall for all culverts except culverts under driveways, crossing a major channel, or located in the floodplain of a major channel.

10.1.2 Maximum Allowable Headwater

The maximum allowable headwater on the culvert for the initial design storm shall be the lower of the following:

l. Two feet below the pavement edge for drainage areas equal to or exceeding 1,000 acres.
2. One foot below the pavement edge for drainage areas less than 1,000 acres.
3. Two and one-half feet above the inlet crown or above a tailwater elevation that submerges the inlet crown in flat to rolling terrain.
4. Four feet above the inlet crown in a deep ravine.
5. Two feet below the lowest ground elevation adjacent to an occupied building for a 25-year storm.

For major storm culvert design, the maximum allowable headwater shall be 6 inches at the crown of the street or over the top of embankment, whichever is lower.

10.1.3 Roughness Coefficients

Manning's roughness coefficients to be used for culvert design are:

for concrete pipe culverts - 0.013
for corrugated metal pipe culverts - 0.024

10.1.4 Headwalls

Half-height headwalls shall be provided for all culverts. Full-height headwalls may be considered when the savings in possible reduced culvert size and length of culvert offset the additional cost of the headwall.

10.2 General Design Procedures

Following is a recommended process for calculating culvert size:

Step l. List design data

a. Design discharge (Q) in cubic feet per second (cfs) for initial and major design storm runoff.
b. Approximate length (L) of culvert, in feet.
c. Culvert slope (S_o), in feet per foot.

d. Allowable headwater depth (AHW), in feet.

e. Downstream channel depth (TW) in feet and permissible velocity in feet.

f. Type of culvert, first trial (entrance type, material, and shape).

Step 2. Determine the first trial diameter (D) size by one of the following methods.

a. Arbitrarily select a diameter size (based on engineering experience).

b. Determine diameter size using appropriate nomograph of Exhibit X-1 and assuming HW /D = 1.5.

c. Determine diameter size so that its cross section area A = Q/V where V = upstream channel velocity.

If the trial diameter size for a single conduit culvert size is too large because of limited overhead clearance or availability of size, try alternate design methods such as lowering the invert, drop inlet or multiple conduits. Assume the flow is equally divided among each of the conduits for multi-conduit design of the same size.

Step 3. Assume Inlet Control

a. Using appropriate nomographs of Exhibit X-1 with diameter of - culvert (D), discharge (Q), and entrance type read ratio of headwater · depth to diameter of culvert (HW /D) and calculate the headwater (HW) depth. HW = (HW/D) D

b. If HW is greater than the allowable headwater depth (AHW), try a different culvert size. Tailwater conditions are neglected in this pert of the procedure.

Step 4. Assume Outlet Control

a. Use Exhibit X-2 with type of pipe and type of headwall, read the culvert entrance loss coefficient (Ke)·

b. Use appropriate nomographs of Exhibit X-3 with discharge (Q), culvert size (D), culvert length (L), and loss coefficient (K_e), read head (H).

c. Use Exhibit X-4 with discharge (Q), culvert size (D), read critical depth of culvert (de).

d. Compute $(D + d_c)/2$.

e. Determine h_o which equals the greater value of $(D + d_c/2$ or downstream channel depth (TW).

f. Compute $L \times S_o$.

g. Compute $HW = H + h_o - (L \times S_o)$

h. Compare the headwater values determined for inlet control and outlet control, the higher HW value governs and indicates the type of control.

i. If outlet control governs and HW is greater than the allowable headwater, try a larger conduit. Since outlet control is the constraint and a smaller size was acceptable for inlet control, the larger conduit does not have to be checked for inlet control.

Step 5. If outlet control governs, check accuracy of HW value.

a. If $HW \geq D + ([\,l+Ke]\, v^2)/2g$, where V = Q/A and g = 32.2 ft/sec^2 HW is accurate and design is acceptable for HW.

b. If HW ≥ 0.750, HW is sufficiently accurate and design acceptable for HW .

c. If HW < 0.7 SD, redesign is required.

Step 6. Compute outlet velocity (Vo) For inlet control:

a. Use Exhibit X-5 for the solution of Manning's equation with - culvert slope (S_o), Manning's roughness coefficient (n) and culvert size (D), reed the flowing full capacity and the flowing full velocity of the culvert.

b. Use Exhibit X-6 with the proportional value of design discharge to flowing full capacity and read the proportional value of design velocity to flowing full velocity. Calculate design velocity equals proportional value of design velocity to flowing full velocity times flowing full velocity.

For outlet control:

a. The tailwater is greater than the height of the $V_o = Q/A$, where A is the full cross sectional area of the culvert.

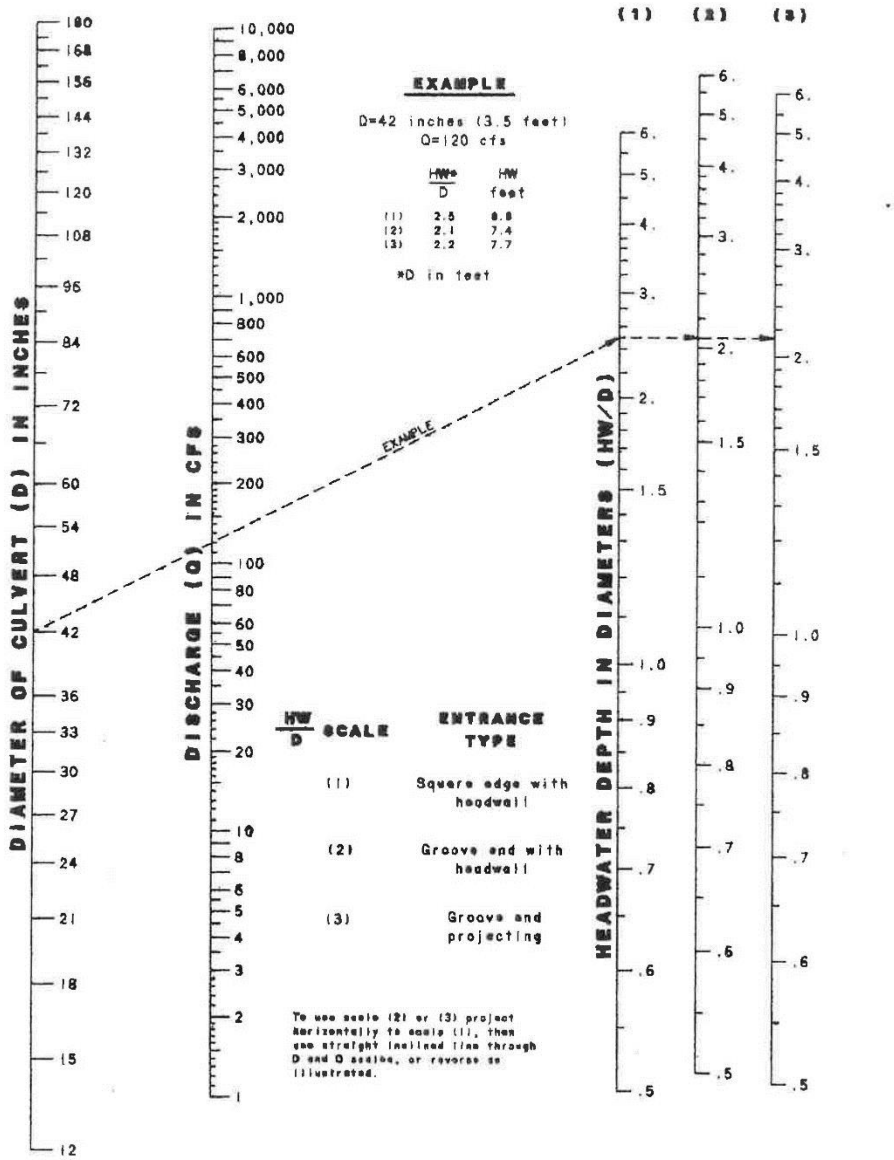
b. If tailwater or critical depth is less than the height of the culvert, the $V_o = Q/A$ where A is the area of flaw corresponding to the tailwater or critical depth whichever gives the greater area of flow.

