Stormwater Management Rules and Regulations

Part 1

Technical Reference Manual

CITY OF CINCINNATI
DEPARTMENT OF PUBLIC WORKS
DIVISION OF STORMWATER MANAGEMENT UTILITY

STORMWATER MANAGEMENT
RULES AND REGULATIONS

PART 1
TECHNICAL REFERENCE MANUAL

JUNE 1989

Prepared by

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PREAMBLE

The purpose of Chapter 720-STORMWATER MANAGEMENT CODE is to provide for effective management and financing 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 authorize the establishment and implementation of a master plan for storm drainage including design, coordination, construction, management, operation, maintenance, inspection, and enforcement; to establish reasonable storm drainage service charges based on each property's contribution of stormwater runoff to the system and use of the services and facilities; 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 Chapter 720, 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 Utility Engineer in accordance with Section 720-23 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 chapter.

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

(4) To facilitate the enforcement of this chapter.

(5) To prescribe the collection procedures and timing of service charge bills.

(6) 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.

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

The Rules and Regulations promulgated in accordance with Section 720-23 are divided into two parts:

Part 1: Technical Reference Manual
Part 2: Stormwater Management Design Manual

Neither submission of a plan under provisions of the Rules and Regulations promulgated in accordance with Section 720-23 nor compliance with provisions of the Rules and Regulations promulgated in accordance with Section 720-23 shall 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.

Certain information in the Technical Reference Manual and Stormwater Management Design Manual was taken from public documents and reproduced. The City does not take responsibility for the accuracy of this information.

RECOMMENDED:

T. A. Stitt, P.E.
City Stormwater Engineer

George Rowe, P.E.
Director of Public Works

Thomas A. Saygers, P.E.
Director of Sewers

R. A. Castellini
City Solicitor

The following Stormwater Management Rules and Regulations are hereby approved and made effective July 3, 1989.

Scott Johnson
City Manager

In order to maintain consistency between the Stormwater Management Design Manual and the Technical Reference Manual (condensed version of the Stormwater Management Design Manual), all articles, figures, tables, and exhibits have the same number. The Table of Contents is the same in both manuals, but only the items with an asterisk are found in the Technical Reference Manual.

All forms are included in both manuals. Under the form number on each form is the article number that explains the use and description of that form.

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CHAPTER 1. INTRODUCTION

1.1 General

In August of 1984, the Council of the City of Cincinnati enacted City Ordinance 330-84 which was later codified in the Cincinnati Municipal Code as Chapter 720, Stormwater Management Code. This chapter established the Stormwater Management Utility (Utility) and provided for the creation of a comprehensive drainage code and other regulations necessary to commence the operation of the Utility.

Created as a division of the Department of Public Works (Department), the Utility shall be administered by the Utility Engineer under the supervision of the director of the Department. In general, the Utility shall be 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 provision and use of such facilities and associated services; and enforcing the provisions of this code. It shall not be responsible for sanitary or combined sewers; subsurface 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 Utility Engineer for review and approval. The Utility must approve before hand any construction, alteration, or change in any watercourse.

The purpose of the drainage code is to provide organization and direction for mitigating the damaging effects of stormwater runoff in the City of Cincinnati.

In order to enforce the requirements of the drainage code, the Utility Engineer may inspect construction premises and notify owners when the work does not comply with the code or the approved plans. When permitted by the code, the Utility Engineer may issue a stop work order, revoke a permit, or abate an emergency condition. Landowners with bona fide complaints may appeal these decisions or request a variance before a board of appeals.

In accordance with the authority given in the Code, the rules and regulations contained herein provide engineering tools for developing control policies and procedures whereby the policies can be followed.

These rules and regulations are supplemental to the Cincinnati Municipal Code including Chapters 720 and 1156. Compliance with these rules does not relieve Owners of compliance with all applicable codes and ordinances.

The rules and regulations portion 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 Utility insist on rigid adherence to a standard set of design specifications. As reflected in this portion, the emphasis should be on performance.

The rules and regulations provide a uniform design procedure and worksheets for summarizing and submitting the design plans in an acceptable and understandable manner to the Utility. 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.

These rules and regulations provide 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 Cincinnati.

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 these rules and regulations.** 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 drainageways 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. 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.

2.1 Control of Stormwater Runoff

These rules and regulations are 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 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 Class A and Class B property developments as defined in Section 720-55 of the Cincinnati Municipal Code in which the total number of contiguous developed **properties is less than four.** 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 on providing a detention facility, and the development work has begun prior to completion of the detention facility, the Utility Engineer is authorized to take such action as deemed necessary to ensure that the detention facility is completed.

If the work so initiated shall be a cause for emergency action, the Utility Engineer may take such action as described in Section 720-71 of the Cincinnati Municipal Code.

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 at the County Court House and a copy provided to the Utility 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 Cincinnati, it shall be the duty of the Utility 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 Cincinnati 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 2-, 10-, 25-, and 100-year frequency, 24-hour storm.

2.6 Multijurisdiction Activities

The City of Cincinnati is surrounded by a series of incorporated communities. The City and these communities are within the County of Hamilton and State of Ohio. 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 these rules and regulations is in conflict with other jurisdictions, the Utility 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 Cincinnati from adjoining incorporated or county watersheds, the Utility Engineer will request that new facilities in the adjoining body abide by the rules and regulations contained herein.

If necessary, the Utility Engineer will meet with the designer of these facilities and provide any appropriate assistance. When the City of Cincinnati contributes runoff to adjoining bodies, the City of Cincinnati facilities shall be designed and constructed in accordance with these rules and regulations.

2.7 National Flood Insurance Program

Various areas of the City of Cincinnati and Hamilton 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 defined by Chapter 1156 of the Cincinnati Municipal Code and is based on Flood Boundary and Floodway Maps prepared by the FEMA for the City of Cincinnati and Hamilton County. The maps for the City of Cincinnati are available for review at the Utility's office and the County maps are available at the County Engineer's office. Copies of the maps can be obtained from the National Flood Insurance Program, P.O. Box 34604, Bethesda, Maryland 20034 or by calling (800) 638-6620.

2.7.1 Flood Protection Within the Development

Finished floor elevations including basements shall be set a minimum of 1 foot above the 100-year water level computed within the development. For commercial or industrial developments, dry floodproofing may be substituted in lieu of elevating the finished floor. Chapter 1156 of the Cincinnati Municipal Code provides requriements and must be consulted.

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

All development within areas of special flood hazard, as defined by Chapter 1156 of the Cincinnati Municipal Code, or as determined by the Utility 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 floodproofing 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 of Cincinnati, Department of Public Works, Division of Engineering has prepared "Rules and Regulations" for subdivision designs. These rules and regulations shall be adhered to in the subdivision of land for private use and street developments.

The Utility 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 rules and regulations 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 Utility 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 Hamilton County by the County Clerk thereby satisfying any additional requirements imposed by the County Clerk. Once the easement has been properly prepared, it shall be submitted to the City of Cincinnati for acceptance and then recorded with the County Clerk.

DESCRIPTION OF EASEMENT

Metes and Bounds Description
or
Map Description

We, the undersigned grantors, in consideration of ____________________ ____________________ dollars ($____________) do hereby adopt and confirm this plat and grant unto the City of Cincinnati permanent easements as shown hereon for the construction, operation, and maintenance of a storm sewer and appurtenances thereto, together with the right-of-entry and subject to restrictions described hereon.

No structure of any kind which can interfere with access to said public sewer shall be placed in or upon a permanent sewer easement, excepting items such as recreational surfaces, paved areas for parking lots, driveways, or other surfaces used for ingress and egress, plants, trees, shrubbery, fences, landscaping, or other similar items being natural or artificial.

Any of the aforesaid surfaces, paved areas, plants, trees, shrubbery, fences, landscaping, or other similar items which may be placed upon such said permanent easement shall be so placed at the sole expense and risk of the property owner and the grantees or assigns of this permanent easement henceforth shall not be responsible to any present owners of the property, nor to their heirs, executors, administrators, or assigns, for the condition, damage to, or replacement of any such aforesaid items, or any other items placed upon the easement, resulting from the existence or use of the said permanent easement by the grantees or assigns.

The easement area and drainage facility will be maintained by ____________ ____________________.

Any structure constructed on grantor's property adjoining said permanent sewer easement exists shall be kept not less than 3 feet outside the permanent sewer easement line nearest the site of the proposed structure.

Any deviation from the aforesaid restrictions shall be petitioned by written request to the grantees or their assigns. Each such request shall be considered on an individual basis with approval not being unreasonably withheld.

We also grant unto the City of Cincinnati temporary easements for access and construction purposes as shown hereon.

WITNESSES	SIGNED
______________________________	______________________________
______________________________	______________________________
______________________________	______________________________
______________________________	______________________________

For Easement No. _______________

STATE OF OHIO
COUNTY OF HAMILTON

[Acknowledgement form for individuals, alternative form required for coporation or individuals]

The foregoing instrument was acknowledged before me this ______ day of ____________, 19__ by ____.
(names of grantors)

DEED REFERENCE

Property shown hereon was conveyed to ________________________________ by deed recorded in Deed Book _______, Page ____________, Hamilton County Recorder's Office.

CERTIFICATION BY CLERK

Date: _________________

I hereby certify that the storm sewer easement shown hereon was accepted by Ordinance No. ____________ passed by the Council of the City of Cincinnati, State of Ohio, on ____.

____
Clerk of Council

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 Utility. A National Pollutant Discharge Elimination System (NPDES) permit from the Ohio Environmental Protection Ageny (Ohio EPA) is required for all processed water. If approval is granted by the Ohio EPA and the Utility 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 15 feet from any stormwater facility. An exception to this may be aboveground 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 these Rules and Regulations.

2.15 Bonds

The City of Cincinnati 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 Utility Engineer.

CHAPTER 3. STORMWATER FACILITIES DESIGN PROCESS AND DRAINAGE REQUIREMENTS

3.1 General

The Utility Engineer has the authority to review all plans and issue a permit as described in Section 720-29 and related sections of the Cincinnati Municipal Code. The facility projects that require plans submitted to the Utility Engineer are described herein. The Utility Engineer is designated as the person who is responsible for the review of plans and specifications for all stormwater facilities and the issuing of permits. Various types of review by the Utility Engineer shall consist of, but not be limited to, the following.

A. Projects by the Utility 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 Utility outlining the work to be accomplished. As provided in Section 720-29 of the Cincinnati Municipal Code, the submittals for a permit to construct stormwater facilities may be made directly to the Utility or through the building permit process.

Where stormwater facilities are planned in connection with building projects, the permit for the stormwater facilities alone shall be a part of the building permit system. The building department shall submit the appropriate portions of the permit plans to the Utility for review and comment. Where a permit is to be granted for stormwater projects only, the permit shall be reviewed and granted by the Utility Engineer.

The developer, the person requesting a permit, or his engineer shall discuss the proposed stormwater plan, while still in sketch form, with the staff of the Utility 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 Utility.

3.2 Design Process for the City Utility Agencies

The City of Cincinnati 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 Utility or other agencies of the City.

The submittal of plans for public agencies outside the Utility but within the City, shall be as follows. Plans and specifications shall be submitted to the Utility along with calculations, drawings, and other supporting data with a memo describing the proposed work. The Utility Engineer shall examine the submittal in the same manner as described in Section 720-33 of the Cincinnati Municipal Code.

For stormwater facilities designed by other public bodies, such as the Ohio Department of Transportation (ODOT), the submittals shall be made in a similar fashion as above.

3.3 Design Process for Private Applicants

For the facilities being planned by individuals or private corporations, the submittal shall be as described in Section 720-31 of the Cincinnati Municipal Code. The following steps shall be followed.

Step I	The owner or his engineer shall submit a sketch or concept plan and meet with the Utility Engineer, if needed, for 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 a deposit for plan review in an amount determined by the Utility Engineer.
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 Utility 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 Utility Engineer.
Step VII	The Utility Engineer shall review the plans again and return his findings within 30 days.
Step VIII	A permit shall be issued. The final payment of review fees shall be made.

3.3.1 Fees

The Utility shall collect a fee or assessment for the following.

A. Storm drainage service (monthly) payable in City Treasurer's Office, Room 202, City Hall.

B. Permit and Inspection Fees, payable at the Utility office.

C. 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 Utility designs and/or constructs, or contracts for the construction of, such facilities.

D. 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.

E. Inspection and plan review. Fees for permits required by Section 720-29 of the Cincinnati Municipal Code as set forth in the rules and regulations 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 a permit 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 and combined 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 Utility Engineer of the City of Cincinnati.

The information included in the plans submitted for review to the Utility 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. (5-foot contour intervals). All elevations shall correlate to the United States Coast and Geodetic Survey datum unless waived by the Utility 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 Hamilton County).

M. Two, 10-, 25-, and 100-year flood elevations for any areas in or within 100 feet of the property. The source of these elevation statistics shall also be shown on the plans.

N. Description of current ground cover and/or land use.

O. Existing and proposed land use including appropriate areas 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 and shall include, but not be limited to, the following.

3.5.1 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 2-, 10-, 25-, 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.

O. 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 Utility 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 Utility 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 Utility 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 Utility before the acceptance of the improvements.

DEPARTMENT OF PUBLIC WORKS
DIVISION OF STORMWATER MANAGEMENT UTILITY
BUILDING PERMIT APPLICATION
SAMPLE

SITE PLAN CHECK LIST

Street and No.______________________ Bldg. Permit No.______________

Owner________________________ Address________________________

Information requested to be shown on the Site Plan

	Ind	No Ind
1. Engineers, Architects, or Surveyors Seal; Directional Arrow		
2. Title, Scale (Min. Scale: 1"=50'), Date, Vicinity Map, Benchmark		
3. Distance from intersecting street		
4. Existing and Proposed Contours or Elevations		
5. Existing and Proposed Builidng or Structures (with dimensions)		
6. Easements (SEWER)		
7. Location, Size, and Elevation of all existing sewers (Storm, Sanitary, Combined)		
8. Location of all proposed sewers, manholes, and inlets (size, length, and elevation of sewers and structures)		
9. Watercourses, Drainage Ditches (Natural or Manmade)		
10. Location of Downspouts, Leaders, and Storm Lateral		
11. Location of Tee Branch, with sea level elevation at connection		
12. Existing and Proposed Elevations at four corners of building		
13. Parking layout, with dimensions and driveways showing drainage and type of pavement and curbs		
14. Location of street sewers and inlets		
15. The geographical position of both the natural features and the works of man indicate areas to remain undisturbed		
16. Lot dimensions with bearings		
17. Lot area in square feet		
18. Street status (existing or proposed) (dedicated or private)		

SURVEY COMPLETE Yes_____ No_____ By______________________

DATE__________________________

REMARKS

____

____

____

____

Form T3-1

CITY OF CINCINNATI
STORMWATER MANAGEMENT UTILITY DIVISION
APPLICATION FOR A PERMIT TO CONSTRUCT STORMWATER FACILITIES

Permit No. ____________________

Project ____________________

Location ____________________

Address ____________________

Owner's Name ____________________

Address ____________________

Telephone Number ____________________

Application Submitted By ____________________

Address ____________________

Telephone Number ____________________

Brief Description of Proposed Work ____________________

____

____

Estimated Cost ____________________

Submittal:

- ☐ Concept Plans
- ☐ Plans
- ☐ Specifications
- ☐ Erosion Control Plan
- ☐ Calculations
- ☐ Maintenance Plan
- ☐ Easement
- ☐ Other ____________________
- ☐ Other ____________________

For Utiltiy Division Use

Approved ☐

Not Approved ☐

Date ____________________

Comments: ____________________

____

____

____

____

____

____

Reviewed By: ____________________

Estimated Plan Review Fee:

$ ____________________

Plan Review Fee:

$ ____________________

Amount to be returned/paid

$ ____________________

CITY OF CINCINNATI
STORMWATER MANAGEMENT UTILITY DIVISION

PLAN REVIEWER'S CONTACT MEMO

Permit No.______________________________

Project______________________________ Page No.__________

Location______________________________ Date__________

Item No.	Code Section	Description

Plans Not Approved ☐

______________________________ Date__________
Plan Reviewer's Signature

Signed Agreement:

Plans approved subject to acceptance of agreement by applicant to provide above noted items in compliance with the Stormwater Utility Division Code.

