

**STORMWATER
MANAGEMENT
CRITERIA**

ISSUED OCTOBER 2023

PREPARED BY CITY OF MANHATTAN PUBLIC
WORKS ENGINEERING WITH TECHNICAL
ASSISTANCE FROM BURNS & McDONNELL
AND BG CONSULTANTS

STORMWATER MANAGEMENT CRITERIA

FOR THE CITY OF MANHATTAN, KS

ISSUED OCTOBER 10, 2023 &

ADOPTED FOR USE AS OF NOVEMBER 1, 2023

PREPARED BY CITY OF MANHATTAN PUBLIC WORKS ENGINEERING

WITH TECHNICAL ASSISTANCE FROM

BURNS & McDONNELL AND BG CONSULTANTS

Cover photo of Wildcat Creek, by city staff



Table of Contents

Section 1.0 Introduction	1
11 Purpose.....	1
12 What is included in this document.....	1
13 Definitions	2
14 Revision History	6
Section 2.0 General Requirements.....	7
21 Applicability and Authorization	7
22 Level of Service.....	7
221 Hydrology	7
222 Conveyance	7
223 Collection.....	8
224 Detention.....	8
225 Post-Construction Stormwater BMPs.....	8
23 Waiver	9
Section 3.0 Drainage Submittals.....	11
31 Applicability	11
32 Drainage Submittals	12
321 Lot of Primary Concern.....	13
33 Project Types and Requirements.....	13
331 Planning Project.....	13
332 Building Project.....	13
333 Site Improvement Project.....	15
334 Public Improvement Project.....	15
34 Procedures for Review and Approval.....	15
341 Study Documentation.....	21
342 Construction Documentation	23
Section 4.0 Drainage Easements	27
41 Description	27
42 Easement Types.....	27
43 Easement Sizing.....	28
431 Underground Conveyance and Associated Inlets and Swales.....	28
432 Overflow Pathways.....	28
433 Engineered Channels	28
434 Natural Stream Systems	29

435	Surface Detention Basins.....	29
436	Underground Detention Basins	29
437	Post-Construction Best Management Practices	29
438	Maintenance Access Paths	30
439	Other Features.....	30
44	Maintenance Duties within Easements.....	30
45	Natural Stream Corridors	30
46	Designated Special Flood Hazard Areas	34
Section 5.0 Hydrology.....		35
51	Description	35
52	Runoff Methodologies.....	35
521	Hydrograph Method.....	37
522	Rational Method.....	38
53	Design Event.....	39
54	Time of Concentration.....	40
541	Sheet Flow	40
542	Shallow Concentrated Flow.....	41
543	System Flow.....	42
55	Lag Time.....	43
56	Computer Programs	43
Section 6.0 Conveyance.....		45
61	Description	45
62	Requirements	45
621	Underground Enclosed Conveyance System.....	45
622	Overflow Pathways.....	47
623	Conveyance Swales.....	47
624	Engineered Channels.....	47
625	Culverts.....	48
626	Natural Streams.....	49
627	Outlet Protection and Energy Dissipation	50
628	Grade Control Requirements	50
63	Design Procedures.....	51
631	System Capacity.....	51
632	Channel Lining Materials	54
633	Riprap Apron Outlet Protection	54



634	Energy Dissipation	56
635	Grade Control	57
64	Computer Programs	58
Section 7.0 Collection		59
71	Description	59
72	Allowable Inlet Types	59
73	Design Method	59
731	On-Grade Inlets	59
732	Sump Inlets in Street	59
733	Area Inlets.....	59
74	Inlet Locations	60
75	Allowable Gutter Depth & Spread.....	60
751	Street Inlet System Calculation	61
Section 8.0 Detention		63
81	Description	63
82	Requirements	63
821	Allowable Release Rates.....	63
822	Above-Ground Detention	64
823	Underground Detention	65
824	Outlet Structure.....	65
825	Fee In Lieu of Detention	66
83	Design Procedures.....	66
831	Establish Release Rate for the Base Condition.....	66
832	Release Rates for Special Conditions.....	66
833	Outlet Structures	68
84	Computer Programs	70
Section 9.0 Post-Construction Stormwater BMPs.....		71
91	Description	71
92	Requirements	71
93	Design Procedures.....	71
Section 10.0 References		73
Section 11.0 Appendices		75