c. If $V_o \leq$permissible downstream velocity, minimal channel protection is required (see Chapter 11).

d. If $V_o >$ permissible downstream velocity, channel protection or energy dissipation is required (see Chapter 11).

Step 7. Record final design data.

The preceding design approach in calculating culvert size is devoted entirely to culvert hydraulics. In addition, although not a part of this manual, the culvert needs to be structurally designed to assure the selected pipe is of proper strength and has sufficient bedding conditions and caver to support the anticipate loads.

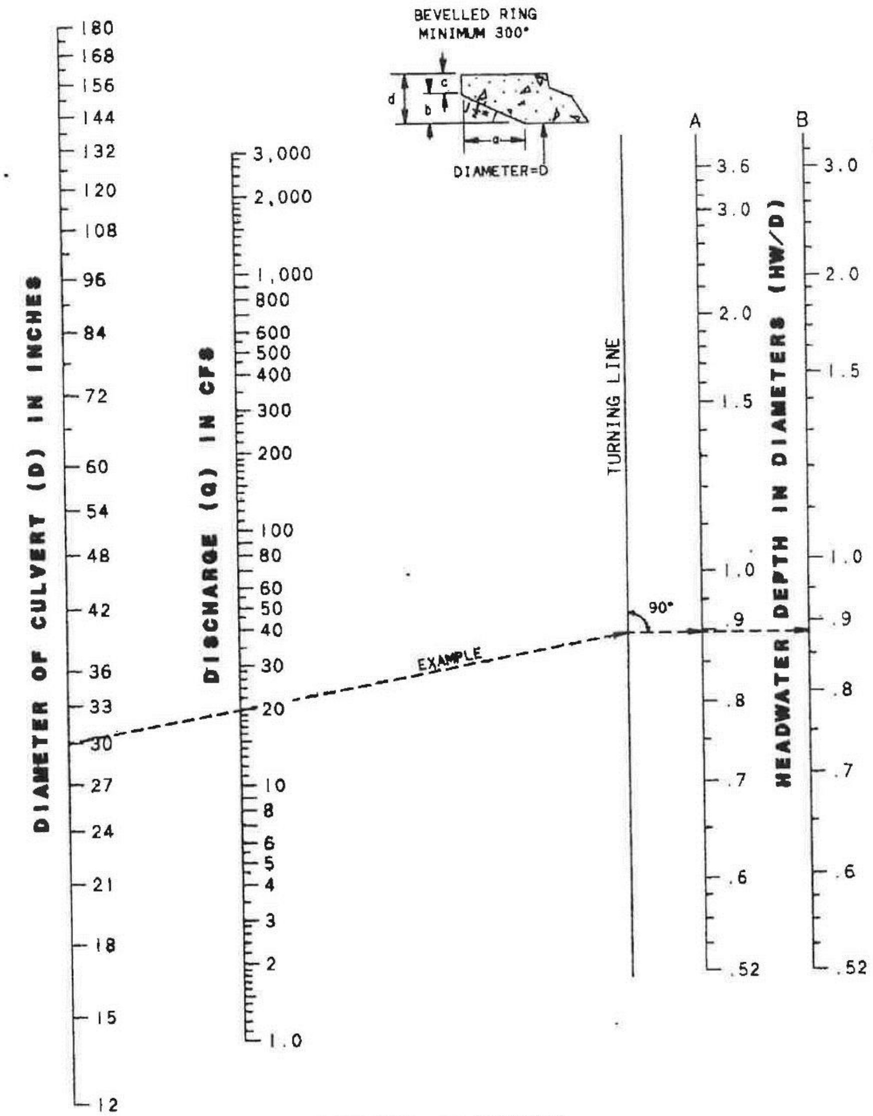


HEADWATER SCALES 2 & 3
REVISED MAY 1964

INLET CONTROL
HEADWATER DEPTH FOR CONCRETE PIPE CULVERTS

Exhibit X-1

$\frac{b}{D}$	$\frac{a}{D}$	$\frac{c}{D}$	$\frac{d}{D}$	ENTRANCE TYPE
0.042	0.063	0.042	0.083	A
0.083	0.125	0.042	0.125	B



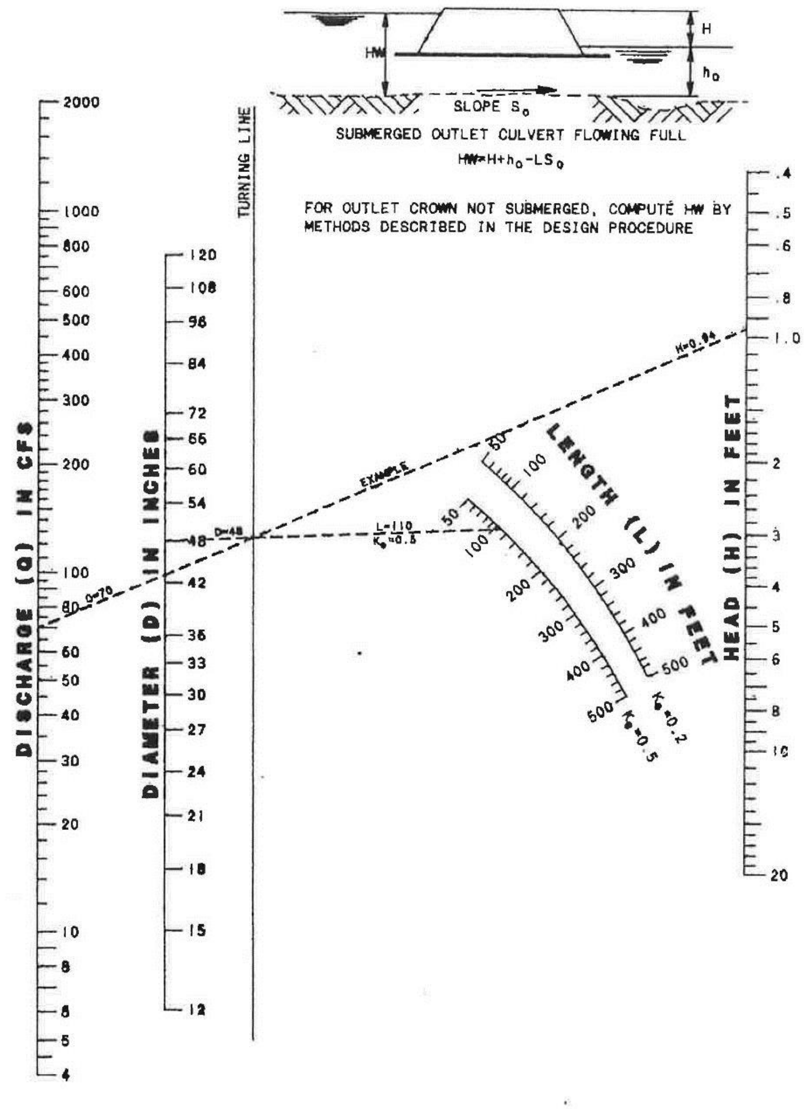
INLET CONTROL
HEADWATER DEPTH FOR CIRCULAR PIPE CULVERTS WITH BEVELLED RING

Exhibit X-1 (cont.)