______________________________ Date__________
Applicant's Acceptance

______________________________ Date__________
Plan Reviewer's Signature

Form T3-3

CHAPTER 4. EPA: NPDES PERMIT REQUIREMENTS

This chapter is reserved for any necessary National Pollutant Discharge Elimination System permit requirement specifications and related information.

5.2 Rainfall Intensity-Duration-Frequency

A tabulation of rainfall intensities for the 2-, 10-, 25-, and 100-year recurrence intervals, and for durations ranging from 10 through 200 minutes, has been developed for Cincinnati and is shown in Exhibit V-2. 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.

5.3 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-2, locate a duration of 16.0 minutes, and read:
10-year rainfall intensity = 4.46 inches per hour
100-year rainfall intensity = 6.35 inches per hour

5.4 Rainfall Distribution by Time

Total rainfall amounts for Cincinnati 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: 1 Hour (Inches)	6 Hours (Inches)	12 Hours (Inches)	24 Hours (Inches)
1	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
50	2.71	3.90	4.44	5.28
100	3.00	4.32	4.92	5.76

DURA TION (MIN.)	RAINFALL INTENSITY (IN/HR) FOR RECURRENCE INTERVAL OF 2 YR	10 YR	25 YR	100 YR	DURA TION (MIN.)	RAINFALL INTENSITY (IN/HR) FOR RECURRENCE INTERVAL OF 2 YR	10 YR	25 YR	100 YR
10.0	4.08	5.45	6.30	7.69	36.0	1.98	2.83	3.36	4.17
10.5	4.00	5.38	6.15	7.50	38.0	1.90	2.74	3.23	4.02
11.0	3.92	5.26	6.02	7.39	40.0	1.82	2.66	3.14	3.92
11.5	3.83	5.18	5.95	7.23	42.0	1.77	2.57	3.02	3.79
12.0	3.77	5.08	5.84	7.17	44.0	1.72	2.50	2.95	3.68
12.5	3.70	5.00	5.75	7.00	46.0	1.67	2.42	2.87	3.58
13.0	3.63	4.94	5.65	6.92	48.0	1.62	2.36	2.80	3.46
13.5	3.57	4.83	5.58	6.80	50.0	1.56	2.30	2.72	3.39
14.0	3.50	4.78	5.48	6.70	52.0	1.51	2.24	2.66	3.30
14.5	3.45	4.68	5.40	6.60	54.0	1.47	2.20	2.59	3.21
15.0	3.40	4.60	5.35	6.50	56.0	1.42	2.13	2.52	3.13
15.5	3.35	4.53	5.24	6.40	58.0	1.39	2.08	2.48	3.03
16.0	3.30	4.46	5.18	6.35	60.0	1.36	2.03	2.42	3.00
16.5	3.23	4.40	5.10	6.27	65.0	1.29	1.92	2.28	2.80
17.0	3.17	4.35	5.02	6.20	70.0	1.22	1.82	2.16	2.65
17.5	3.10	4.26	4.97	6.08	75.0	1.16	1.74	2.04	2.52
18.0	3.05	4.21	4.90	6.00	80.0	1.10	1.67	1.96	2.40
18.5	3.01	4.16	4.82	5.95	85.0	1.05	1.59	1.88	2.29
19.0	2.98	4.09	4.77	5.86	90.0	1.00	1.52	1.79	2.20
19.5	2.95	4.02	4.72	5.78	95.0	0.97	1.47	1.71	2.10
20.0	2.89	4.00	4.64	5.73	100.0	0.93	1.40	1.65	2.01
21.0	2.82	3.89	4.54	5.58	110.0	0.86	1.31	1.52	1.88
22.0	2.75	3.80	4.42	5.45	120.0	0.81	1.22	1.43	1.75
23.0	2.67	3.70	4.33	5.34	130.0	0.76	1.15	1.33	1.65
24.0	2.59	3.60	4.22	5.21	140.0	0.72	1.09	1.27	1.55
25.0	2.52	3.53	4.14	5.08	150.0	0.68	1.02	1.20	1.47
26.0	2.46	3.44	4.02	5.00	160.0	0.65	0.98	1.13	1.40
27.0	2.40	3.38	3.97	4.90	170.0	0.62	0.94	1.08	1.33
28.0	2.33	3.28	3.86	4.80	180.0	0.60	0.89	1.02	1.27
29.0	2.28	3.22	3.80	4.72	190.0	0.57	0.85	0.99	1.21
30.0	2.22	3.15	3.73	4.61	200.0	0.55	0.82	0.95	1.17
32.0	2.14	3.03	3.59	4.44					
34.0	2.05	2.93	3.45	4.29					

DESIGN RAINFALL INTENSITIES

EXHIBIT V-2

6.2 Peak Flow: Rational Method (Preferred Method for Determining the Peak Rate of Runoff for Drainage Areas less than 10 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.

6.2.1 Adopted Runoff Coefficients

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

The runoff coefficients used in the Rational Method differ from the intensity of development factor used in the monthly storm drainage service charge (SDSC). This is because the "rational method" runoff coefficient is used to estimate the total amount of runoff from an individual parcel of land and whereas the intensity of development factor (IDF) is the assignment of numerical values to various land uses, and the applications of standard land uses to individual properties based on random sampling of similar land uses under typical conditions for the purpose of computing the City's SDSC.

It is not contended that the land use assignment and associated IDF is identical with the rational method coefficient of each, but rather that the assigned IDF values appropriately reflect the differences among various classes of users of the stormwater systems and represent an equitable basis in determining the SDSC.

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

6.2.3 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.

6.2.4 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 may be estimated from chart (Exhibit VI-4). The time of flow in natural channels and open or closed channels may be estimated by applying the Manning Formula (Exhibit VI-10).

6.2.6 Example - Rational Method Number 2 (Simplified)

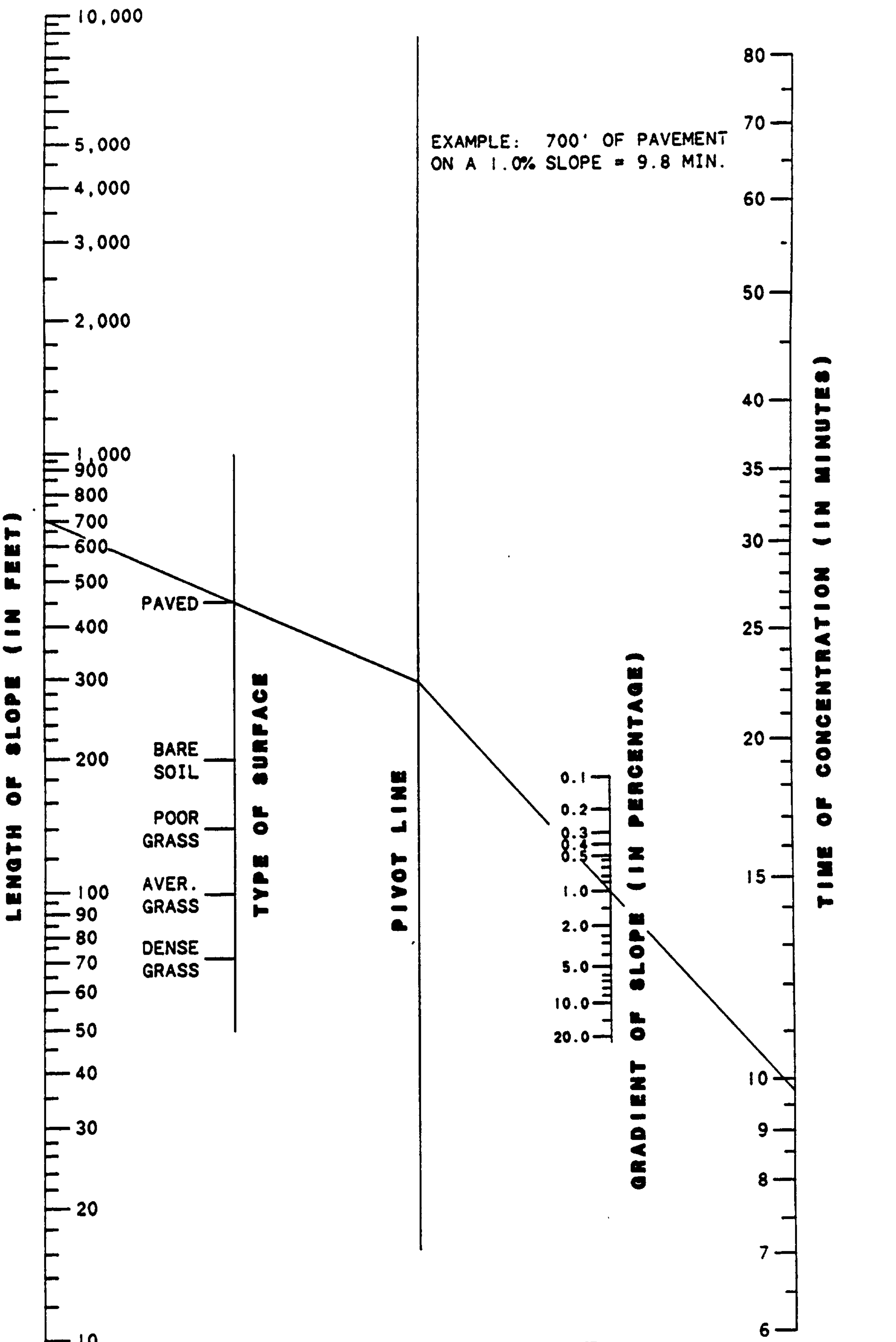
Determine the 10-year discharge from a 10-acre watershed assuming a runoff coefficient of 0.3 and a time of concentration of 12.0 minutes.

Step 1. Use Exhibit V-2, 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).

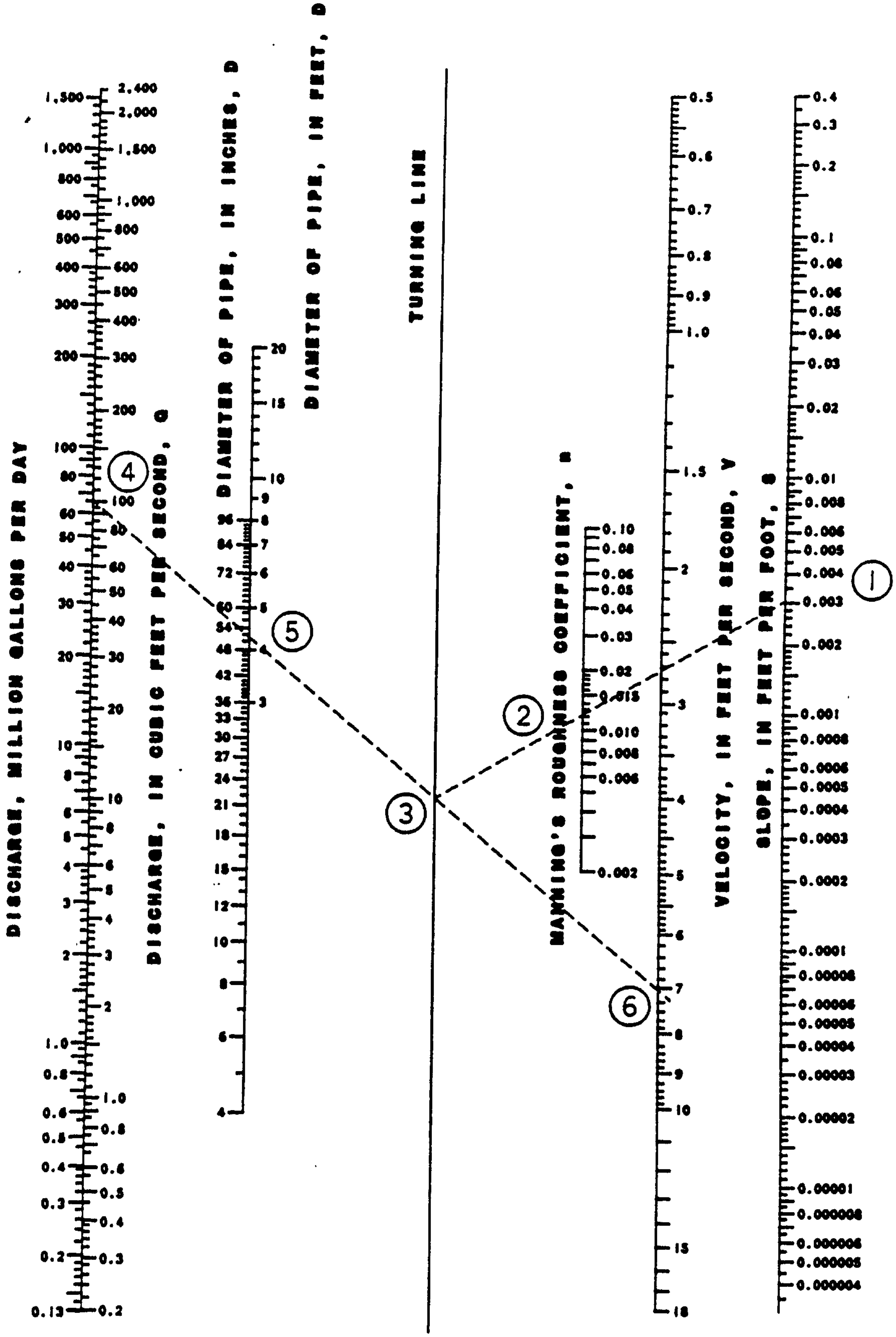
6.4 Hydrograph Methods

For areas between 10 and 200 acres, the preferred hydrograph method of calculation is the Soil Conservation Service, Technical Release No. 55 Graphical Peak Discharge method. For areas greater than 200 acres, the preferred hydrograph method of calculation is the Soil Conservation Service, Technical Release No. 20 method. For more detailed information, see Article 6.4 in the Stormwater Management Design Manual.