List of Tables

Table 3.1	Drainage Submittal Requirements.....	16
Table 4.1	Minimum Buffer Widths for Natural Streams.....	31
Table 5.1	Composite CN by Land Use and Soil Group	36
Table 5.2	Example Composite CN Calculation	37
Table 5.3	Rational Method Correction for Time of Concentration	38
Table 5.4	Rational Runoff Coefficients	39
Table 5.5	Roughness Coefficients for Sheet Flow.....	41
Table 5.6	NRCS Velocity Equations.....	42
Table 6.1	Pipe Anchor Spacing Requirements.....	46
Table 6.2	Manning's Roughness Coefficients	52
Table 6.3	Head Loss Coefficients	53
Table 6.4	Permissible Shear Stresses for Lining Materials	56
Table 6.5	Retardance Classification of Vegetal Covers.....	57
Table 7.1	Allowable 10-Year Gutter Spread by Street Type	60
Table 8.1	Allowable Release Rate by Design Event	64
Table 8.2	Freeboard Requirements	64
Table 8.3	Orifice Coefficients.....	70

List of Figures

Figure 3.1	Planning Project Flowchart.....	17
Figure 3.2	Building Project Flowchart.....	18
Figure 3.3	Site Improvement Project Flowchart.....	19
Figure 3.4	Public Improvement Project Flowchart	20
Figure 4.1	Defining the Location of Toe of Bank, Example.....	33
Figure 4.2	Additional Stream Setback for Steep Banks	34

List of Appendices

Appendix A1	Riley County Rainfall Depths by Recurrence Interval.....	75
Appendix A2	Intensity-Duration-Frequency Values	76
Appendix A3	Manhattan, Kansas 6-hour Dimensionless Rainfall Distribution.....	78
Appendix A4	Velocity vs. Slope for Shallow Concentrated Flow	79
Appendix B1	Inlet Control Nomograph, RCP Culverts	80
Appendix B2	Inlet Control Nomograph, CMP Culverts.....	81
Appendix B3	Inlet Control Nomograph, RCPHE Culverts.....	82
Appendix B4	Inlet Control Nomograph, RCB (Box) Culverts.....	83
Appendix B5	Outlet Control Nomograph, RCP Culverts	84
Appendix B6	Outlet Control Nomograph, CMP Culverts.....	85
Appendix B7	Outlet Control Nomograph, RCPHE Culverts.....	86
Appendix B8	Outlet Control Nomograph, RCB (Box) Culverts.....	87
Appendix C1	Riprap Apron Outlet for Min. Tailwater	88
Appendix C2	Riprap Apron Outlet for Max. Tailwater.....	89
Appendix D1	Spread Width for Gutter Flow on Grade.....	90
Appendix D2	Capacity of A-5 Non-Setback Curb Inlet on Grade	91
Appendix D3	Capacity of A-7.5 Non-Setback Curb Inlet on Grade	92
Appendix D4	Capacity of A-10 Non-Setback Curb Inlet on Grade	93
Appendix D5	Capacity of A-5S Setback Curb Inlet on Grade	94
Appendix D6	Capacity of A-7.5S Setback Curb Inlet on Grade	95
Appendix D7	Capacity of A-10S Setback Curb Inlet on Grade	96
Appendix D8	Capacity of B-3 and B-3S Curb Inlets on Grade	97
Appendix D9	Capacity of B-6 and B-6S Curb Inlets on Grade	98
Appendix D10	Capacity of B-9 and B-9S Curb Inlets on Grade.....	99
Appendix D11	Capacity of Curb Inlets in Roadway Sags	100
Appendix D12	Capacity of Type 1 Area Inlet	101
Appendix D13	Capacity of Type 2, 3 and 4 Area Inlets.....	102
Appendix D14	On-Grade Inlet Calculations, Background.....	103

Introduction

1.1 Purpose

The purpose of this document is to replace in full the Stormwater Design Criteria given in Appendix I of the 1995 Stormwater Management Master Plan. This new Stormwater Management Criteria document reflects experience gained, satisfy regulatory requirements, and establishes clear and consistent criteria for the design and analysis of stormwater infrastructure. These Criteria are intended to be used by planners, designers, and contractors, encouraging use of the best available data combined with practical application to make stormwater management decisions that will enhance and benefit the City of Manhattan, Kansas (City).