TYPE OF PIPE	HEADWALL TYPE		
	Full	One-half	None
Concrete or Vitrified (thick wall with groove end entrance)	0.2	0.2	0.2
Corrugated Metal (thin wall with beveled entrance)	0.25	0.9	0.9
Concrete or Vitrified (thick wall with square cut end entrance)	0.5	0.5	0.5

CULVERT ENTRANCE LOSS COEFFICIENT k_e

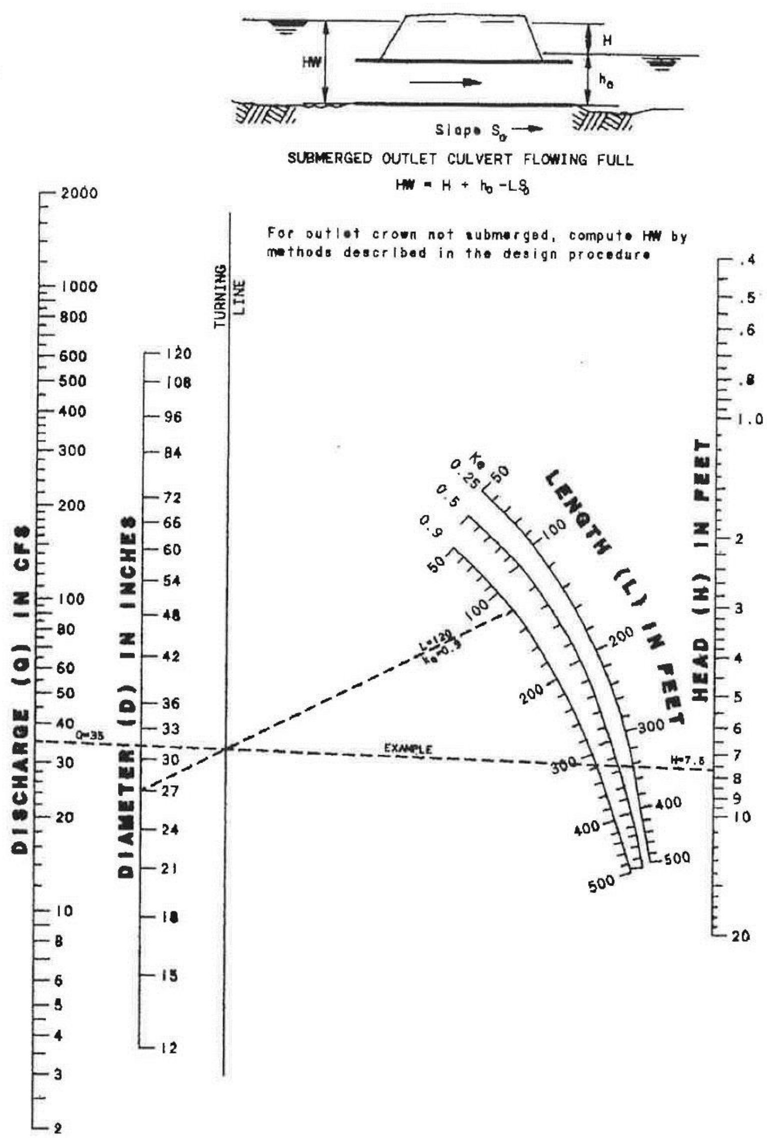
Exhibit X-2



OUTLET CONTROL

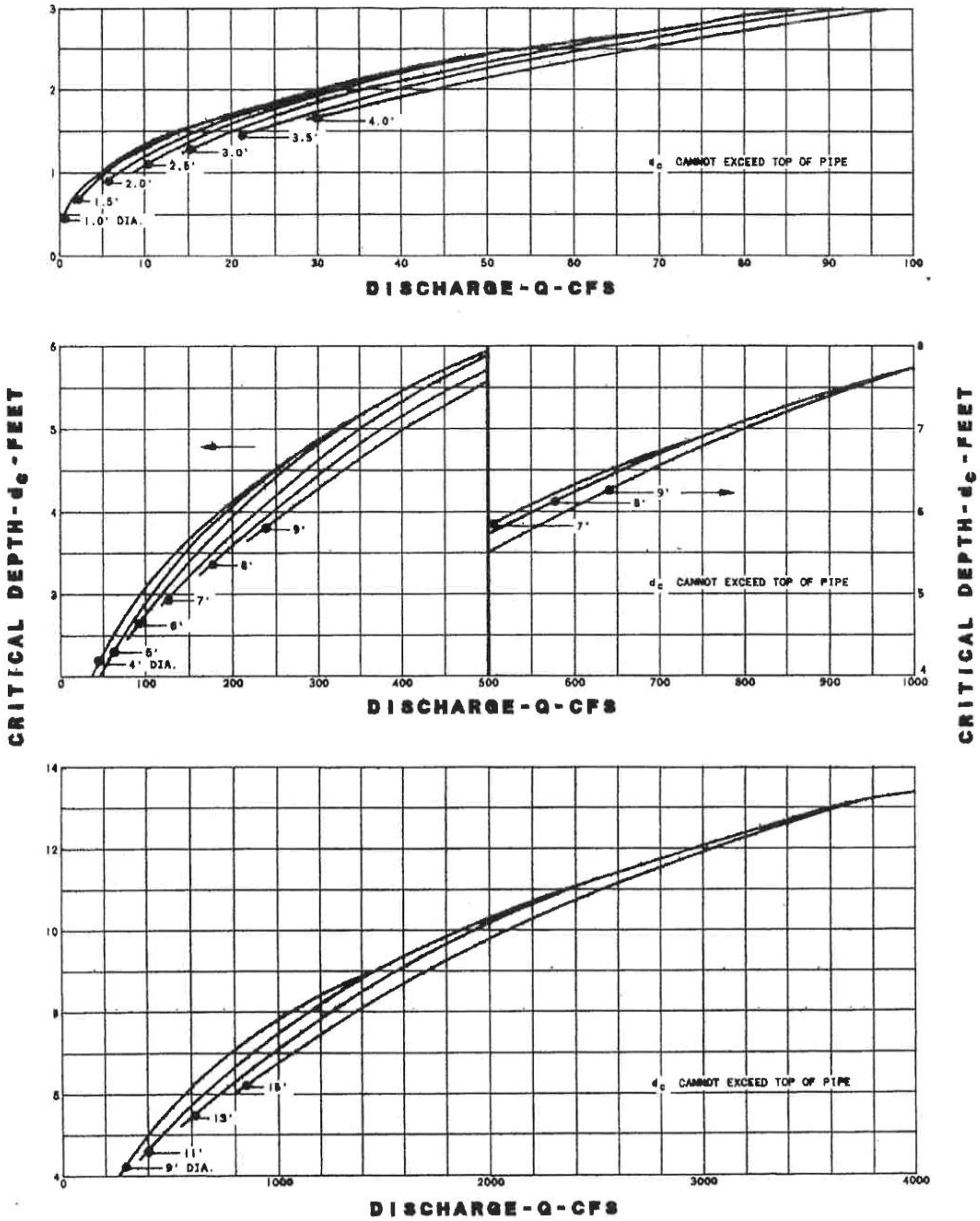
HEAD FOR CONCRETE PIPE CULVERTS FLOWING FULL n=0.012