OVERLAND FLOW TIME

EXHIBIT VI-4



NOMOGRAPH FOR SOLUTION OF THE MANNING FORMULA

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

EXHIBIT VI-10

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 Exhibit XI-3	Land Use Description Include Treatment, Practice & Condition Exhibit XI-5	CN Exhibit (3) VI-5	CN Exhibit (3) VI-17	% of Area (acres) (4)	Product (3) x (4) (5)
			Totals =		

CN (weighted) = $\frac{\text{total col. (5)}}{\text{total col. (4)}}$ [__________] = __________ ; 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) $Ia = 0.2 \left[\frac{1000}{\text{weighted CN}} - 10\right]$				
4)	(Ia) / (P)				
5)	Unit Peak Discharge Use TC, Ia/P, and Exhibit XI-8				CFS/Square Mile-inch
6)	Runoff Depth (Q) Use P, CN, and Exhibit XI-6				inches
7)	Ponding and Swampy Area Adjustment Factor Use % PND, and Exhibit XI-11				
8)	Adjusted Peak Discharge (q_p) 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

FORM T6-1
(6.4.1.1)

7.1.3 Selection of Shape

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.

7.2.1 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. Major channels are the following streams: Ohio River, Little Miami River, Mill Creek, Mill Creek-East Fork, Mill Creek-West Fork, Duck Creek, Muddy Creek, West Fork, Clough Creek, Congress Run, and Amberley Creek.

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 50- and 100-year frequency storms 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 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, 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 1.00 percent for grass or sod lined channels.

7.4 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: $V = (1.49\ r^{2/3}\ S^{1/2})/(n)$, 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.

7.4.1 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 helpful. 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.

7.4.3 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.

7.4.6 Summary of Design Procedures

The following summarizes general procedures for the design of open channels using the formatted form T7-1.

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

Step 2. Quantify value of $Ar^{2/3}$ for Discharge (Q) and Velocity (V), column 5: $Ar^{2/3} = (nQ)/(1.49 \; S^{1/2})$

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

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) $\leq V_{max}$ (column 12), continue; if not, choose a different n or S and restart at Step 1, or choose a different channel cross-section and restart at Step 4.

Step 9. Calculate Z for critical flow $Z = Q/\ g^{1/2}$ (column 13).

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

Step 11. Using Exhibit VII-5, find d_c/b (column 15).

Step 12. Multiply $d_c/b \times b$ to get d_c (column 16).

Step 13. 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 (Vc) > column 11 (v) flow is subcritical

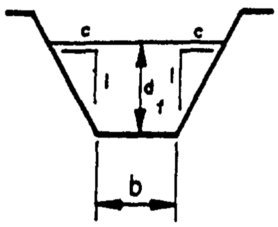
If column 16 (d_c) > column 8 (d_f)
and column 17 (Vc) < column 11 (v) flow is supercritical

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 $\geq d_c$.



$$Ar^{2/3} = \frac{n\ Q}{1.49\sqrt{s}} \qquad r = A/wp$$

d_f	b=2, c=2		b=2, c=3		b=2, c=4		b=3, c=2	
	$Ar^{2/3}$	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
1.0	2.90	4.00	3.56	5.00	4.21	6.00	3.83	5.00
1.1	3.53	4.62	4.38	5.83	5.21	7.04	4.60	5.72
1.2	4.23	5.28	5.30	6.72	6.35	8.16	5.47	6.48
1.3	5.00	5.98	6.33	7.67	7.63	9.36	6.41	7.28
1.4	5.86	6.72	7.48	8.68	9.06	10.64	7.44	8.12
1.5	6.79	7.50	8.74	9.75	10.64	12.00	8.56	9.00
1.6	7.81	8.32	10.13	10.88	12.38	13.44	9.77	9.92
1.7	8.91	9.18	11.64	12.07	14.29	14.96	11.07	10.88
1.8	10.10	10.08	13.28	13.32	16.37	16.56	12.47	11.88
1.9	11.38	11.02	15.05	14.63	18.36	18.24	13.97	12.92
2.0	12.76	12.00	16.97	16.00	21.07	20.00	15.56	14.00
2.1	14.23	13.02	19.03	17.43	23.70	21.84	17.27	15.12
2.2	15.81	14.08	21.23	18.92	26.53	23.76	19.07	16.28
2.3	17.48	15.18	23.59	20.47	29.55	25.76	20.99	17.48
2.4	19.26	16.32	26.10	22.08	32.78	27.84	23.01	18.72
2.5	21.14	17.50	28.77	23.75	36.22	30.00	25.15	20.00
2.6	23.13	18.72	31.61	25.48	39.87	32.24	27.41	21.32
2.7	25.24	19.98	34.61	27.27	43.75	34.56	29.78	22.68
2.8	27.45	21.28	37.78	29.12	47.85	36.96	32.27	24.08
2.9	29.79	22.62	41.21	31.03	52.10	39.44	34.88	25.52
3.0	32.24	24.00	44.64	38.00	56.75	42.00	37.62	27.00

TRAPEZOIDAL CHANNELS HYDRAULIC CHARACTERISTICS

TABLE 7-1

Step 16. Compute the anticipated depth of flow in the design channel for the 50and 100-year frequency storm.

7.4.8 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 (Vmax = 4), and a 10-year discharge of 15 cfs (Q = 15).

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

Step 2. Compute $Ar^{2/3} = (nq)/(1.49\ S^{1/2}) = (0.025 \times 15)/(1.49 \times 0.020^{1/2}) = 1.78$

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 $Ar^{2/3} = 1.78$ 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
0.95	0.5
4.21	1.0

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

A	d_f
2.00	0.5
6.00	1.0

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

Use largest d_f of 0.89 versus 0.67.

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-5 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.

$$d_f = 0.89 \quad > \quad d_c = 0.76$$

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

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

7.6 Floodway Delineation and Regulation

The Federal Emergency Management Agency (FEMA) has published a Flood Insurance Study for the City of Cincinnati dated April 15, 1982. This study contains Flood Boundary and Floodway Maps showing the Regulatory Floodway Areas of special flood hazards, profiles of water surface elevations for the 10-, 50-, 100-, and 500-year floods along the Ohio River, Little Miami River, Muddy Creek, Mill Creek, Mill Creek-East Fork, Mill Creek-West Fork, West Fork, Clough Creek, Duck Creek, and Congress Run. Where such data exists, it should be utilized to provide floodway limits and control elevations in storm water facility design.

The designer is referred to Title XI of the Cincinnati Municipal Code, the Cincinnati-Ohio Basic Building Code: Chapter 1156 - Floodplain Management for additional information.

EXHIBIT VII-1

OPEN CHANNEL SYMBOLS, EQUATION, AND GEOMETRIC FORMULA

SYMBOLS

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 surface in a channel
V	fps	Mean velocity of flow
Vc	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

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

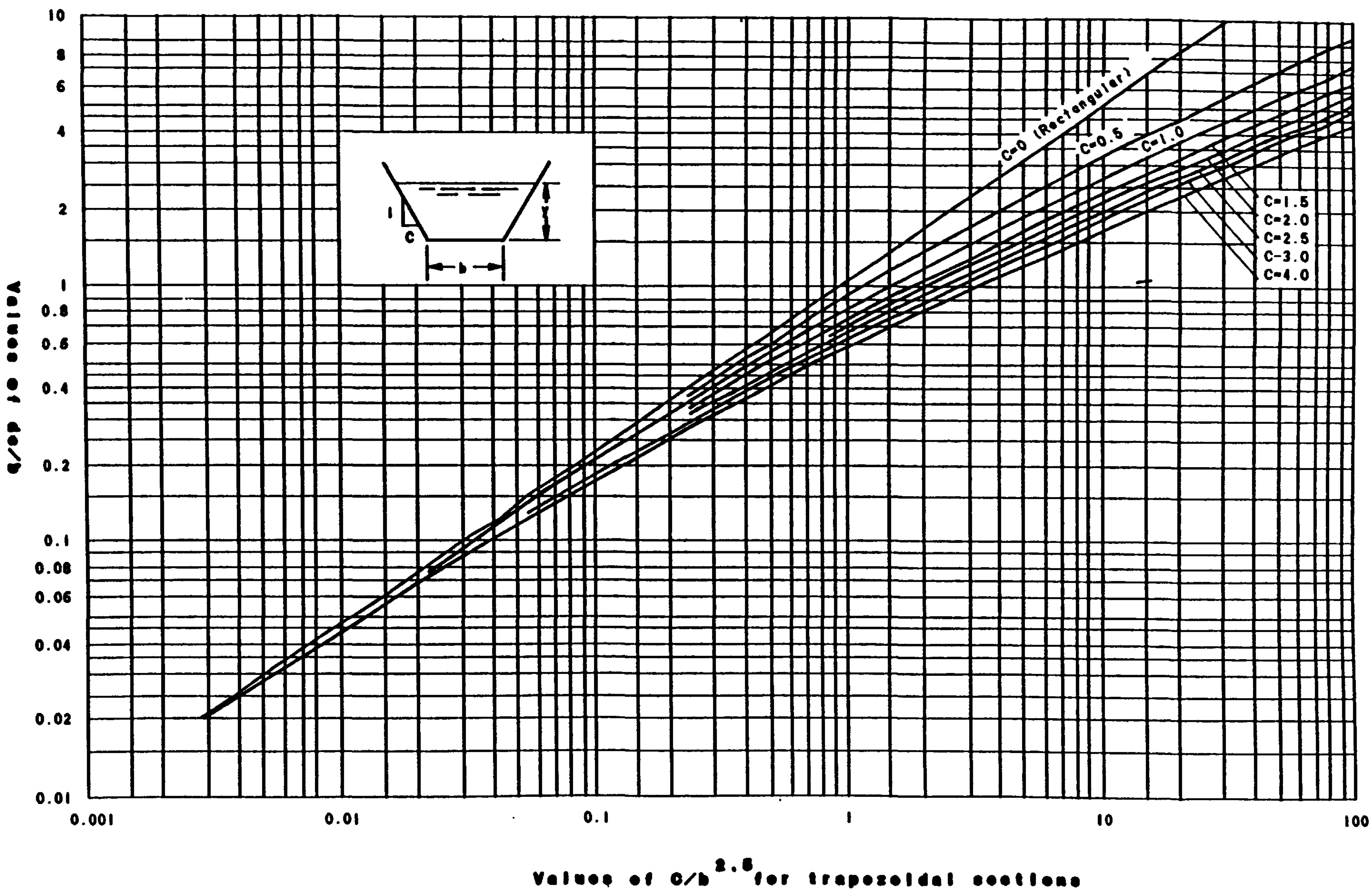
Geometric Formula

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

EXHIBIT VII-2

MANNING ROUGHNESS COEFFICIENTS

I. Open Channels Lined (Straight Alignment)	
A. Concrete	0.015
B. Concrete, bottom, sides, as indicated	
1. Stone in mortar	0.020
2. Riprap	0.025
C. Gravel bottom, sides as indicated	
1. Concrete	0.020
2. Riprap	0.028
D. Brick	0.017
E. Asphalt	0.015
II. Open Channels, Excavated (Straight Alignment, Natural Lining)	
A. Earth, fairly uniform section	
1. Grass, some weeds	0.025
2. Dense weeds	0.035
3. Sides clean, gravel bottom	0.030
B. Rock	
1. 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 uncut	
1. 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-5

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
(7.4.6)

8.2 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.

8.2.1 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 50- and 100-year water surface elevations for all streets and inlets shall be shown.

8.2.2 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.

8.2.3 Gutter Inlets: Continuous Grade

Gutter inlets shall be according to City of Cincinnati standard drawings Accession No. 49011 through 49015 and shall have a local depression of 3/4 inch below the normal gutter flow line. For calculations the following values shall be used:

	Single Gutter Inlet	Double Gutter Inlet
local depression (a)	3/4 inch = 0.0625 feet	3/4 inch = 0.0625 feet
width of grate	1.4 feet	1.4 feet
length of grate (L)	2.5 feet	5.0 feet
perimeter of grate (P)	4.6 feet	6.9 feet
total clear opening area of grate (A)	1.6 square feet	3.3 square feet

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.

8.2.4 Combination Inlets: 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 be City of Cincinnati standard drawings Accession Nos. 49016 through 49018 and shall have a local depression of 3/4 inches below the gutter flow line. For calculations the following values shall be used:

	Combination Inlet
local depression (a)	3/4 inch = 0.0625 feet
width of grate	1.4 feet
length of grate (L)	5.0 feet
perimeter of grate (P)	6.9 feet
total clear opening area of grate (A)	3.3 square feet

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 low 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.

8.2.5 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.

8.2.6 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 1.00 percent for grass or sod lined channels and 0.50 percent for paved or lined channels.

8.3 General Design Procedures

A generalized design approach to inlet spacing is as follows:

Step 1. 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 VIII-2). As a general rule, the carryover flow 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.

8.3.1 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 feet 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 VIII-1. The nomograph may be used for all gutter configurations.

8.3.2 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 flow 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-2 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-2 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.

8.3.3 Example - Capacity of a Grate Inlet on Continuous Grade

Find the discharge intercepted by the grate inlet of a City of Cincinnati single gutter inlet, Accession Nos. 49011, 49012, and 49015, 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 VIII-1 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 flow (Qa') outside of the grate width = spread - width of grate = 6 - 1.4 = 4.6 ft. Depth (d') = width x cross slope = 4.6 x 0.025 = 0.115 ft. Use Exhibit VIII-1 with S = 0.03 ft/ft d' = 0.115 feet and Z/n = 2667. 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 - flow outside of grate).

Step 5a. Use Exhibit VIII-2 Chart A with d' = 0.115 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-2 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/Qa) x 100 = (0.92/1.5) x 100 = 61

Step 9. Check that intercept flow picks up 85 percent of flow in gutter. (1.5)(0.85) = 1.28 cfs > 0.92 cfs. Therefore, change location of inlet or try a double gutter inlet.

8.3.4 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 1. 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 from 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-4 with the values of Q/P and Q/A and read 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 to 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.

8.3.5 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 VIII-1.

Step 4. Enter Chart A of Exhibit VIII-2 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 VIII-2 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, $Q = Q/Q_a \times Q_a$.

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

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

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

8.3.6 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 VIII-3) as follows:

Step 1. 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.