These Criteria have been developed and are applicable to the types of drainage systems and facilities ordinarily encountered in local urban and suburban areas. Other special situations may be encountered that require added criteria or more complex technical analysis than included herein.

1.2 What is included in this document

The document is organized as follows:

- ▶ Section 2.0. The *General Requirements* section of these Stormwater Management Criteria state the criteria's applicability within the stormwater system, define who can professionally seal stormwater designs, defines authorization of the City Engineer, and references other applicable criteria.
- ▶ Section 3.0. The *Drainage Impact Study* section of these Stormwater Management Criteria describe the submittal requirements and review process for stormwater management applicable to projects submitted for new development, redevelopment, impervious site improvements, and additions/expansions to existing stormwater systems and facilities.
- ▶ Section 4.0. The *Drainage Easements* section of these Stormwater Management Criteria establish the easement requirements associated with stormwater management. This section also outlines related requirements and land management tools such as stream corridors.
- ▶ Section 5.0. The *Hydrology* section of these Stormwater Management Criteria define the hydrologic calculations and assumptions to design stormwater management collection, conveyance, and detention facilities. This section includes two methods for calculating runoff, a Hydrograph Method, and the Rational Method, and defines when each method is applicable.
- ▶ Section 6.0. The *Conveyance* section of these Stormwater Management Criteria establish requirements for the design of enclosed conveyance systems, open channels, channel materials, and culverts. This section also defines when outlet protection, energy dissipation, and grade control are required through the conveyance system and provides design guidance.



- ▶ Section 7.0. The *Collection* section of these Stormwater Management Criteria dictates inlet placement and sizing.
- ▶ Section 8.0. The *Detention* section of these Stormwater Management Criteria define when stormwater detention is required and establishes allowable release rates based on tributary drainage area.
- ▶ Section 9.0. The *Post-Construction Stormwater Best Management Practices (BMPs)* section of these Stormwater Management Criteria assists the City in compliance with the Kansas Department of Health and the Environment (KDHE) Municipal Separate Storm Sewer System (MS4) permit requirements.
- ▶ Section 10.0. *References*. Sources used in development of these Stormwater Management Criteria are documented in the *References* section.
- ▶ Section 11.0. *Appendices*. Supplemental lists, tables, and figures referenced throughout these Stormwater Management Criteria are compiled in the *Appendices* for quick access and ease of substitution as available data are updated.

1.3 Definitions

Definitions useful in providing context and understanding of this Stormwater Management Criteria document include, but are not limited to, the following:

- ▶ Annual Recurrence Interval (ARI): A statistical term for the average frequency that a given event may be expected to occur, although it does not imply that the event will occur regularly at even intervals. It can also be defined as the reciprocal of the probability of an event. i.e., A 50-year storm has a probably of 0.02 (2%) chance of occurring in any given year. Also referred to as return frequency or return period.
- ▶ City: The municipal body having jurisdiction and authority to govern. For these Criteria, “City” shall mean the “City of Manhattan, Kansas”.
- ▶ City Engineer: The municipal engineer having jurisdiction and authority to review and approve analysis and design of stormwater systems. All references in this document to "City Engineer" shall mean the "City Engineer or authorized representative of the City Engineer".
- ▶ Conveyance Swale: A turf grass channel designed with a less rigid cross-sectional shape traversable by a mower with turf grass. (As used herein, a conveyance swale is not to be confused with a vegetated swale as defined in the Post-Construction BMP Manual. A “vegetated swale” is planted with dense vegetation not intended to be mowed for the purpose of conveying and treating stormwater as a structural BMP to meet water quality requirements.)
- ▶ Culvert: A conduit conveying a stream or open channel under a road, railroad, sidewalk, driveway, or other transportation-related pathway.
- ▶ Detention Facility: A storage facility for the temporary storage of stormwater runoff whereby the controlled discharge rate is less than its peak inflow rate. Often referred to a “detention basin” or “detention pond”. This definition also includes underground facilities.