Exhibit X-3



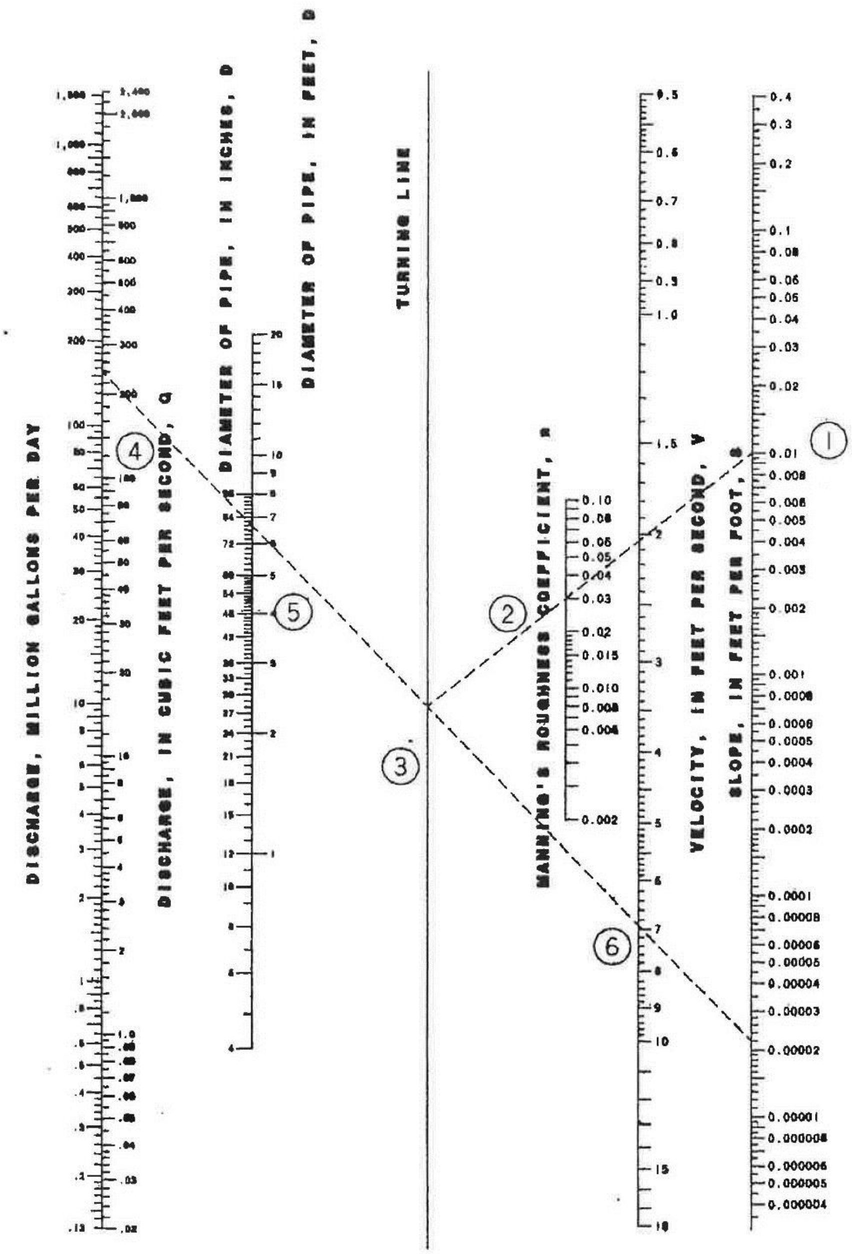
OUTLET CONTROL
HEAD FOR STANDARD C. M. PIPE CULVERTS FLOWING FULL n=0.024

Exhibit X-3 (cont)