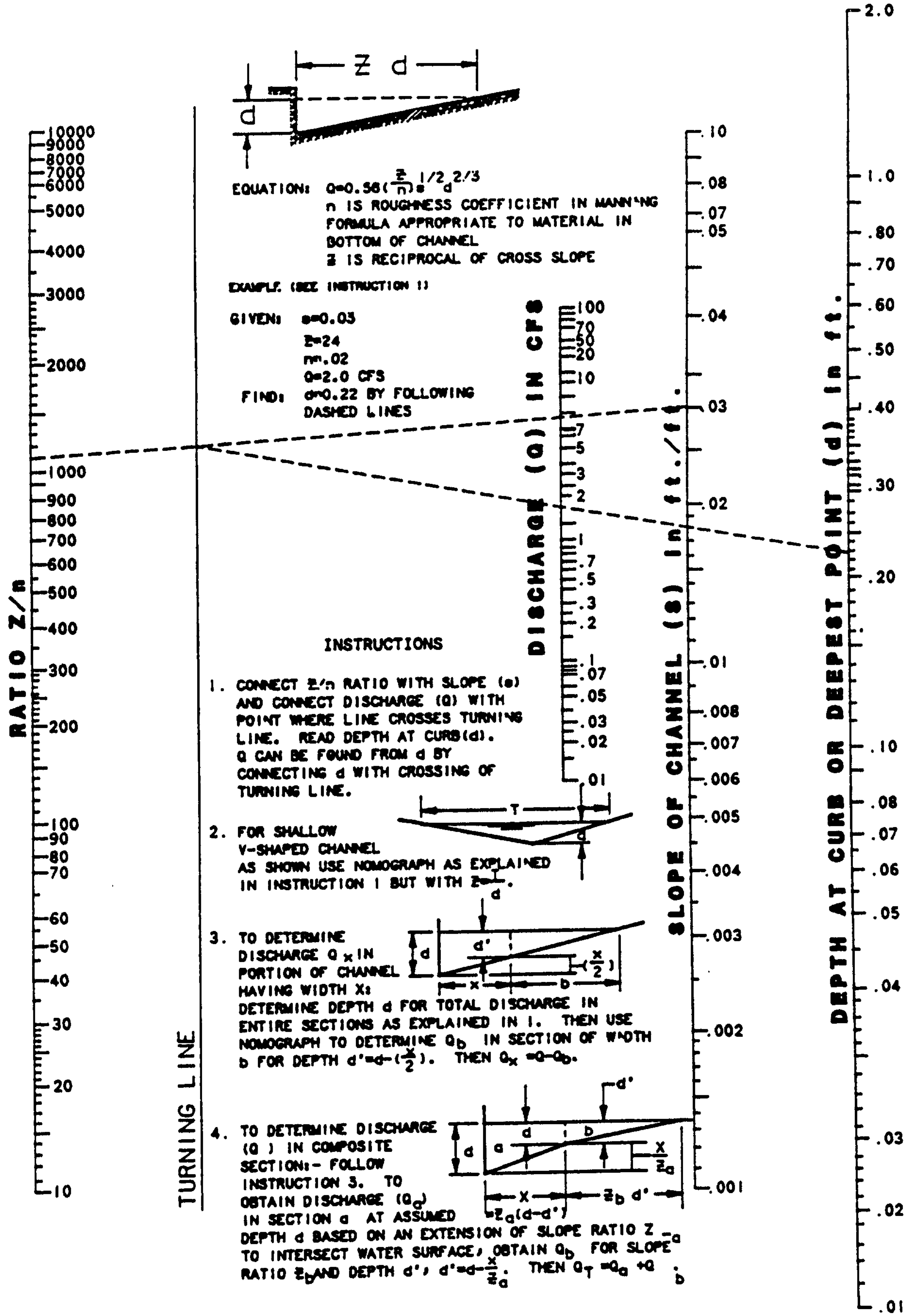
Step 4. Determine the ratio of ponded water depth (H) to vertical curb opening height (h), H/h, using Exhibit VIII-3.

Step 5. Calculate the ponded water depth, $H = H/h \times h$ (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 the design are necessary.



NOMOGRAPH FOR FLOW IN TRIANGULAR CHANNELS

EXHIBIT VIII-1

CHART A

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

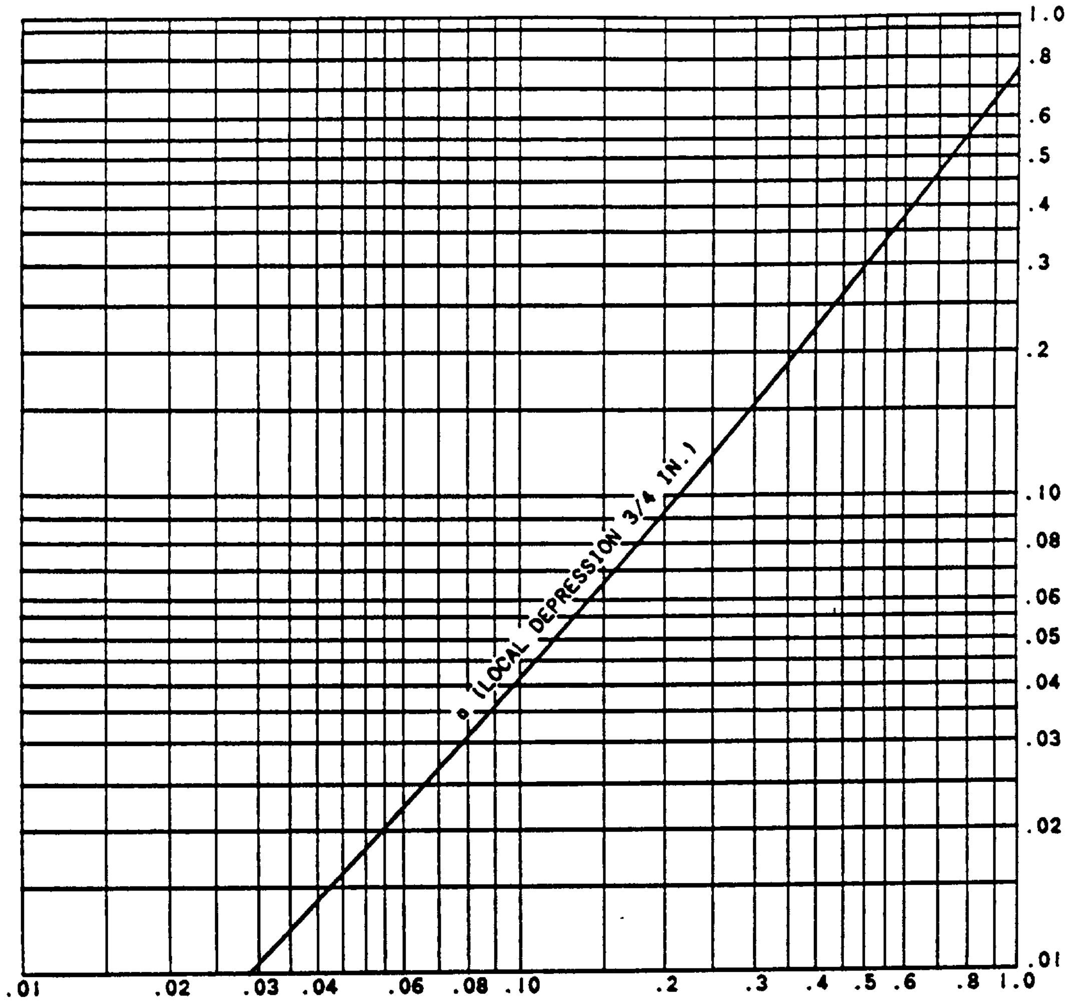
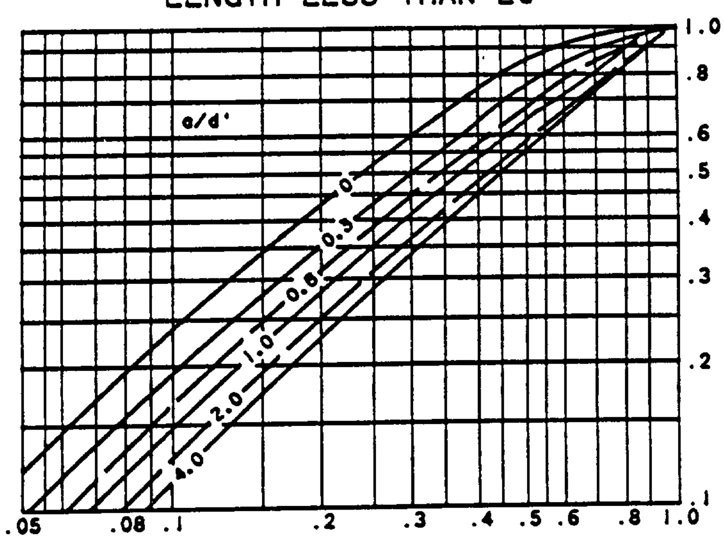


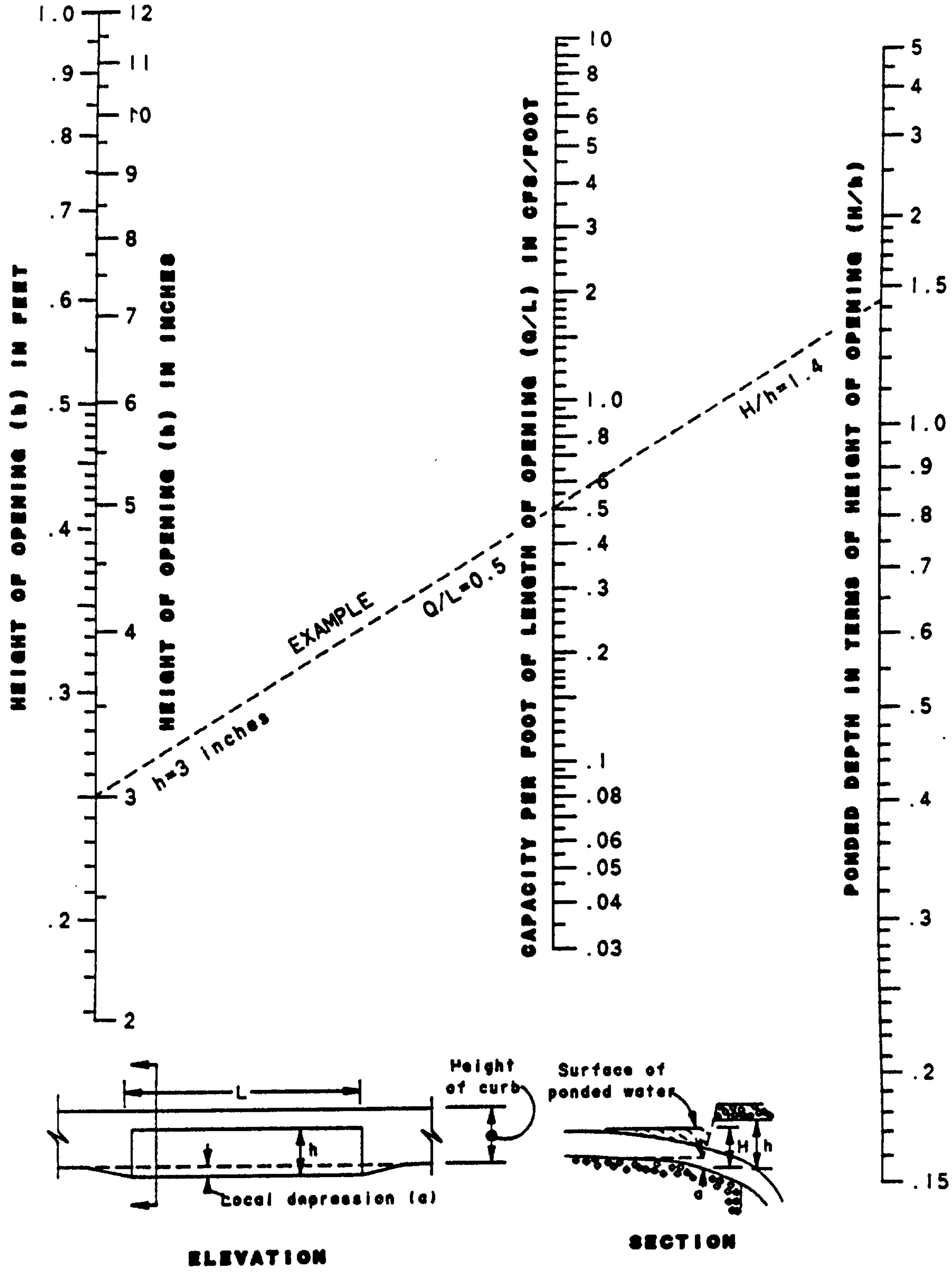
CHART B

PARTIAL INTERCEPTION RATIO FOR INLETS OF LENGTH LESS THAN La



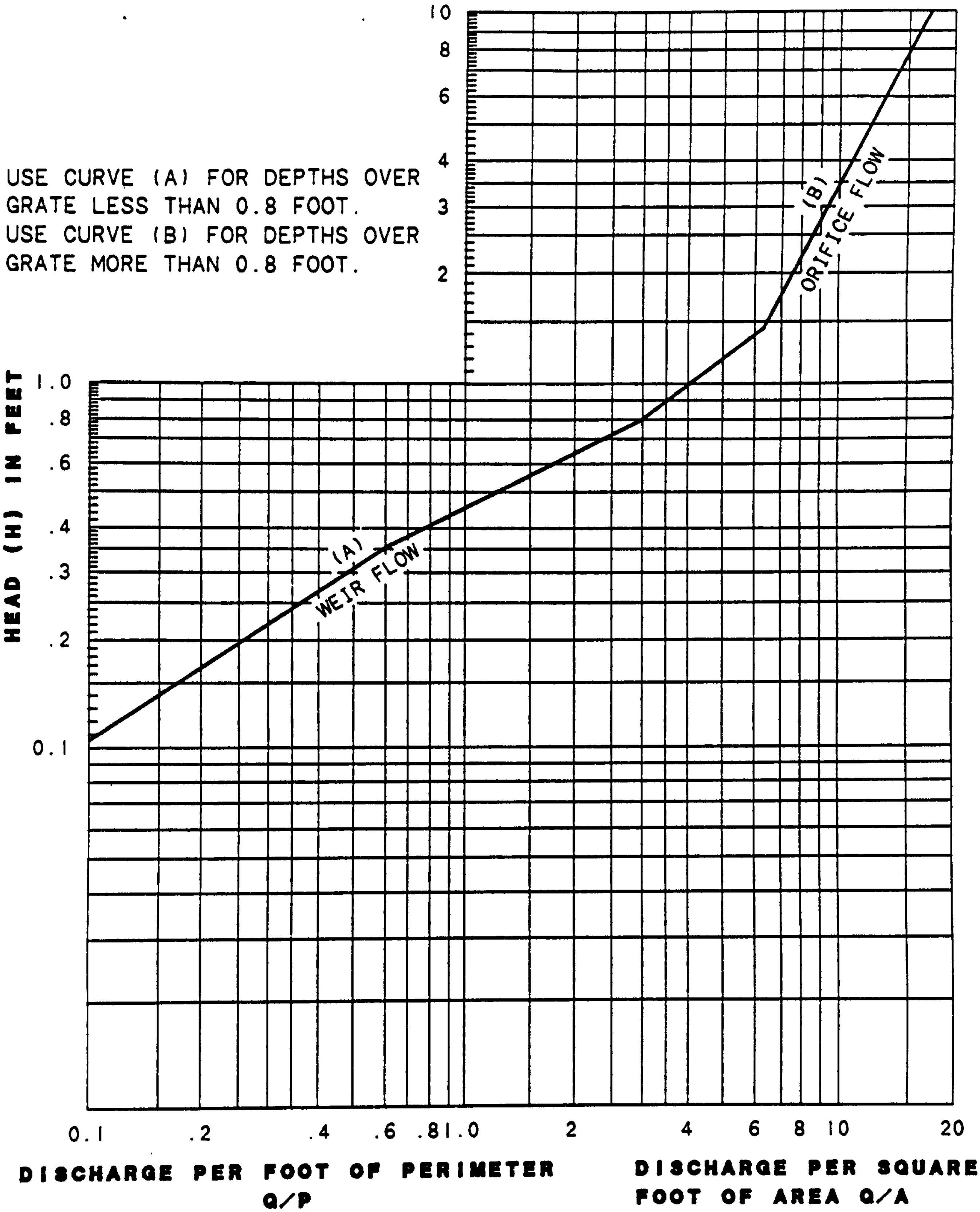
CAPACITY OF CURB OPENING INLETS ON CONTINUOUS GRADE

EXHIBIT VIII-2



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

EXHIBIT VIII-3



CAPACITY OF GRATE INLET IN SUMP
(WATER PONDED ON GRATE)

EXHIBIT VIII-4

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	I YEAR FREQUENCY	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		

EXHIBIT VIII-5

9.2.1 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.