- ▶ **Developer:** The legal owner or owners of a lot or any land included in a proposed development, or the holder of an option or contract to purchase, or any person having the authority to submit an application for approval of a subdivision.
- ▶ **Development:** Any man-made change to improved or unimproved real estate, including buildings or other structures, paving, and other utility systems including, but not limited to, stormwater, sanitary sewer, and water. Man-made changes to previously improved real estates commonly referred to as “redevelopment.”
- ▶ **Drainage:** The removal of surface water or groundwater from land by means of an inlet-and-piping system, swales and channels, site grading, or other means, which include runoff controls to alleviate flooding and to minimize erosion and sedimentation during and after construction or development.
- ▶ **Easement:** An easement grants one or more property rights by the property owner to and/or for use by the public, a corporation, or another person or entity. The property owner retains title of the land under the easement.
- ▶ **Enclosed System:** Enclosed stormwater conveyance systems consist of inlets, pipes, conduits, manholes and junction boxes intended to capture and convey stormwater runoff through underground structures. They may also be referred to as an “Underground System”. (Also see definition for Open System.)
- ▶ **Energy Dissipation:** A physical process whereby the potential energy of stormwater discharging into a natural or engineered channel is converted to kinetic energy, or dissipated, to reduce or eliminate erosion.
- ▶ **Engineered Channel:** An open channel designed by an engineer which typically consists of a trapezoidal or rectangular cross-section with channel materials including, but not limited to vegetation (beyond turf grass), riprap, concrete, or other manufactured products. For the purposes of this standard, Engineered Swales are considered distinct from Conveyance Swales or Water Quality Channels.
- ▶ **Finish Floor Elevation:** The elevation of the main, first floor of living space of a habitable structure. If a structure is a slab on grade, the elevation of the slab is the finish floor elevation. If the structure has a crawl space or basement, the elevation of the main floor above the crawl space or basement is the finish floor elevation.
- ▶ **Floodplain:** The normally dry land adjoining rivers, streams, lakes, or other bodies of water that is inundated during flood events. To provide a standard national procedure for floodplain management, the U.S. Federal Emergency Management Agency (FEMA) has adopted the 100-year flood as the base flood.
- ▶ **Freeboard:** The difference in elevation between the high-water mark or maximum design water surface elevation and a point of reference, such as a dam top, open channel top of bank, or finish floor elevation of a building. It is an allowance against overtopping as a safety factor for possible flooding, wave action or other transient disturbances.

- ▶ **Grade Control:** Structural improvements placed in the channel bottom to prevent long-term channel flowline/slope degradation. Such measures may include an energy dissipation component.
- ▶ **Hyetograph:** A graphical representation of the distribution of rainfall intensity over time.
- ▶ **Hydrograph:** Tables or charts that display the change of a hydrologic variable over time. Many different unit hydrograph methods have been developed (SCS, Snyder, Clark, etc.) to estimate the amount of runoff flow from a design storm.
- ▶ **Hydrology:** The science dealing with the properties, distribution, and circulation of water on and below the earth's surface and in the atmosphere.
- ▶ **Impervious Surface:** A surface condition that does not allow for the infiltration of stormwater to a high degree, such as parking lots, roofs, driveways, private walkways, and patios. Aggregate surfaced roadways and parking areas with highly compacted subgrades are classified as impervious surfaces.
- ▶ **Licensed Professional:** A Professional Engineer, Landscape Architect or other professional registered and licensed to practice in the State of Kansas, and as used in this document, is qualified by education and experience in the technical profession of analysis and design of stormwater management systems.
- ▶ **Lowest Opening Elevation:** The lowest open elevation of a structure for which stormwater may enter the structure. The lowest opening elevation may be equal to the finish floor elevation or may be below it with foundation wall penetrations or window wells. The lowest opening elevation may also be equal to the basement floor elevation when a walkout basement is present.
- ▶ **Natural Stream:** A stream or drainage course formed over time by natural hydrologic, geologic and geomorphologic processes without human activity and typically characterized by a meandering condition with exposed natural soil, sand, gravel and/or rock surfaces, and lined or bordered by native vegetation (herbaceous and/or woody).
- ▶ **Naturalized Channel:** A stream or drainage course with similar characteristics of a natural channel but was initially formed by human activity and with little to no subsequent human activity.
- ▶ **Open Channel System:** Surface conveyance stormwater systems that do not have a top enclosure, including natural streams, engineered channels, and/or conveyance swales. (Also see definition for Enclosed System.)
- ▶ **Overflow Pathway:** A companion stormwater conveyance system intended to accommodate flows that exceed the capacity of the primary stormwater conveyance system. The overflow pathway is generally open channel surface conveyance designed to handle 100-yr event overflows from an enclosed stormwater system designed for the city-standard 10-yr event, however, there are no constraints on the type of primary system or overflow pathway. The pathway generally includes segments of conveyance swale, road gutters, and guided conveyances in paved areas.
- ▶ **Outlet Protection:** The structural methods to provide erosion control and/or energy dissipation measures at the discharge point of a conveyance system.