CRITICAL DEPTH
CIRCULAR PIPE

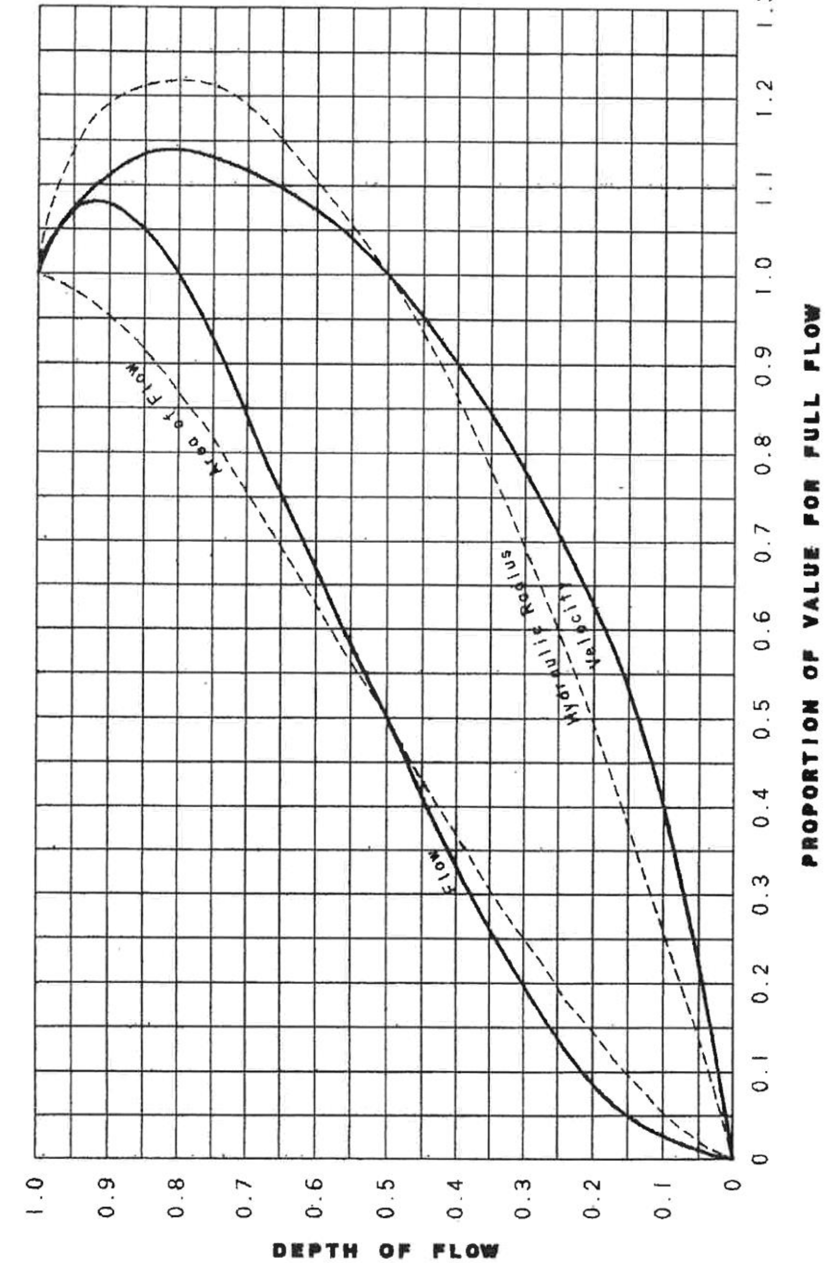
Exhibit X-4



NOMOGRAPH FOR SOLUTION OF THE MANNING FORMULA

$$Q = AV = A\frac{1.49}{n} r^{2/3} s^{1/2}$$

Exhibit X-5



RELATIVE VELOLCITY AND FLOW IN CIRCULAR PIPE FOR ANY DEPTH OF FLOW

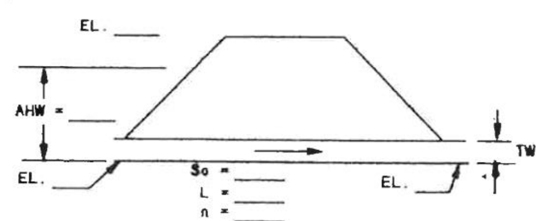
Exhibit X-6

CULVERT SIZE COMPUTATIONS

PROJECT ______________________ DESIGNER ______________ DATE __________

			HEADWATER COMPUTATIONS													OUTLET CONT.			
			INLET CONT.		OUTLET CONTROL $HW = H + h_o - LS_o$										Size OK if HW>			
1 CULVERT DESCRIPTION (ENTRANCE TYPE)	2 SIZE D	3 Q	4 $\frac{HW}{D}$	5 HW	6 K_e	7 H	8 d_c	9 $\frac{d_c+D}{2}$	10 TW	11 h_o	12 LS_o	13 HW	14 Controlling HW	15 Allowable Headwater AHW	16 $D+\frac{(1+K_e)V^2}{2g}$	17 .75D	18 OUTLET VELOCITY	19 COMMENTS
	IN	CFS		FT		FT	FT	FT	FT	FT	FT	FT	FT	FT	FT	FF	FPS	

LOCATION: __________ STATION: __________



ALLOWABLE OUTLET VELOCITY = ______

Form T10-1

CHAPTER 11. CHANNEL PROTECTION

11.1 Open Channels

Open channels in subcritical flow (see Chapter 7) are generally designed as grass-lined channels. All channel bottoms shall be sodded. Channel side slopes which are flatter than 2:1 may be sodded or seeded. Channel side slopes of 2:1 or steeper shall be protected with sod or lined with concrete, riprap, brick, asphalt, or other erosion-resistant lining. Open channels carrying supercritical flow shall be lined with concrete on the bottom and on the side slopes to the full design depth.

11.2 Culvert Headwalls

Culverts at collector streets, and main arteries, shall be provided with concrete headwalls.

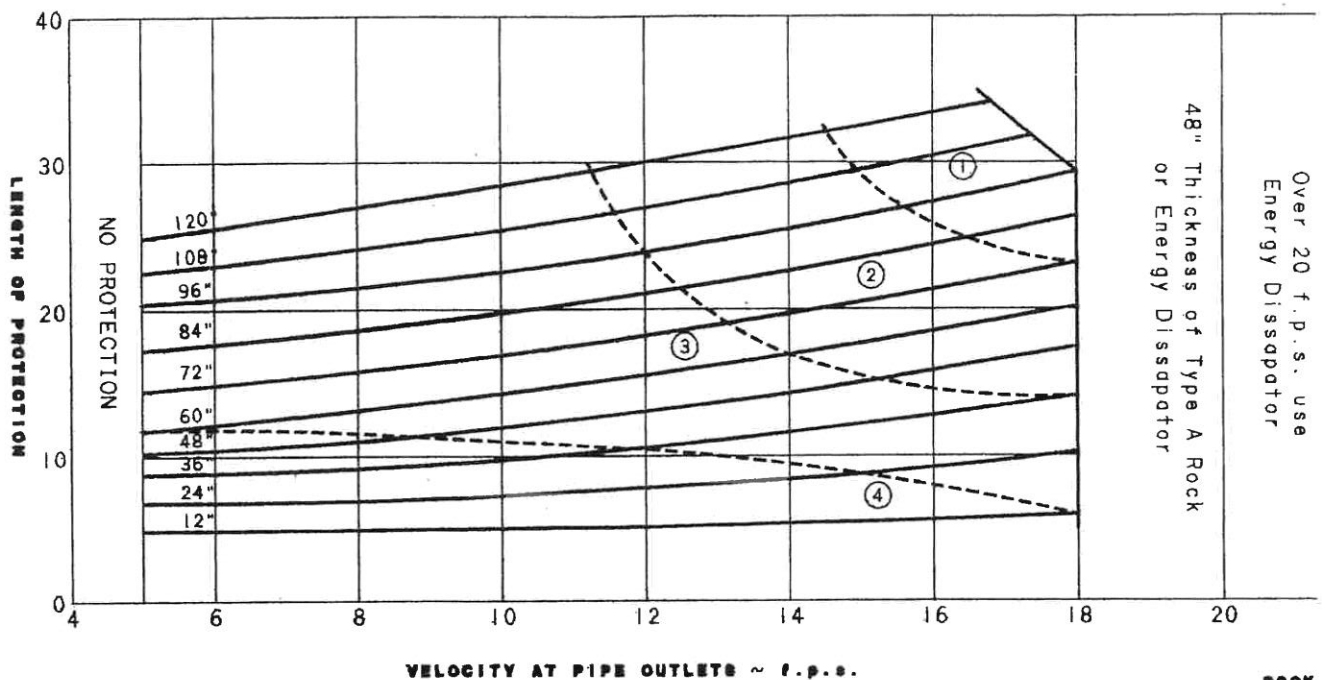
11.3 Energy Dissipation

Outfalls from storm sewers and culverts shall be designed to minimize erosion action on the channel at and downstream from the outfall. At all outfalls, rock protection shall be provided as given in Exhibit Xl-1.

11.4 Example - Energy Dissipation

Find the length and type of rock channel protection from a 48-inch concrete culvert, with an outfall velocity of 12 fps.

> Step l. Use Exhibit XI-1 with culvert size of 48 inch and pipe outlet velocity of 12 fps and read that rock channel protection is required and shall consist of 12-inch rock, 30 inches deep, extending l3.5 feet below the outfall and be 8 feet wide.