9.2.2 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) 1 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.

9.2.3 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.

9.2.4 Time of Concentration

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

9.2.5 Design Discharge Method

The Rational Method or the Soil Conservation Service method may be used for drainage areas less than 10 acres to determine peak discharge. For areas between 10 and 200 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 200 acres, the hydrograph method of calculation shall be used as presented in Soil Conservation Service, Technical Release No. 20.

9.2.6 Hydraulic Design

The hydraulic design of storm sewers shall be based on the Manning Equation: $V = (1.49\ r^{2/3}\ S^{1/2})/(n)$.

9.2.7 Roughness Coefficients

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

Table 9-1

Manning Roughness 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

9.2.8 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.

9.2.9 Conduit Size

The minimum conduit size shall be 12 inches in diameter.

9.2.10 Hydraulics at Structures

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

9.2.11 Location of Sewers

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

9.3 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:

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

2. Typical street cross sections and profiles.

3. Pavement Drainage Computations (use form T9-1 provided).

4. Soil maps and data.

5. Outfall Elevation (from field measurement).

6. Rainfall intensity-duration-frequency curves or tabulation (Exhibit V-2).

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) to the storm sewer inlet.

Step 3. Estimate the slope of the storm sewer to the next manhole and using Exhibit IX-1 with flow, pipe roughness, and pipe slope determine the standard size storm sewer pipe diameter required. For this size, read flowing 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. 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 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 IX-1 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.

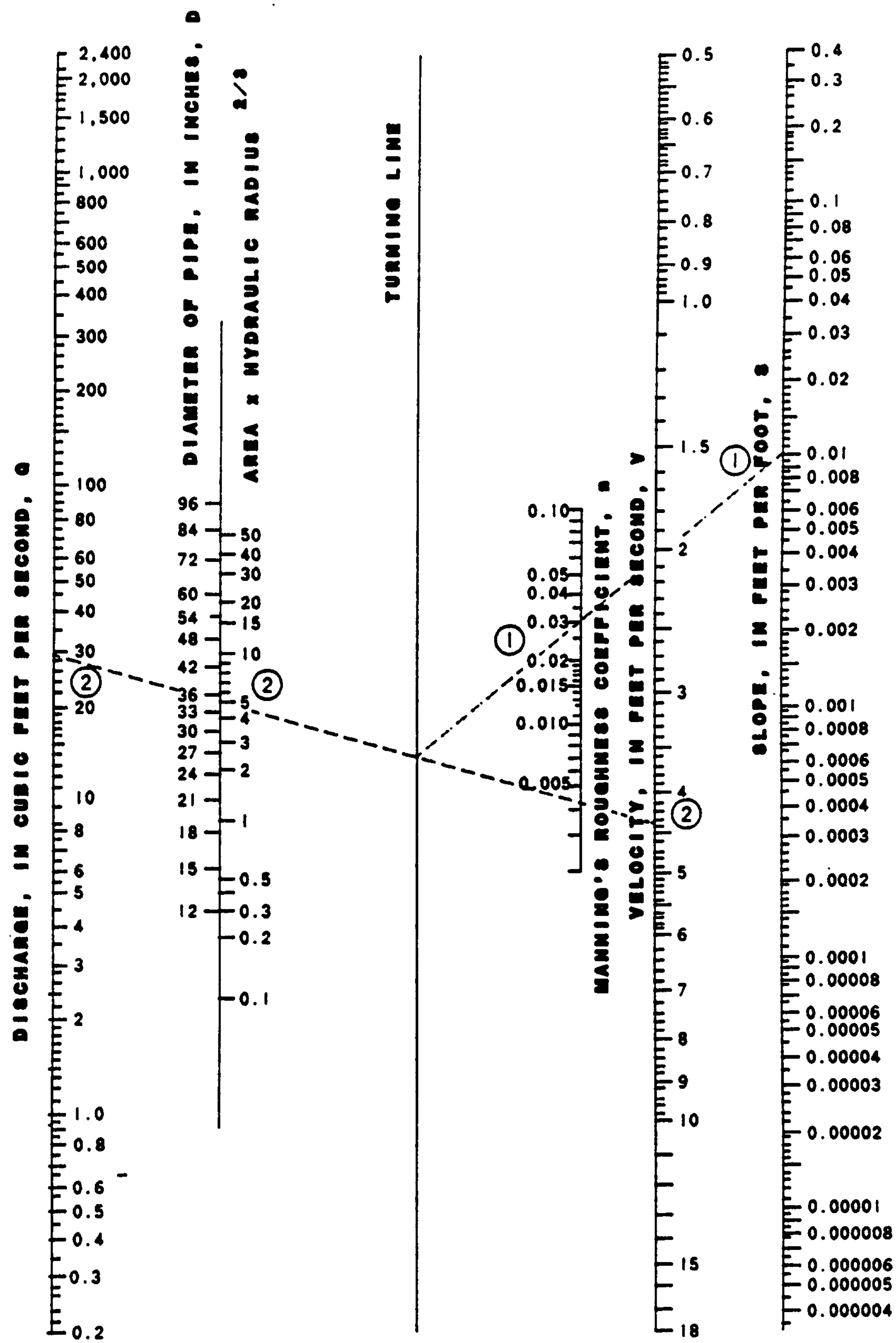
Step 14. Go back to Step 9 and repeat Steps 8 through 11 for each length of storm sewer throughout the system.

Step 15. The hydraulic effects of the 50- and 100-year storms 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.

9.5 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.



NOMOGRAPH FOR SOLUTION OF THE MANNING FORMULA

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

EXHIBIT IX-1

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 ICAI	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			

EXHIBIT IX-2

CHAPTER 10. CULVERTS

10.2.1 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.

10.2.2 Maximum Allowable Headwater

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

1. 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.

10.2.3 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

10.2.4 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.

10.4 General Design Procedures

Following is a recommended process for calculating culvert size:

Step 1. 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-2 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-2 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 part of the procedure.

Step 4. Assume Outlet Control

a. Use Exhibit X-1 with type of pipe and type of headwall, read the culvert entrance loss coefficient (K_e).

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 (d_c).

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 $HW \geq D + ([1+Ke]V^2)/2g$, where $V = Q/A$ and $g = 32.2\ ft/sec^2$

HW is accurate and design is acceptable for HW.

b. If $HW \geq 0.75D$, HW is sufficiently accurate and design acceptable for HW.

c. If $HW < 0.75D$, redesign is required.

Step 6. Compute outlet velocity (V_o)

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), read 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 culvert, then $V_o = Q/A$, 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 flow 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).

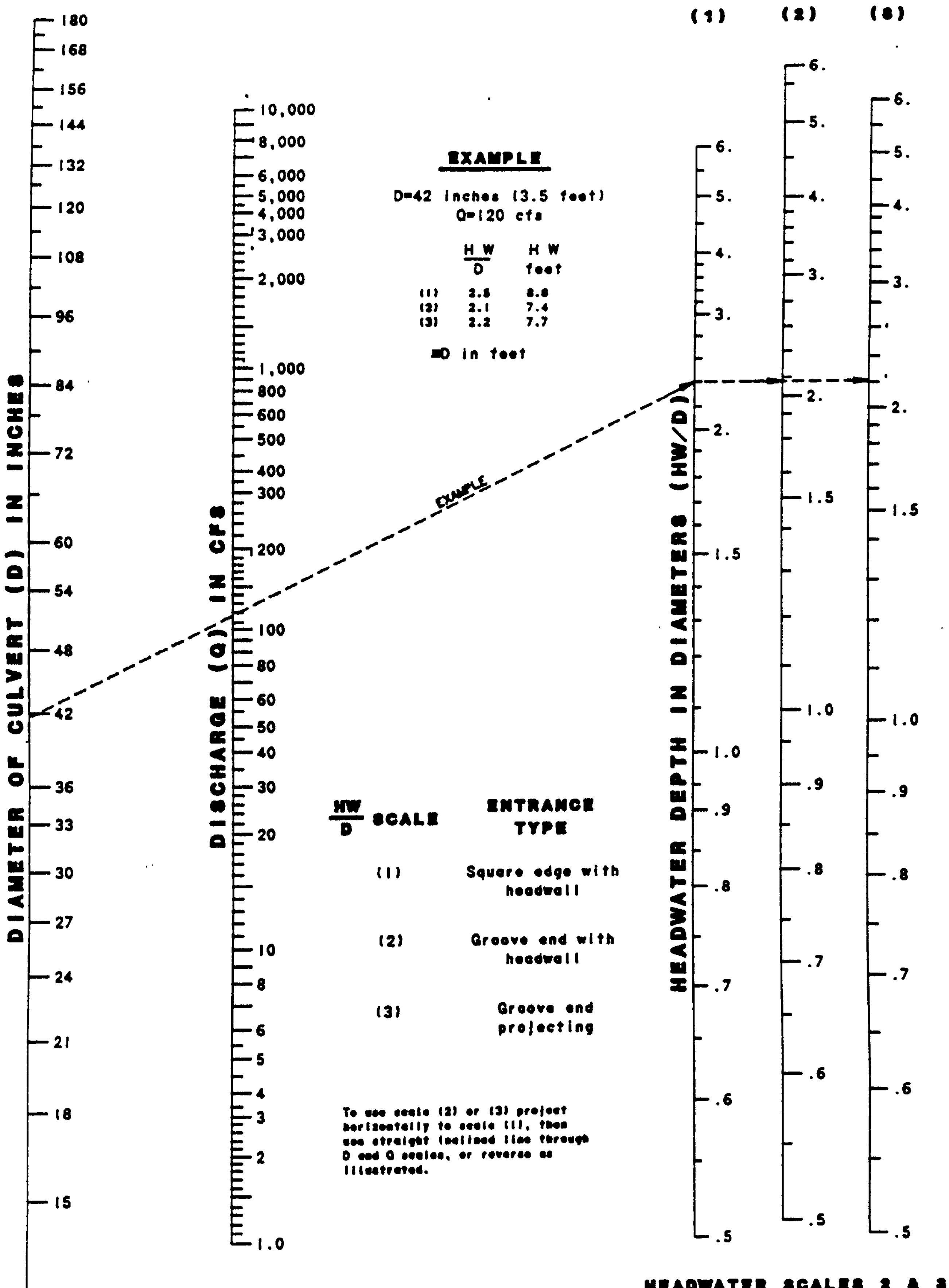
Step 7. Record final design data.

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 cover to support the anticipate loads.

TYPE OF PIPE	HEADWALL TYPE		
	Full	One-half	None
Concrete or Vitrified (thick wall)*	0.2	0.2	0.2
Corrugated Metal (thin wall)	0.25	0.9	0.9
*groove end entrance			