- ▶ Owner: The owner of record of real property.
- ▶ Post-Construction Best Management Practices (PCBMPs): Those methods, including stormwater treatment facilities, that have been determined to be the most effective, practical means of preventing or reducing stormwater pollution to receiving water bodies (rivers, creek, streams, lakes, reservoirs, wetlands, etc.) after construction of a development or redevelopment is complete.
- ▶ Riprap: Broken rock, cobbles, or boulders placed on side slopes or in channels for protection against the action of water and the purpose of preventing erosion.
- ▶ Roughness Coefficient: A design parameter that represents the resistance to flow in conduits, channels and floodplains and is generally associated with the Manning's n value in the Manning's equation, the most used equation to analyze open system flows.
- ▶ Runoff Coefficient: A design parameter that reflects the response of surface runoff from rainfall, also called the "coefficient of imperviousness". Runoff coefficients are a function of watershed characteristics including land use, soil type, and slope of the watershed. The Rational Formula "C" value and SCS Method Curve Number (CN) are both runoff coefficients.
- ▶ Site: A tract, or contiguous tracts, of land owned and/or controlled by a developer or owner. Master development plans, platted subdivisions, and other planned developments shall be considered a single site.
- ▶ Stormwater Pollution: any substance or material carried by drainage, snow melt runoff or other surface runoff which contaminates or adversely alters the physical, chemical, or biological properties of receiving waters, including natural rivers, streams, creeks, lakes, reservoirs or wetlands. Such substances or materials may include, but are not limited to, changes in temperatures, taste, odor, turbidity, or color; where such substance may include but is not limited to, dredged soil, solid waste, incinerator residue, sewage, garbage, sewage sludge, munitions, chemical waste, biological materials, radioactive materials, heat, wrecked or discarded equipment, rock, sand, soil, yard waste, hazardous household wastes, used motor oil, anti-freeze, litter, and industrial, municipal, and agricultural waste discharged into water.
- ▶ Stormwater System: All the natural and man-made facilities and appurtenances such as ditches, natural channels, pipes, culverts, bridges, open improved channels, street gutters, inlets, detention facilities, water quality channels and other post-construction best management practices which serve to convey surface drainage and manage water quality.
- ▶ Stormwater Treatment Facilities (STFs): All structures, plantings, natural features, or other physical elements that are designed, constructed, and maintained for the purpose of preventing or reducing stormwater pollution.
- ▶ Top of Bank: The line of intersection of the side slope of an open channel, whether natural or improved, and the adjacent ground.
- ▶ Tributary Area: All land draining stormwater to a point of consideration, regardless of ownership.
- ▶ Water Quality Channels: Open channel sections that incorporate features intended to enhanced infiltration, sediment, and pollutant removal, extend runoff duration and/or provide ecological

habitat. This definition includes vegetated swales as defined in the Post-Construction BMP manual.

- ▶ *Refer to the Manhattan Development Code (MDC) and the Post-Construction BMP Manual for additional relevant definitions. In the event of an apparent conflict or ambiguity in definitions, the City Engineer will provide the necessary interpretations to apply these criteria.*

1.4 Revision History

This document was developed by City of Manhattan staff in collaboration with Burns and McDonnell and BG Consultants, with technical work beginning in 2020. The previous 1995 SWMMP provided the foundation for the revision, along with reference to other state, federal and local standards. Primary sources of engineering guidance included the Natural Resources Conservation Service (NRCS), the Federal Highway Administration (FHWA), and the U.S Army Corps of Engineers (USACE). Use was made of the Section 5600 Stormwater Design standards published by the Kansas City Chapter of the American Public Works Association. An opinion survey was conducted in June 2020 to determine what design professionals and other stakeholders prioritized for updates. Technical work was prepared by the study team to calibrate the two main hydrology methods for consistency in design.