NOTES

Rock size (6", 12", 18") indicates the square opening on which 85% of the material by weight will be retained.

Minimum width of protection shall be twice the pipe diameter, with 4' being the very minimum.

(Where a stream bed will withstand the calculated velocity without erosion, no rock channel protection will be required)

LEGEND	ROCK TYPE
(1) 48" of 18" rock	A
(2) 36" of 18" rock	A
(3) 30" of 12" rock	B
(4) 18" of 6" rock	C

ROCK CHANNEL PROTECTION
AT CULVERT AND STORM SEWER OUTLETS

Exhibit XI-1

CHAPTER 12. RUNOFF CONTROL METHODS

12. l Design Criteria for Runoff Control

Peak flow runoff controls shall be required on all land developments and redevelopments except land prepared for agricultural crops, orchards, wood lots, sod farms and nursery operations, land grading or leveling for erosion control under direction of the local soil conservation district, and land subdivisions for residential purposes with minimum lot size of 5 acres or more. When phased construction is planned or occurs, the total land area to be developed shall be considered when planning the stormwater facilities.

For all developments or redevelopments, except those exempted above, stormwater detention shall be in accordance with the Stormwater Master Plan and shall be accepted and approved by the City Engineer. Detention shall be provided to assure that the peak rate of runoff from the area after development does not exceed the peak rate of runoff from the same area before development for the 1-, 2-, 5-, 10-, 25-, 50-, and 100-year frequency, 24-hour storms. The 24-hour rainfall amounts are given in Table 5-1.

The recommended method for determining the amount of runoff control is based on the size of the area under study. For sites with drainage areas less than 10 acres, the storage equation method is the preferred method. For sites with drainage areas between 10 and 640 acres, the graphical flow routing method, as defined in the Soil Conservation Services' Technical Release No. 55, is the preferred method. For sites with drainage areas greater than 640 acres, the Soil Conservation Services' Technical Release No. 20 Method is the preferred method. All routing calculations shall account for tailwater conditions of the receiving facility and shall be submitted to the utility.

12. 2 Detention Structures

Detention structures can be categorized as: dry basins, permanent (wet) ponds, storage tanks, and multi-use storage areas such as rooftops, parking lots, roadway embankments, and other shallow holding areas. Structures for detention or retention of stormwater may be considered together since the major control structures function the same for each. The objective of control structures is to reduce peak rate of discharge by storage and controlled release. Any detention basins should be checked for compliance with Chapter 1521 of the Ohio Revised Code and the Ohio Department of Natural Resources (ODNR) Division of Water regulations and, if required, a construction permit must be obtained from the ODNR.

12.3 Design Criteria for Detention (Dry) Basins, (Wet) Ponds

l. Discharge Control Facilities

The outlet structure shall be designed to minimize the transport of floating debris, oil, and grease through the detention facility. The design of the facility shall also include adequate provisions to minimize erosion in the vicinity of the inlet and outlet, and on the side slopes of surface facilities.

2. Detention Period

A minimum of 50 percent of the total storage volume required to attenuate the peek discharge of the facility shall be recovered within a 24-hour time period. The remaining 50 percent shell be recovered within an additional 72-hour time period.

3. Surface Slope

The bottom of a dry detention pond shall be at least 3 feet above the seasonal high water table. For wet ponds, the level of zero storage will be taken as the water surface elevation of the dead storage pool. The minimum bottom width for ponds and open drainage ways shall be 4 feet.

4. Stability Analysis

Where berms constructed of fill are proposed, calculations supporting the stability of the fill berms are to be submitted by a Geotechnical Engineer.

5. Barriers to Access

For fenced facilities, the maximum side slop inside the fence may be 3:1, but the maintenance berm, if required, must be a minimum of 12 feet wide all around the perimeter. Fenced facilities are discouraged.

6. Rights-of-Way and Easements

Outfall ditches and channels shall have sufficient right-of-way for the facility plus an unobstructed maintenance berm on one or both sides. Vehicular access from a public road to the maintenance berm shall be provided. Detention facilities shall have sufficient easement to allow for the installation and maintenance of a maintenance berm. The City Engineer may require a maintenance berm all around the perimeter of the pond. If required, top widths of maintenance berms shall be 10 feet, and cross slopes shall be no steeper than 3/8-inch per foot.

7. Aesthetics

Areas adjacent to ponds shall be graded to preclude the entrance of stormwater, except at planned locations. Where detention areas are located on the project periphery, the developer may be required to provide additional landscaping or screening to adequately protect abutting properties. Grading should take into consideration ease of maintenance, such as mowing.

12.4 Summary of Design Criteria

l. Surface Storage Criteria

A summary of the basic design criteria parameters for detention basins and parking lot storage is given in Table 12-1. They are intended to establish general limits of design and are not all inclusive. In the final analysis, engineering judgment and actual experience are important factors of any design.

Table 12-1
Summary of Design Criteria
For
On-Site Detention/Retention Structures

Control Method	Inside Maximum Side Slope	Maximum/ Minimum Water Depth	Top Width of Embankment	Minimum Maintenance Berm Width
Detention (Dry) Basin	4:1	Maximum 4-6 feet	8 feet	10 feet
Detention (Wet) Pond	4:1	Minimum Pool 10 feet	10 feet	10 feet
Parking Lot Storage	--	Maximum 7 inches	--	--

12.5 Storage Equation (Preferred Method for Determining the Storage Requirement from a Drainage Area of Less Than 10 Acres)

The storage equation method presented here can be used on drainage areas less than 10 acres. The storage equation says the required storage volume equals the 100-year post-development peak discharge at Q_{100} post minus, the 100-year predevelopment peak discharge Q_{100} pre times 30 minutes. The general procedure for flow routing by the storage equation is as follows:

Step 1. Determine the predevelopment and post-development peak discharges for the 1-, 2-, 5-, 10-, 25-, 50-, and 100-year frequency event using the Rational Method.

Step 2. Determine the required storage volume by the storage equation. The required storage for each frequency event shall equal the frequency event's post-development peak discharge divided by the 100-year post development peak discharge times the required storage volume as determined by the storage equation.

Step 3. Size the outlet facility so that for each frequency event the outlet discharge does not exceed the predevelopment discharge.

Step 4. Design the detention/retention structure according to the design criteria given in this chapter.

12. 5. l Example - Storage Equation

Determine the required storage volume for a 5-acre watershed and a predevelopment runoff coefficient equal to 0.3 and a post-development runoff coefficient equal to 0.65. The time of concentration (TC) has been calculated to be 15 minutes for predevelopment conditions and 8.0 minutes for post development conditions. Since for post-development the TC of 8.0 is less than TC of the minimum value, use 10 minutes. Because the area is less than 10 acres, the storage equation can be used. For this example, the l-, 2-, 5-, 10-, 25-, and 50-year frequency predevelopment discharges are not to be calculated as they are not required for the storage volume although these discharges are needed to size the outlet facility.