CULVERT ENTRANCE LOSS COEFFICIENT k_e

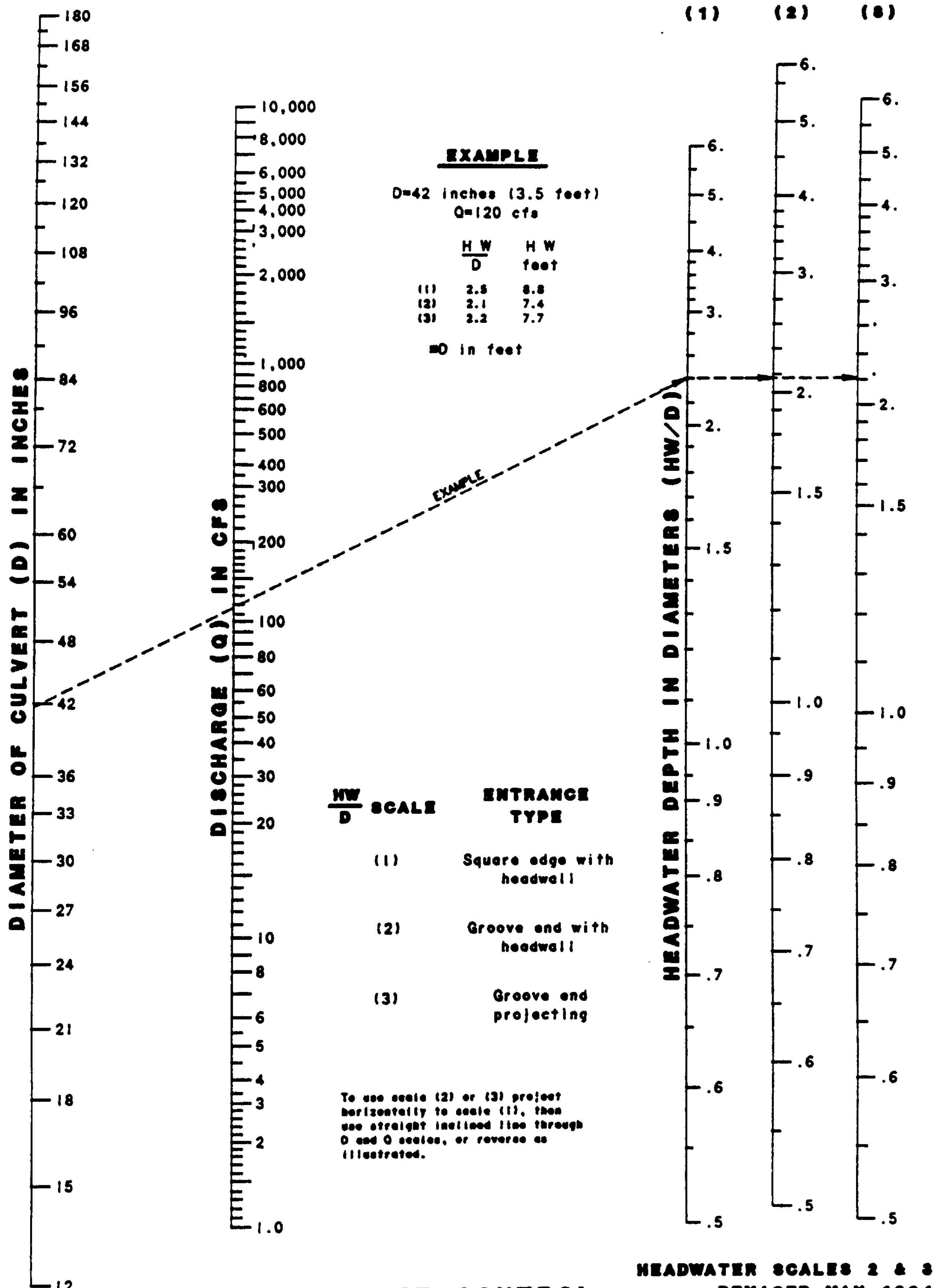
EXHIBIT X-1



HEADWATER SCALES 2 & 3
REVISED MAY 1964

INLET CONTROL
HEADWATER DEPTH FOR CONCRETE PIPE CULVERTS

EXHIBIT X-2

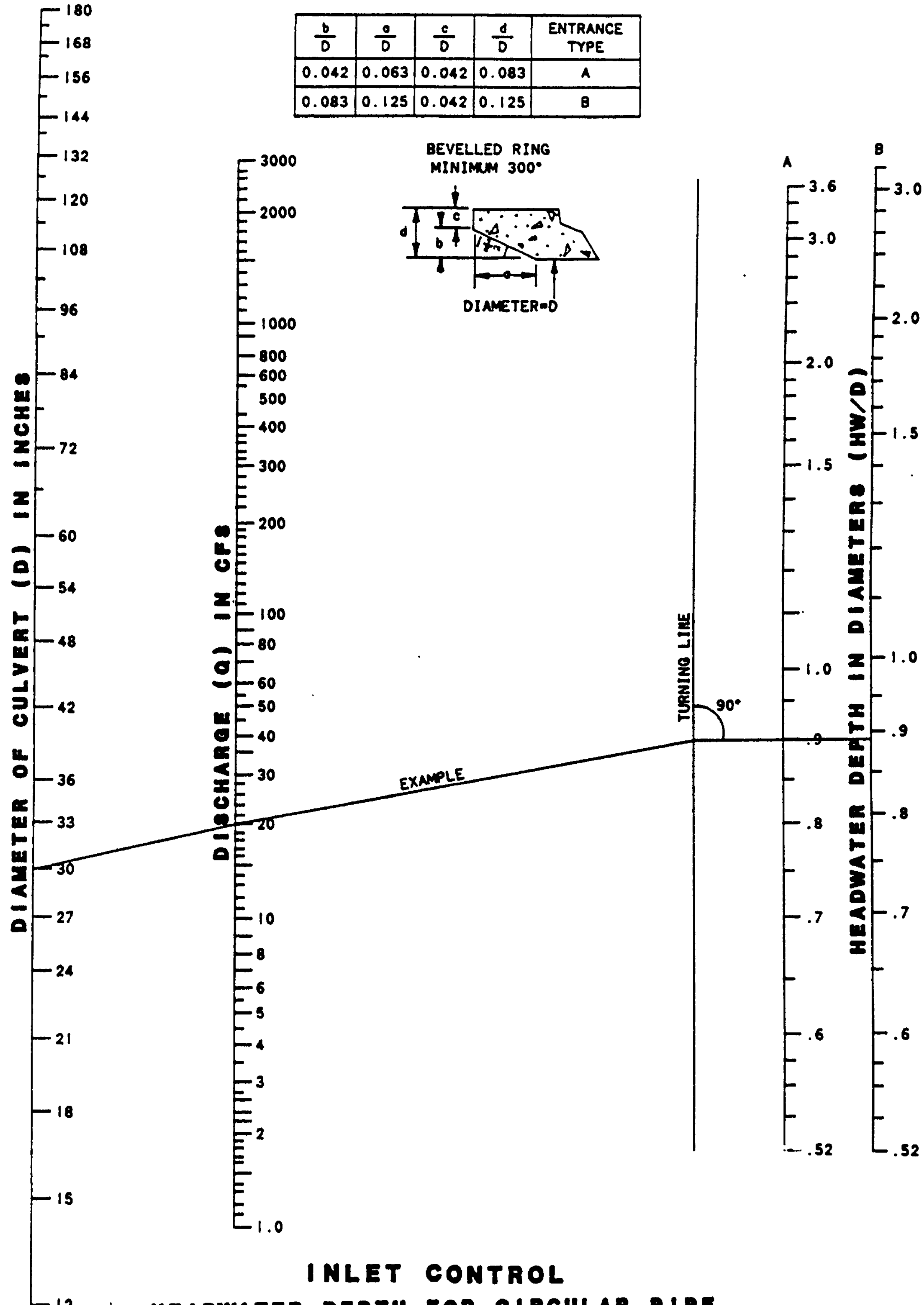


HEADWATER SCALES 2 & 3
REVISED MAY 1964

INLET CONTROL
HEADWATER DEPTH FOR CONCRETE PIPE CULVERTS

EXHIBIT X-2
CONTINUED

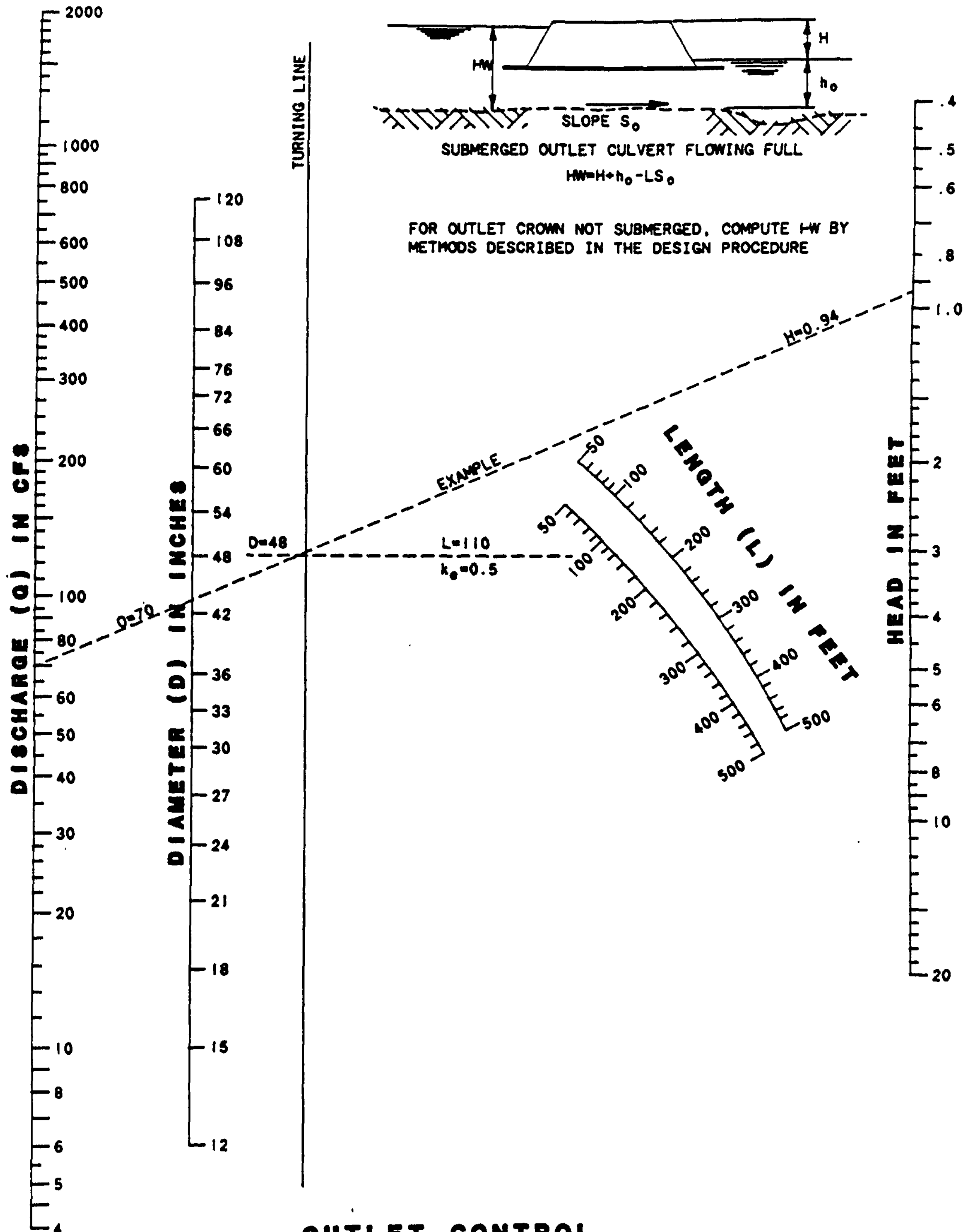
b/D	a/D	c/D	d/D	ENTRANCE TYPE
0.042	0.063	0.042	0.083	A
0.083	0.125	0.042	0.125	B



INLET CONTROL

HEADWATER DEPTH FOR CIRCULAR PIPE CULVERTS WITH BEVELLED RING

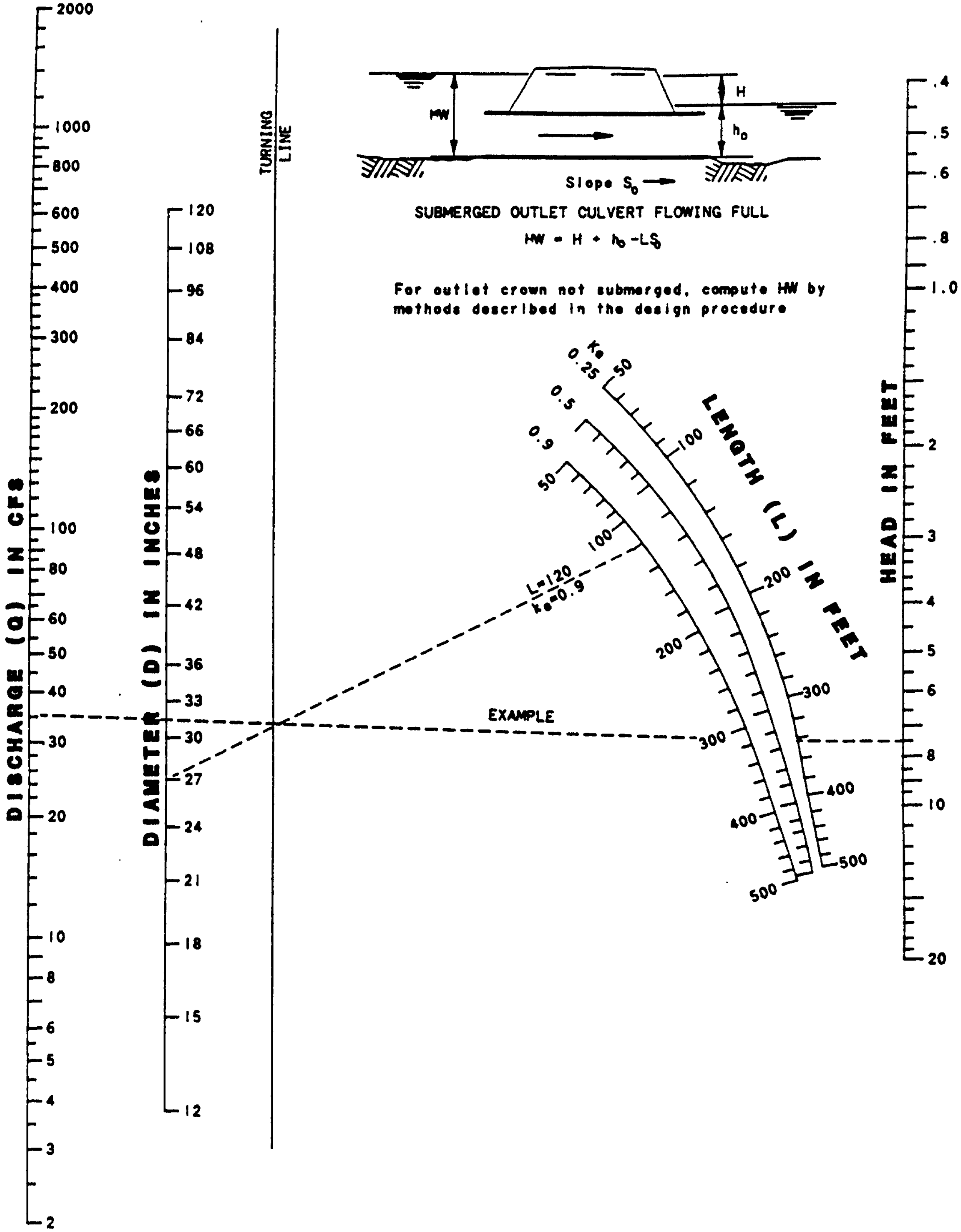
EXHIBIT X-2 (Cont.)