A draft document was circulated for public review in the fall of 2022, with the comment period including a public meeting held on October 18, 2022. The primary area of revisions following the first comment period related to the design studies and review processes, lot grading, guidance on drainage easements, refinements to hydrologic methods and hydraulic design, and standards related to detention. A final draft was placed on second public comment from August 12 to September 7, 2023, with a presentation on the draft given to the Manhattan City Commission on August 22, 2023. No technical comments were received during the second review. The final edition of the document included a clarification regarding detention basin release rates as well as additional design guidelines for larger detention basins.

General Requirements

2.1 Applicability and Authorization

These criteria apply to all new stormwater systems, and to the improvement of existing stormwater systems. The criteria described herein also apply to the rehabilitation and/or replacement of existing stormwater systems.

The design of all stormwater systems shall be sealed by a Licensed Professional of the State of Kansas. The designer shall submit additional design information as the City Engineer requires, including but not limited to the requirements outlined in Section 3.0.

Stormwater systems shall comply with applicable laws and responsibilities of the federal and state regulatory agencies having jurisdiction, including the US Army Corps of Engineers, the Kansas Department of Health and Environment and the Kansas Department of Agriculture, Division of Water Resources.

2.2 Level of Service

2.2.1 Hydrology

The Hydrograph Method shall be used to determine the peak runoff flowrate (i.e., the design flowrates) for sizing of stormwater infrastructure with drainage areas less than 1 square mile (640-acres). For watersheds larger than 1 square mile, the designer shall consider other regional guidance for methodology, design storm, and calibration of results for approval by the City Engineer.

The Rational Method may be used in lieu of the Hydrograph Method for sizing of stormwater collection and conveyance systems with drainage areas less than 300-acres unless a stormwater detention facility is located upstream of the system.

See Section 5.0 for all the requirements related to determine hydrologic design inputs and calculations.

2.2.2 Conveyance

1. Capacity of the enclosed system and open channel system shall be designed for up to a 10-year annual recurrence interval (ARI) event.
2. Conveyance systems located within the floodway of the 100-year flood shall be designed for the 100-year peak flow.
3. Overflow pathways shall be provided for all conveyance systems to convey the excess flows from the 100-year ARI event not conveyed by the primary conveyance system.
4. Conveyance swales shall at a minimum convey the 10-year ARI event, the design event, unless the conveyance swale is also serving as an overflow pathway for larger less frequent design events.
5. Engineered channels shall at a minimum convey the 10-year ARI event, the design event, with the inundation from the 100-year ARI event included in the drainage easement.



6. Culverts shall be designed to convey the 10-year ARI event, the design event, unless the culvert is located beneath public streets classified as “arterials”. If the culvert is located beneath an “arterial” street, the 50-year ARI event shall be the design event.
7. Riprap aprons or other appropriate energy dissipation shall be provided for culverts and pipe outfalls, as needed in accordance with Section 6.0.
8. Grade control, when required, shall be designed per the requirements of this criteria.
9. The contributing drainage area to each distinct discharge location leaving a site shall not be altered from pre-existing conditions by more than 5 percent, except as may be approved by waiver following evaluation of downstream impacts.
10. System Type Application:
 - a. Enclosed systems shall be used for drainage within the right-of-way of improved streets and in residential areas or commercial areas not served by an appropriately protected natural or naturalized stream. Exceptions are made for water quality conveyance systems that are part of a post-construction stormwater BMP system designed in accordance with Section 9.0.
 - b. The upstream-most inlet to an enclosed system segment from a residential backyard area shall generally be provided prior to the contributing drainage area exceeding 2.0 acres.
 - c. For other developments with paved areas, the upstream-most public inlet or junction box must generally be placed where runoff will leave the development, at a suitable point in or adjacent to the receiving public right-of-way.
 - d. The overflow system design must begin at the upstream-most inlet. Natural and naturalized streams within an adequate stream corridor are the preferred means of conveyance for streams having a drainage area larger than 20 to 40 acres or when an enclosed system is no longer economical.
 - e. Other than roadside ditches in rural street sections, the use of engineered channels is generally discouraged, for reasons of maintenance, aesthetics, and environmental conservation.