Step l. Use Exhibit V-1 with TC pre = 15 and TC post = 10 and read predevelopment rainfall intensity I_{100} = 6.50

Post-development rainfall intensity I_1 = 3.07, I_2 = 4.08, I_5 = 4.85, I_{10} = 5.45, I_{25} = 6.30, I_{50} = 7.02, and I_{100} = 7.69

Calculate discharge Q=CIA

Predevelopment

100-year event Q100 pre = 0.3 x 0.650 x 5 = 9.7 cubic feet per second (cfs)

Post-development

1-year event: Q_1post = 0.65 x 3.07 x 5 = 10.0 cfs;
2-year event: Q_2post = 0.65 x 4.08 x 5 = 13.3 cfs;
5-year event: Q_5post = 0.65 x 4.85 x 5 = 15.8 cfs;
10-year event: Q_{10}post = 0.65 x 5.45 x 5 = 17.7 cfs;
25-year event: Q_{25}post = 0.65 x 6.30 x 5 = 20.5 cfs;
50-year event: Q_{50}post = 0.65 x 7.05 x 5 = 22.8 cfs; and
100-year event: Q_{100}post = 0.65 x 7.69 x 5 = 25.0 cfs.

Step 2. Calculate storage volume by the storage equation = (Q_{l00}post - Q_{100}pre) x 30 = (25.0 - 9.7) x 30 x 60 sec/min = 27,540 cubic feet (cf)

Required storage for each frequency event

1-year event (10.0/25.0) x 27,540 = 11,016 cf;
2-year event (13.3/25.0) x 27,540 = 14,651 cf;
5-year event (l5.8/25.0) x 27,540 = 17,405 cf;
10-year event (17.7/25.0) x 27,540 = 19,498 cf;
25-year event (20.5/25.0) x 27,540 = 22,583 cf;
50-year event (22.8/25.0) x 27,540 = 25,116 cf; and
100-year event (25.0/25.0) x 27,540 = 27,540 cf.

12.6 Graphical Flow Routing (Preferred Method for Determining the Storage Requirement from a Drainage Area Between 10 and 640 Acres)

The graphical method presented herein was developed by the Soil Conservation Service and is found in Chapter 7 of the Urban Hydrology for Small Watersheds, Technical Release Na. 5 5. It is based on average storage and routing effects using the storage-indication method of routing. The graphs relate inflow (Q_i) and release rate (Q_0) to storage requirements for single or multiple stage outlet structures. Emergency spillway flow (overflow) is not considered in this method.

Use of this graph will result in rough approximation since this method is based on several general assumptions and the procedure may significantly overestimate the required storage requirements. The results of the Graphical Flow Routing method should be interpreted accordingly.

For any application where the graphical method is not appropriate, a more accurate flow routing method, such as the storage indication method, is needed to determine storage requirements.

The following summarizes general procedures for the determination of storage capacity using the graphical flow routing method.

Step l. Determine the past-development volume of runoff (Vr), the peak inflow discharge (Q_i), and the peak outflow discharge (Q_o) for the 2-, 10-, 25-, and 100-year frequency events using the graphical peak discharge method. Normally the peak inflow discharge equals the post-development peak discharge and the peak outflow discharge equals the predevelopment peak discharge.

Step 2. Calculate the ratio of peak outflow discharge to the peak inflow discharge (Q_o /Q_i) for the 2-, 10-, 25-, and 100-year frequency events.

Step 3. Use Exhibit XII-1 and determine the ratio of storage volume to the post-development volume of runoff (V_s/V_r) for each event in Step 2.

Step 4. Calculate the required storage volume (V_s) $V_s = V_r$ x (V_s/V_r). The required storage volume (V_s) is expressed in the same units as the post-development volume of runoff (V_r). If V_r is expressed in inches of runoff, the conversion to acre feet is: multiply V_r times 53.33 (the conversion factor from inches per square mile to acre feet) times drainage area in square miles. To convert acre feet to cubic feet, multiply V_r expressed in acre feet times 43,560 (the conversion factor from acre feet to cubic feet).

Step 5. Check that for each frequency event the outflow structure releases the desired rate of outflow at the corresponding storage elevation. This can be done by constructing a stage-discharge and stage-storage relationship for the outlet structure. To be a satisfactory design, the stage of each frequency event should result in a release rate that is equal to or less than the desired rate of outflow which would result in the actual storage being equal to or greater than the required storage.

Step 6. Design the detention/retention basin according to the design criteria given in this chapter.

12.7 Critical Storm

The critical storm is determine so that the peak rate of runoff from the storms more frequent than the critical storm will be further controlled. The general procedure for determining the critical storm is as follows:

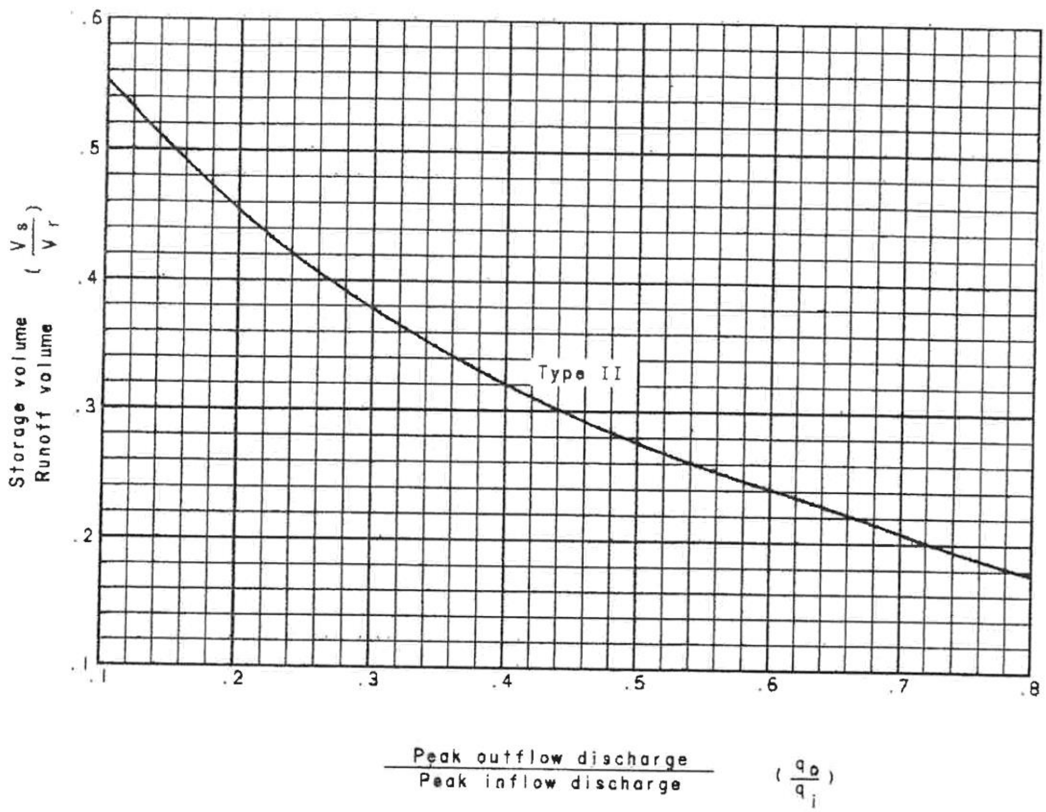
Step 1. Determine the predevelopment and post-development runoff volume for the 1-year frequency, 24-hour event.