OUTLET CONTROL

HEAD FOR CONCRETE PIPE CULVERTS FLOWING FULL n=0.012

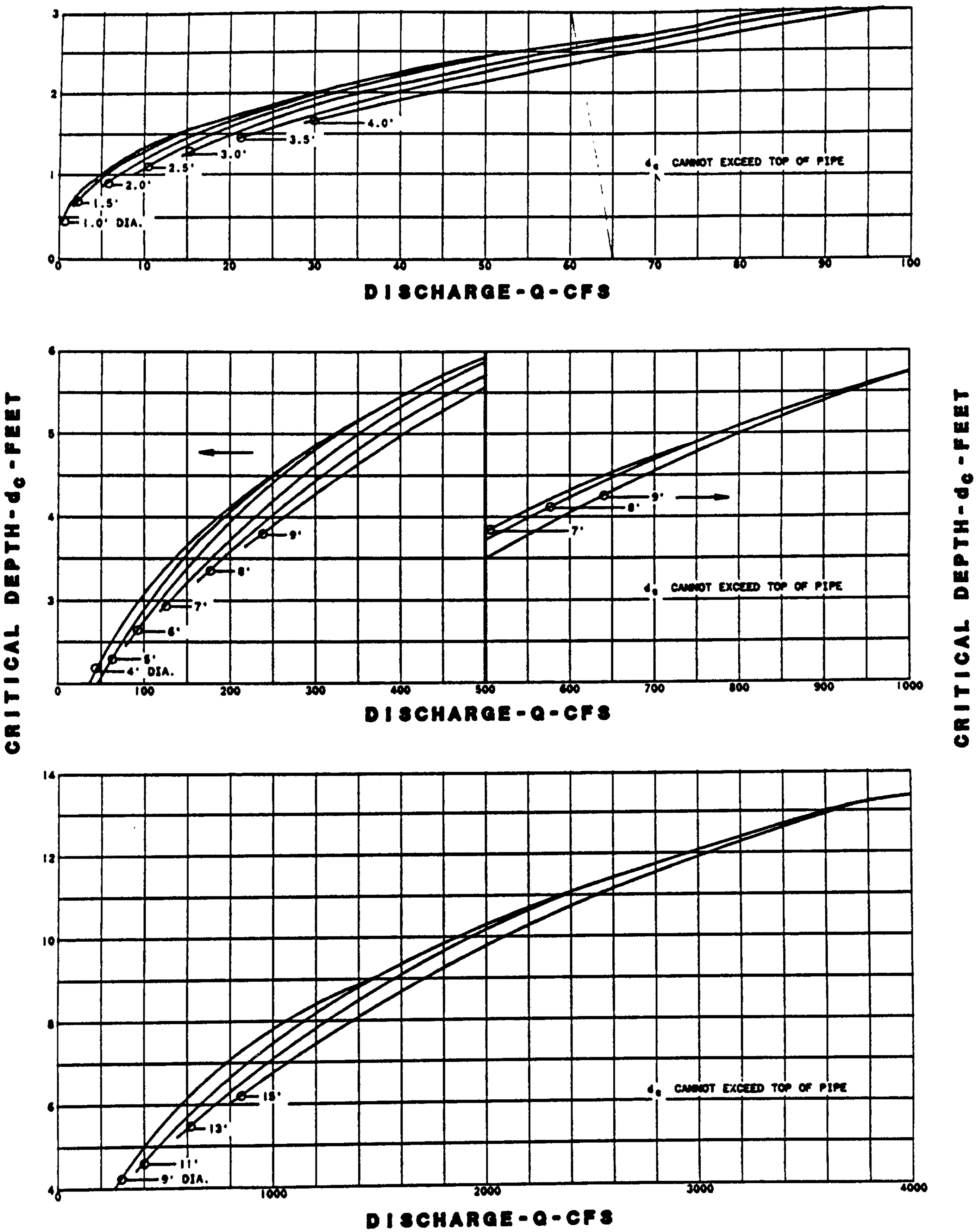
EXHIBIT X-3



OUTLET CONTROL

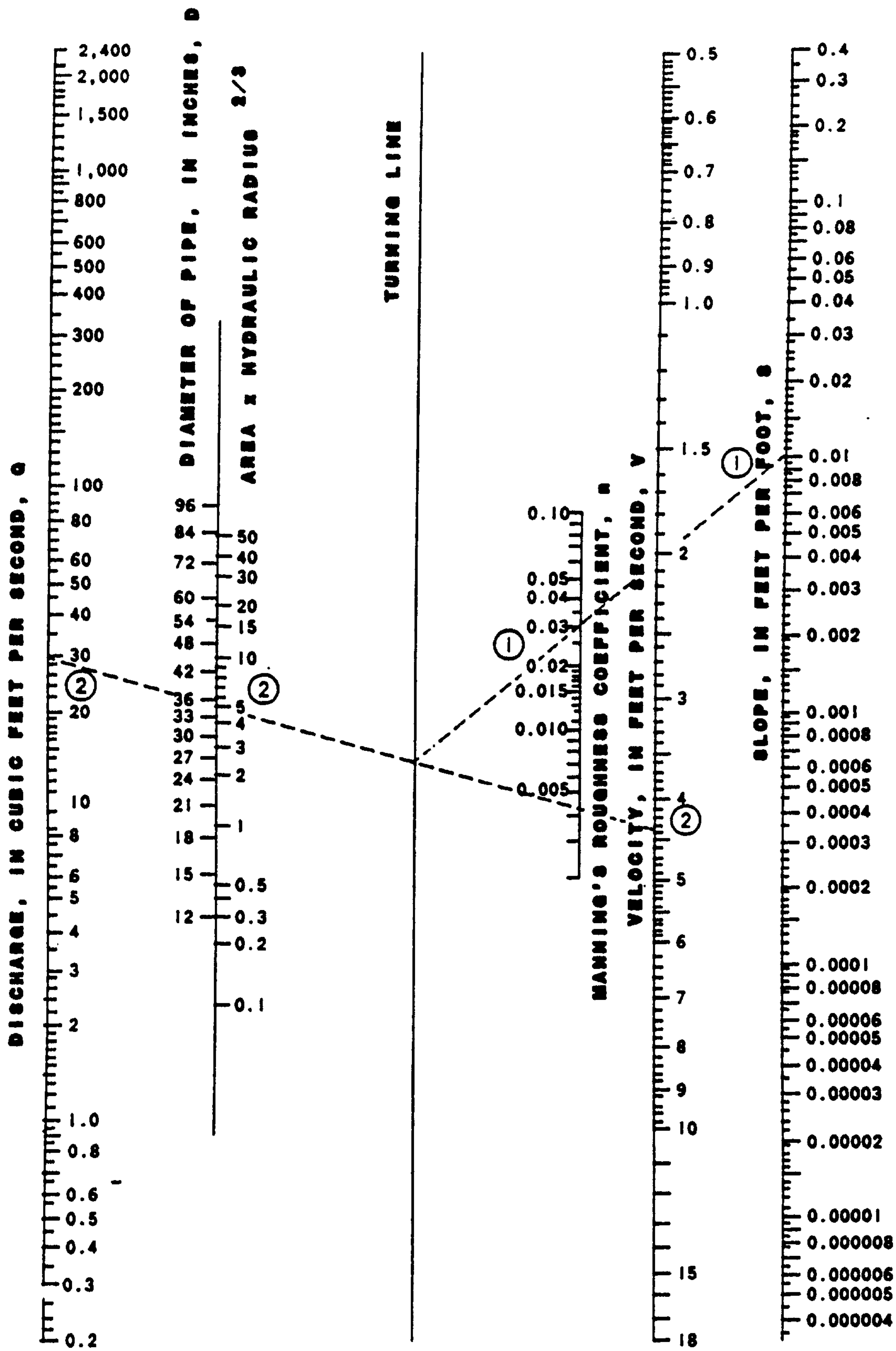
HEAD FOR STANDARD C. M. PIPE CULVERTS FLOWING FULL n=0.024

EXHIBIT X-3 (Cont.)



CRITICAL DEPTH
CIRCULAR PIPE

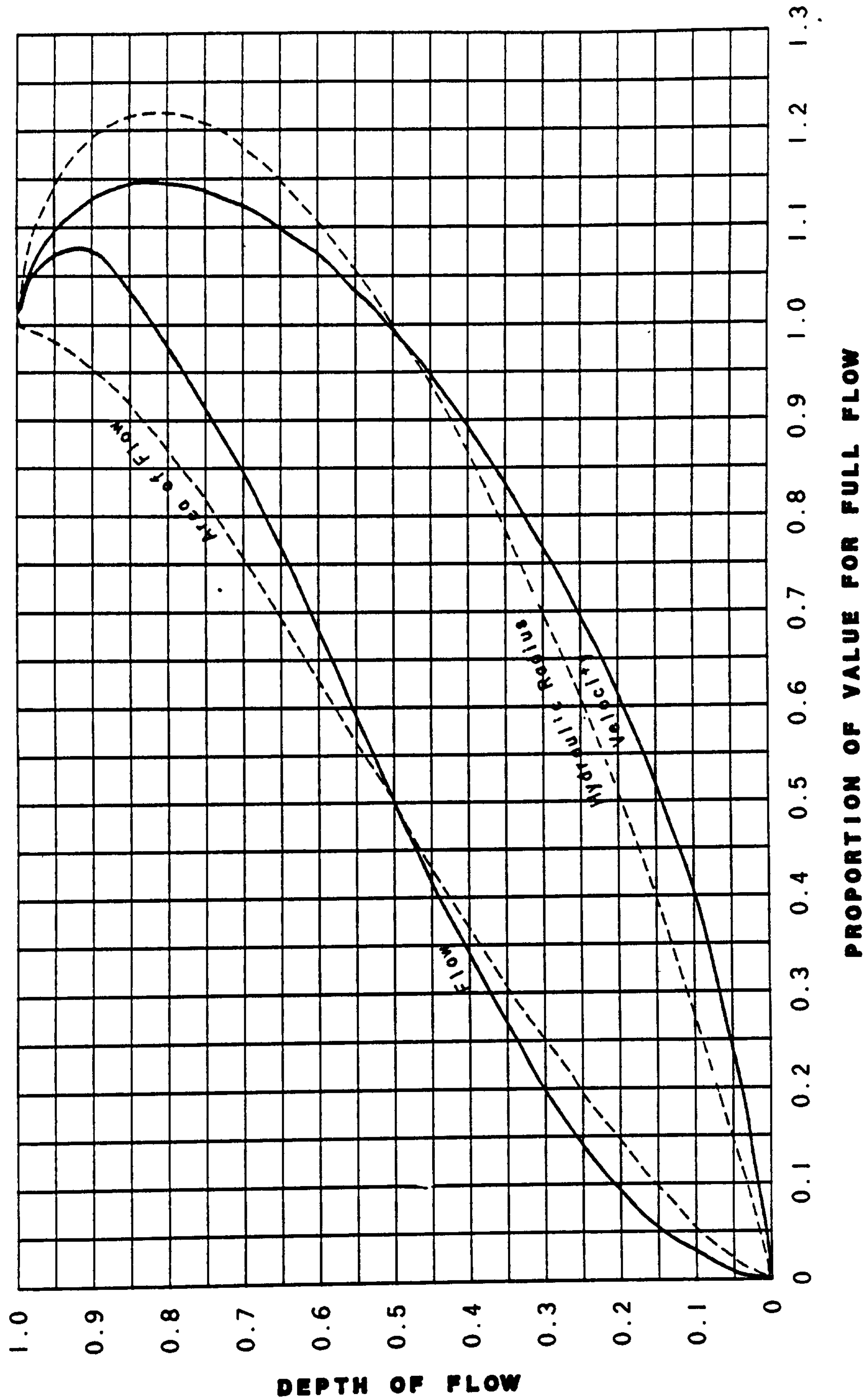
EXHIBIT X-4



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 __________

1 CULVERT DESCRIPTION (ENTRANCE TYPE)	2 SIZE D	3 Q	HEADWATER COMPUTATIONS										14 Controlling HW	15 Allowable Headwater AHW	OUTLET CONT. Size OK if HW>		18 OUTLET VELOCITY	19 COMMENTS
			INLET CONT.		OUTLET CONTROL $HW = H + h_o - LS_o$													
			4 $\frac{HW}{D}$	5 HW	6 Ke	7 H	8 d_c	9 $\frac{d_c + D}{2}$	10 TW	11 h_o	12 LS_o	13 HW			16 $D + \frac{(1+Ke)V^2}{2g}$	17 75D		
	IN	CFS		FT		FT	FT	FT	FT	FT	FT	FT	FT	FT	FT	FF	FPS	

LOCATION: __________ STATION: __________

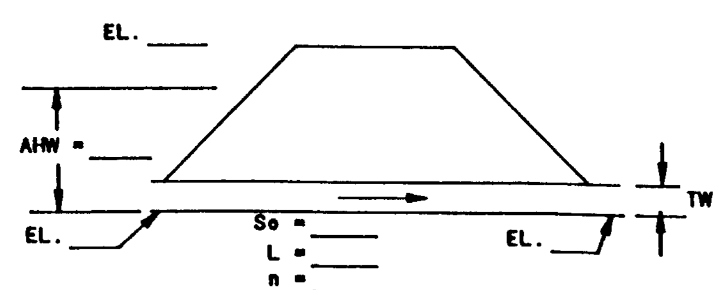


EXHIBIT X-7

CHAPTER 11. CHANNEL PROTECTION

11.2 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 super-critical flow shall be lined with concrete on the bottom and on the side slopes to the full design depth.

11.3 Culvert Headwalls

Culverts at collector streets, main arteries, and freeways shall be provided with concrete headwalls. For culverts of 24 inches or less in diameter, headwall design shall be as shown on the City of Cincinnati Standard drawings, Accession No. 49030. For culverts larger than 24 inches in diameter, special design is required to provide details of concrete dimensions and steel reinforcement. Such special designs shall consider the headwall to be a retaining wall for design considerations and will require the approval of the Stormwater Management Utility.

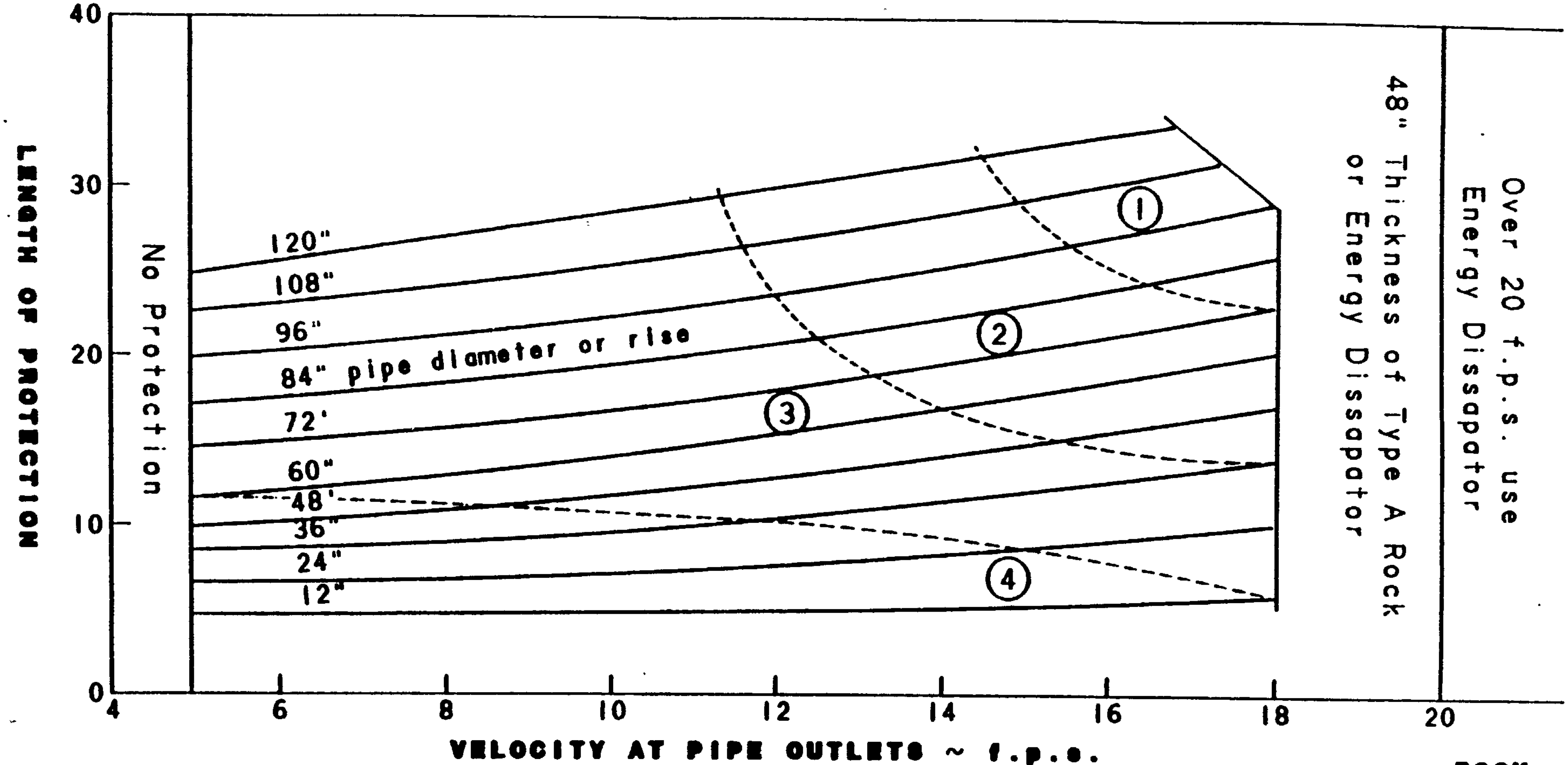
11.4 Energy Dissipation

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 XI-1.

11.5 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 1. 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 13.5 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, wit` 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

12.2 Design Criteria for Runoff Control

Peak flow runoff controls shall be required on all land developments and redevelopments except for those which contain only Class A and/or Class B property as defined in Section 720-55 of the Stormwater Management Code and which comprise less than four contiguous properties. Exemption from runoff controls will also be granted for developments of less than one-half acre if the difference between the predevelopment and post-development runoff coefficient is less than 20 percent. 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 Management Utility's Master Plan and shall be accepted and approved by the Utility 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 2-, 10-, 25-, 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 200 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 200 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.

12.4 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.

12.7.1 Detention (Dry) Basins, (Wet) Ponds

1. 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 peak discharge of the facility shall be recovered within a 24-hour time period. The remaining 50 percent shall 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 Utility 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.

8. Combined Sewer Areas

Detention/retention ponds that discharge to combined sewers may only discharge the 10-year predevelopment flow to the combined sewer. Storage outflows greater than that rate must discharge to the downstream surface drainage system to ensure that the pond discharge does not overload the combined sewer.

12.7.4 Summary of Design Criteria

1. 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	--	--

12.9.1 Storage Equation (Preferred Method for Determining the Storage Requirement from a Drainage Area of Less Than 10 Acres)

The storage equation method presented here is a simplified method for computing the required storage for developments of less than 10 acres. The procedure is as follows:

Step 1. Calculate a time factor for the predevelopment and post-development conditions using the equation $TF = (2-C)A - 10C + 20$, where TF = time factor in minutes; A = drainage in area acres; and C = runoff coefficient.

Step 2. Compute the predevelopment and post-development runoffs using the rational formula ($Q = CIA$) for the 2-, 10-, 25-, and 100-year storms, where I = rainfall intensity (in/hr) from Exhibit V-2 for the time factor calculated in Step 1.

Step 3. Calculate the required storage for each design storm using the equation $S_x = (Q_{post} - Q_{pre}) \times TF_{post} \times 60$, where S_x = required storage volume in cubic feet for the x-year storm.

12.9.2 Example - Storage Equation

Determine the required storage volumes for the 2-, 10-, 25-, and 100-year storms for a 5-acre watershed with a predevelopment runoff coefficient equal to 0.3 and a post-development runoff coefficient equal to 0.65.

Step 1. Compute the time factor:

$$TF_{pre} = (2 - 0.3) \times 5 - 10 \times 0.3 + 20 = 25.5 \text{ minutes}$$

$$TF_{post} = (2 - 0.65) \times 5 - 10 \times 0.65 + 20 = 20.2 \text{ minutes}$$

Step 2. Use Exhibit V-2 with TF_{pre} = 25.5 and TF_{post} = 20.2 and read for:

Predevelopment I_2 = 2.49, I_{10} = 3.48, I_{25} = 4.08, and I_{100} = 5.04;

Post-development I_2 = 2.88, I_{10} = 3.98, I_{25} = 4.62, and I_{100} = 5.70.

Calculate discharge for:

2-year event: $Q_{pre} = 0.3 \times 2.49 \times 5 = 3.7$ cfs, $Q_{post} = 0.65 \times 2.88 \times 5 = 9.4$ cfs;

10-year event: $Q_{pre} = 0.3 \times 3.48 \times 5 = 5.2$ cfs, $Q_{post} = 0.65 \times 3.98 \times 5 = 12.9$ cfs;

25-year event: $Q_{pre} = 0.3 \times 4.08 \times 5 = 6.1$ cfs, $Q_{post} = 0.65 \times 4.62 \times 5 = 15.0$ cfs; and

100-year event: $Q_{pre} = 0.3 \times 5.04 \times 3 = 7.6$ cfs, $Q_{post} = 0.65 \times 5.70 \times 5 = 18.5$ cfs.

Step 3. Calculate the required storage:

2-year event: $S_2 = (9.4 - 3.7) * 20.2 * 60 = 6{,}908$ c.f.;

10-year event: $S_{10} = (12.9 - 5.2) * 20.2 * 60 = 9{,}332$ c.f.;

25-year event: $S_{25} = (15.0 - 6.1) * 20.2 * 60 = 10{,}787$ c.f.;

100-year event: $S_{100} = (18.5\ 7.6) * 20.2 * 60 = 13{,}211$ c.f.

The 100-year storage could be developed as a 1/8-acre detention basin with a maximum storage depth of 3 feet, assuming 4:1 side slopes or as an underground pipe, 7 feet diameter and 340 feet in length.

12.9.3 Graphical Flow Routing (Preferred Method for Determining the Storage Requirement from a Drainage Area Between 10 and 200 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 No. 55. 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_o) 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 1. Determine the post-development volume of runoff (V_r), 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 (see Article 6.4.1.1). Normally the peak inflow discharge equals the post-development peak discharge and the peak outflow discharge equals the predevelopment peak discharge.

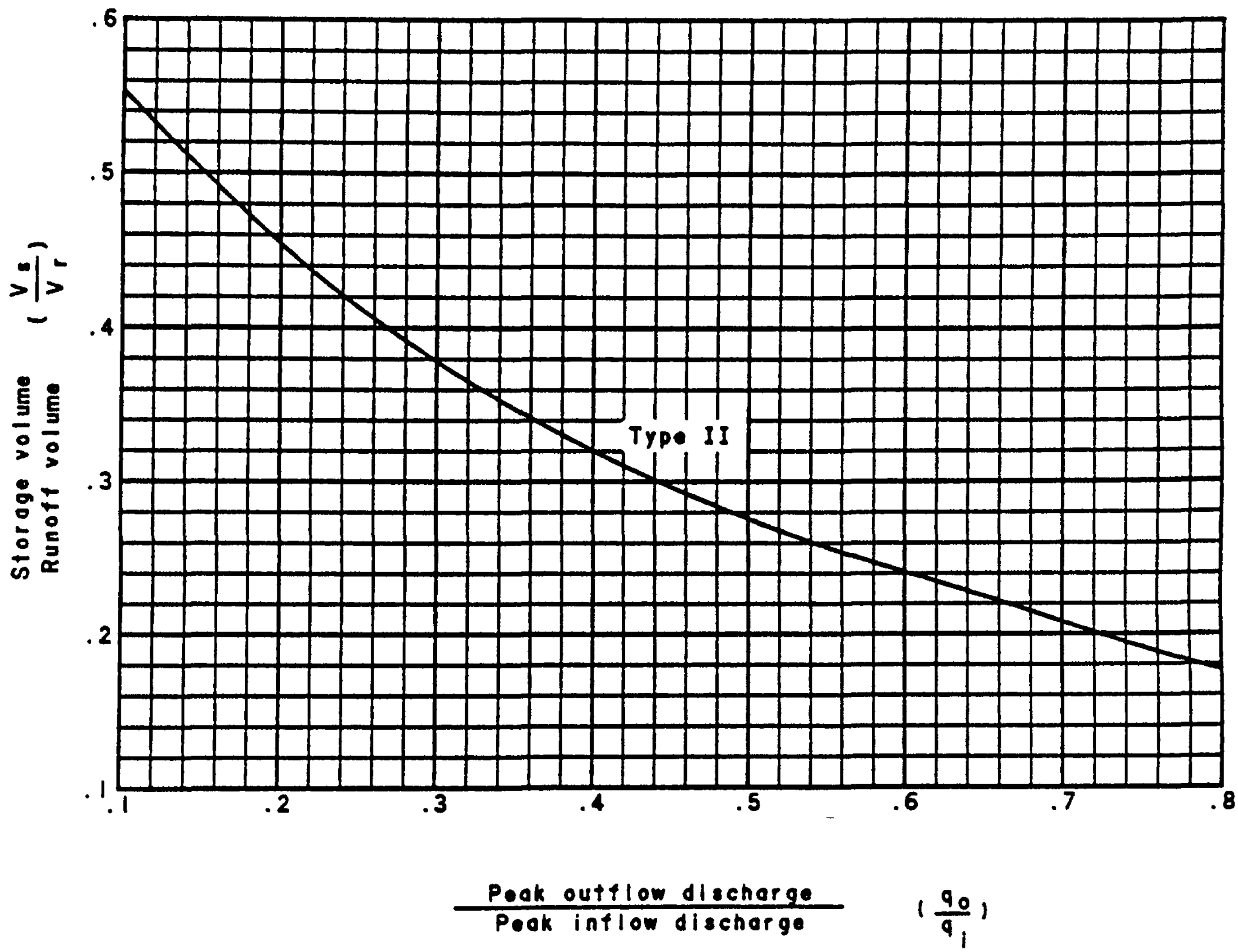
Step 2. Calculate the ratio of peak outflow discharge to the peak inflow discharge (Q_o/Q_i) for the 2-, 10-, 25-, and 100-year frequency events.

Step 3. Use Exhibit XII-5 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) $V_s = V_r \times (V_s/V_r)$. 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.



APPROXIMATE DETENTION BASIN ROUTING

EXHIBIT XII-5

GRAPHICAL FLOW ROUTING COMPUTATIONS

	PRE-DEVELOPMENT	POST-DEVELOPMENT					REQUIRED STORABLE VOLUME EXHIBIT XII-5	
1 STORM FREQUENCY	2 PEAK DISCHARGE Qo	3 PEAK DISCHARGE Qi	4 VOLUME RUNOFF Vr i	5 RELEASE RATE Qo	DISCHARGE RATIO 6 Qo/Qi	VOLUME RATIO 7 Vs/Vr i	8 Vs	9 Vs
YEARS	CFS	CFS	INCIES	CSM			INCHES	ACRE FT

FORM T12-1
(12.9.8)

STORAGE-INDICATION COMPUTATION TABLE

PROJECT ______________________ DESIGNER ______________ DATE _________

1 Elevation	2 O_2	3 S_2	4 $\frac{O_2}{2}$	Δt = min. 5 $\frac{S_2}{\Delta t}$	6 $\frac{S_2}{\Delta t} + \frac{O_2}{2}$
FT	CFS	CF	CFS	CFS	CFS

FORM T12-2
(12.9.7)

STORAGE-INDICATION OPERATING TABLE

PROJECT ________________ DESIGNER ________________ DATE ______

1 Hydrograph Time	2 Routing Interval	3 Time	4 Inflow	5 Ave. Inflow	6 $S_1/\Delta t+O_1/2$	7 O_1	8 $S_2/\Delta t+O_2/2$	9 O_2
HRS	MINUTES	MINUTES	CFS	CFS	CFS	CFS	CFS	CFS

FORM T12-3
(12.9.7)

13.3 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:

1. 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.

13.5 Long-Term Erosion and Sedimentation Control

When long-term erosion and sedimentation problems are anticipated, the stormwater utility engineer shall require that measures be taken to control the situation and such measures may include:

1. 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

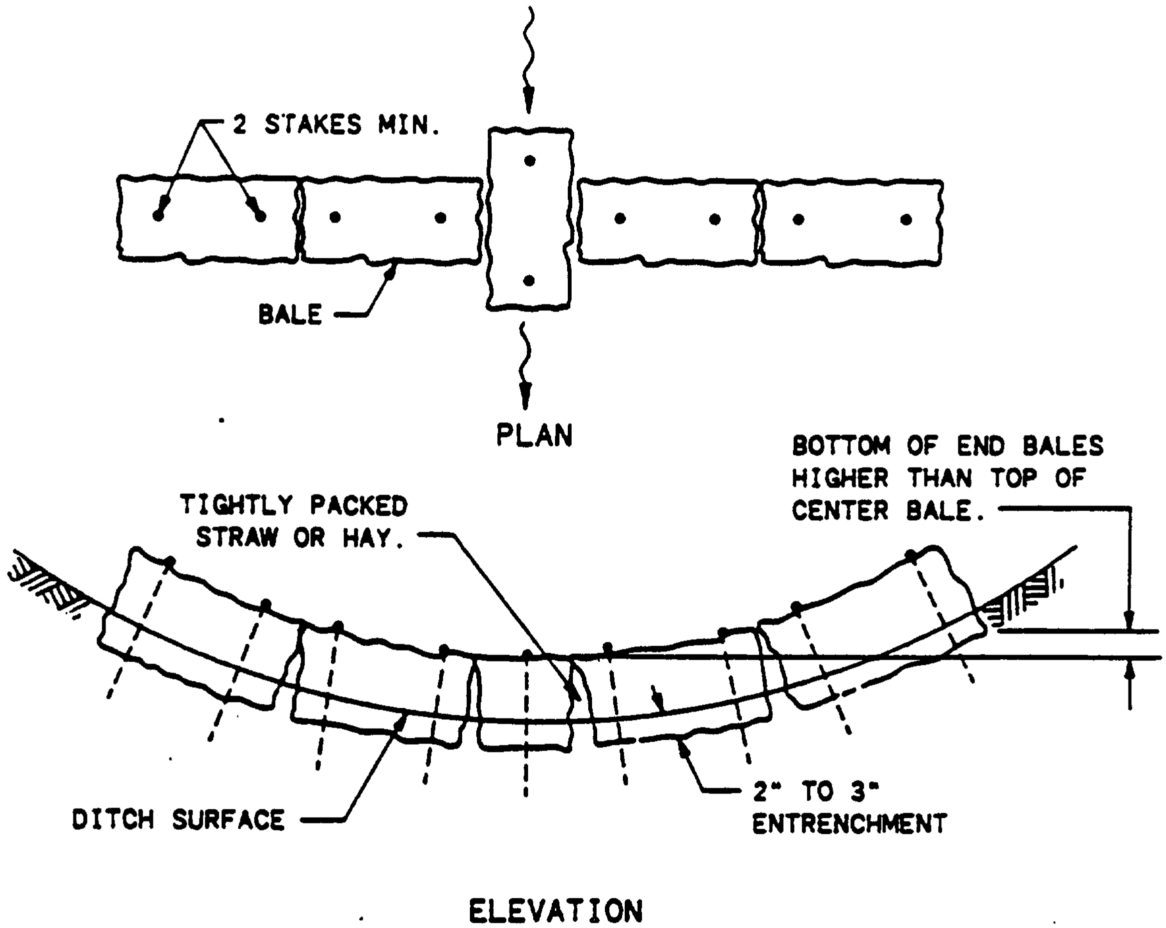
3. Use other methods to control sediment pollution; this may include, but is not limited to a combination of paragraphs (1) and (2) of this standard, provided those methods are acceptable to the utility.

13.6 Control of Sloughing, Landsliding, and Dumping

To control sediment pollution of public water caused by sloughing, landsliding, or dumping of earth material, or placing of earth material into such proximity that it may readily slough, slide, or erode into public waters by natural forces, no person shall:

1. 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 shall 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

STORMWATER MANAGEMENT

City of Cincinnati
Stormwater Management Utility
Room 445, City Hall
Cincinnati, Ohio 45202