Step 2. Calculate the percentage of increase in runoff volume by dividing the post-development runoff volume by the predevelopment runoff volume.

Step 3. Determine the critical storm from the following table:

Percentage of Increase in Runoff Volume	Critical Storm in years
0 to >10	1
≤ 10 to >20	2
≤ 20 to >50	5
≤ 50 to >100	10
≤ 100 to >250	50
≤ 250 to >500	100
≤500	

Step 4. The peak rate of runoff for both the critical storm and all storms more frequent than the critical storm shall not exceed the peak rate of runoff from a 1-year predevelopment storm. The peak rate of runoff from the area after the development for storms of less frequent occurrence than the critical storm shall not exceed the predevelopment peak rate of runoff for the same frequency storm before development.



APPROXIMATE DETENTION BASIN ROUTING

Exhibit XII-1

CHAPTER l3. EROSION AND SEDIMENTATION CONTROL

13.l Sediment Control

Sediment basins are barriers or dams constructed across a waterway or at another suitable location to intercept sediment-laden runoff and to retain a portion of the sediment. Sediment basins are used at the downstream end of a construction site which exposes soil for potential erosion to protect the downstream drainage system and properties from sediment deposition.

Sediment control measures shall generally conform to the following design criteria:

l. For drainage areas less than 5 acres, straw bale ditch checks shall be installed, if needed, as per Exhibit XIII-1 and shall have small pits excavated behind them. These ditch checks shall generally be located at changes in grade and other critical locations. Ditch checks shall be spaced so that no check is within the backwater of a downstream check.

2. For drainage areas from 5 through 20 acres, sediment basins or dams shall be constructed in accordance with the U.S. Soil Conservation Service handbook Water Management and Sediment control for Urbanizing Areas. The sediment basins or dams shall provide a minimum of 67 cubic yards of storage for each acre of contributing area.

3. For drainage areas larger than 20 acres for which off-site drainage cannot be diverted around the project area, the channel bed and banks shall be shaped and stabilized with temporary or permanent lining and a straw bale dike constructed along the banks to intercept runoff and filter out sediment. Where the project area does not drain directly into a channel, a straw bale dike shall be constructed at the edge of the construction site.

Details of the sediment basin design and construction shall be submitted for approval and shall contain the following:

1. Specific location of the basin.
2. Plan view of the dam, storage basin, and emergency spillway.
3. Cross-section of the dam principal and emergency spillways, and a profile of the emergency spillway.
4. Details of pipe connections, riser to pipe connections, riser bases, anti-seep collars, trash racks, and anti-vortex devices.
5. Runoff calculations for the 2-, 10-, and 25-year storms.
6. Storage calculations showing the total storage required, total storage available, and the level of sediment at which cleanout shall be required.
7. Calculations showing the design of the pipe and the emergency spillway.

13. 2 Long-Term Erosion and Sedimentation Control

When long-term erosion and sedimentation problems are anticipated, the City Engineer shall require that measures be taken to control the situation and such measures may include:

l. Design, construct, and maintain concentrated water flow channels such that the velocity of the flow does not exceed the permissible velocities listed elsewhere in this manual; or,

2. Design, construct, and maintain sediment basins sized in accordance with the United States Soil Conservation Service handbook, Water Management and Sediment Control for Urbanizing Areas; or

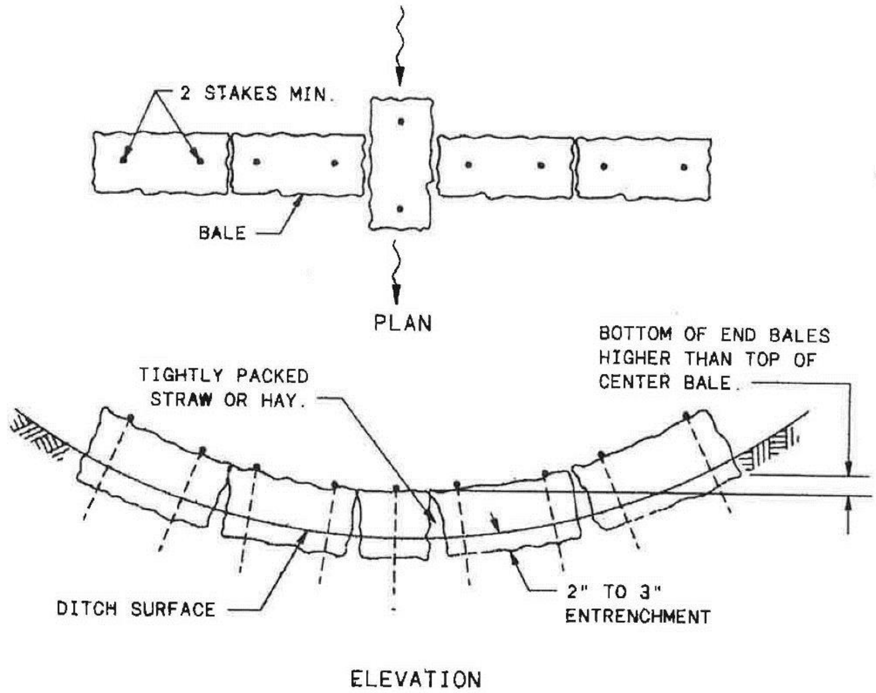
3. Use other methods to control sediment pollution; this may include, but is not limited to a combination of paragraphs (1) and (2) of this standard, provided those methods are acceptable to the City.

13.3 Control of Sloughing, Landsliding, and Dumping

To control sediment pollution of public water caused by sloughing, landsliding, or dumping of earth material, or piecing of earth material into such proximity that it may readily slough, slide, or erode into public waters by natural forces, no person shall:

l. Dump or place earth material into public water or into such proximity that it may readily slough, slide, or erode into public water unless such dumping or placing is authorized by the approving agency for such purposes as, but not limited to, constructing bridges, culverts, erosion control structures, and other in-stream or channel bank improvement works; or

2. Grade, excavate, fill, or impose a load upon any soil or slope known to be prone to slipping or landsliding, thereby causing it to become unstable, unless qualified engineering assistance has been employed to explore the stability problems and made recommendations to correct, eliminate, or adequately address the problems. Grading, excavating, filling, or construction shell commence only after the utility has reviewed and approved the exploratory work and recommendations and the work shall be done in accordance with the approved recommendations.



BALE PLACEMENT:

BALES SHALL BE TIGHTLY PLACED, ADJACENTLY, AND ENTRENCHED 2" TO 3" BEFORE STAKING.

EACH BALE SHALL BE FIRMLY STAKED WITH A MINIMUM OF 2 STAKES AT LEAST 3' IN LENGTH. STAKES SHALL BE WOODEN 2"x2", REINFORCING BARS OR FENCE POSTS.

LOOSE STRAW OR HAY SHALL BE SCATTERED FOR A DISTANCE OF 10' ON THE UPSTREAM SIDE OF EACH DITCH CHECK, AND SHALL BE WEDGED BETWEEN AND UNDER STAKED BALES.

STRAW BALE DITCH CHECKS

Exhibit XIII-1