2.2.3 Collection

Inlet placement in roadway sections shall limit the allowable gutter spread for the 10-year ARI event based on street typology and number of travel lanes, as described in Chapter 7.0.

2.2.4 Detention

Detention shall be provided on a site-by-site basis as determined in Section 8.0 Detention. See Section 8.0 for all stormwater detention requirements and standards.

2.2.5 Post-Construction Stormwater BMPs

Post-Construction stormwater BMPs shall be addressed for all new development and redevelopment projects that disturb greater than or equal to one acre, including projects less than one acre that are part of a larger common plan of development or sale, to protect water quality and reduce the discharge of pollutants to the maximum extent practicable. Post-construction stormwater BMPs shall be designed per Section 9.0 and referenced standards.



2.3 Waiver

These Stormwater Management Criteria are not intended to cover extraordinary situations, and, in such instances, waivers may be allowed, when justified and approved by the City Engineer. Waivers granted and the alternate basis of design shall be clearly documented in drainage submittals and/or on the plans as described in Section 3.0.

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Drainage Submittals

This section describes Drainage Submittal requirements, the type and content of the submittal as well as review and approval procedures. Drainage Submittals are required for new development, redevelopment, certain site improvements, and additions/expansions to existing stormwater systems and facilities. The purposes of Drainage Submittals are to:

- ▶ Review how a project is meeting the stormwater design criteria outlined in this document.
- ▶ Consider and understand stormwater management during the early stages of a project.
- ▶ Design projects around the natural topography of the site
- ▶ Protect property owners and the public from adverse drainage impacts resulting from construction and land development.
- ▶ Minimize risk of potential flooding of existing and proposed buildings
- ▶ Manage the amount of impervious area contributing to larger amounts of stormwater runoff.
- ▶ Identify and maintain sufficient overflow pathways.

3.1 Applicability

Generally, projects that propose to increase stormwater runoff or redirect stormwater discharge locations are required to submit a Drainage Submittal. The level of analysis of the Drainage Submittal required depends on a variety of factors, including development type, lot size, zoning district, amount of disturbed area, and amount of impervious area.

The following project types are exempt from the requirements of this Section:

- ▶ Interior renovations
- ▶ Building additions/expansions adding less than 4,000 square feet of additional impervious area
- ▶ Site improvements not associated with a building permit unless subject to other City-mandated submittal requirements.

New studies or updates to previous studies will be required whenever a project with a prior approved planning action proceeds to final plat or other final planning action or when the plan is subject to a major modification or request for time extension. The City Engineer may waive the requirement for a new study or accept a more limited technical update to a prior study when the results of previous studies are still substantially applicable to the conditions of the site and conforming the requirements of this Criteria. Where previous arrangements of tracts and parcels make full compliance with this Criteria impractical, the City Engineer may consider waivers to modify technical details to fulfill the intent of the performance standards in these Criteria.



3.2 Drainage Submittals

There are two types of Drainage Submittals: A Plot Plan with Elevations and Drainage Impact Study (DIS). A Plot Plan with Elevations is generally for certain Building Projects requiring a Building Permit through the Risk Reduction Department and certain Site Improvement Projects. The Drainage Impact Study has many aspects, any of which may be required for project. More information on the requirements for each type of drainage submittal and the processes for submittal are included in the following sections.

A digital workbook accompanies this drainage criteria manual that includes worksheets detailing the content of a Plot Plan with Elevations and various types of analyses for a Drainage Impact Study. The workbook includes checklists for required maps, information requests, and tables that must be provided in the requested format, unless otherwise approved by the City Engineer. A licensed professional must complete the information on the worksheets.

There are ten worksheets in the workbook, including an initial worksheet summarizing general information that will be completed early in the project process, and subsequent worksheets for each type of stormwater analysis that may be required for project approval:

- ▶ **General Information.** The General Information worksheet in the workbook includes fields for the applicant to fill in basic information about the project. The City Engineer will review the information on this worksheet and then determine which additional worksheets the applicant will need to submit for the appropriate level of Drainage Submittal.
- ▶ **Plot Plan with Elevations.** Applicable projects, as determined by the City Engineer, shall follow the checklist in this worksheet when preparing the project's Plot plan with Elevations. This worksheet is for certain Building and Site Improvement projects.
- ▶ **Hydrology.** Most projects will provide existing and proposed hydrologic information. Worksheet information includes watershed characteristics and runoff flow estimates.
- ▶ **Collection.** Any project that connects to or improves a public stormwater conveyance system must provide existing and proposed collection system information, including inlet sizing. Calculations for non-standard analysis or design must also be provided.
- ▶ **Conveyance.** Any project that connects to or improves a public stormwater conveyance system must provide existing and proposed hydraulic information.
- ▶ **Energy Dissipation.** Any project that must provide energy dissipation analysis or design, as required by Section 6.0.
- ▶ **Detention.** Any project that includes detention facilities, as required by Section 8.0 of the City's Stormwater Design Criteria, shall have design requirements listed, including release rates and storage volumes.
- ▶ **Post-Construction BMPs.** Any project that includes post-construction stormwater best management practices (PCBMPs), as required by Section 9.0 of the City's Stormwater Design Criteria, shall provide the evaluation and applicable design calculations in this worksheet. This worksheet is not inclusive, and any other calculations must be performed per the City of Manhattan's Post-Construction Stormwater BMP Manual. All evaluation and



design performed for BMPs, whether in the worksheet or not, along with any other supporting documentation must be submitted.

- ▶ **Grading Plan.** Checklists are included on two worksheets for Planning and Building Project Grading Plans. Grading Plans are required for Master Development Plans, Preliminary Plats and certain Building Projects for the purpose of evaluating the Lowest Floor or Lowest Opening Elevation in relation to stormwater surface flow, including overflow paths, and easement requirements. The Grading Plan also verifies that proposed site conditions mimic natural topography, maintain overflow pathways, provide appropriate buffer distances to protect stormwater management features and natural resources, and provide flood protection – both regulatory and local. Grading Plans for Planning Projects, or “Subdivision Grading Plans”, shall indicate Lots of Primary Concern (LPC).

3.2.1 Lot of Primary Concern

A Lot of Primary Concern (LPC) is a lot that has been identified on a Subdivision Grading Plan as requiring additional attention during development of the lot to certify the design of structure elevations and site development grading for regulatory and local flood protection in accordance with the subdivision Drainage Impact Study. Pre-existing plats with open, buildable lots may also be evaluated and tagged for LPC’s for the purposes of this criteria. Grading plans and grandfathered plats tagged for LPC’s shall be available to the public.

3.3 Project Types and Requirements

There are four types of projects that will require a Drainage Submittal as described below:

3.3.1 Planning Project

Planning projects are defined as projects that must apply for a land use action to the Community Development Department for approval by either the Manhattan Urban Area Planning Board, the City Commission, or the Board of Zoning Appeals prior to obtaining a building permit.

Land use actions that require a Drainage Impact Study include Master Development Plans, Plats and areas of annexation. Other land use actions, such as rezoning, conditional use permits and variances, may require a Drainage Impact Study if the nature of the action involves stormwater impacts due to site improvements activities, as described in subsection 3.3.3.

3.3.1.1 Plat Notation

The following notation shall be included on preliminary and final plats:

“A drainage impact study (DIS) with a proposed grading plan has been developed for this subdivision. Development shall remain at the proposed grades and elevations within drainage easements unless otherwise approved by the City Engineer.”

3.3.2 Building Project

Building projects are defined as projects that must submit a building permit application to the Risk Reduction Department for approval prior to commencing construction. Building permits are categorized as residential or commercial according to the currently adopted codes. Residential permits



are essentially for detached one- and two-family dwellings and townhouses not more than three stories above grade while commercial permits include everything else (multi-family dwellings, commercial and industrial building construction).

There are three types of drainage-related submittals with building permits:

- 1.) Standard Plot Plan
- 2.) Plot Plan with Elevations
- 3.) Drainage Impact Study

A standard plot plan is governed by related regulations for development in the MDC, currently adopted building codes, and industry-accepted engineering standards for site development grading. The standard plot plan does indicate an understanding of drainage, but its primary purpose is to indicate boundaries, setbacks, easements, site improvements, and the layout and elevations of structures on the lot. The above-grade Lowest Floor or Lowest Opening Elevations may be determined by flood protection, when applicable, but must always be set by good grading practices to shed water away from the structure within the context of the lot boundary topography without adversely affecting adjacent properties and in accordance with the subdivision Grading Plan, if present.

The Plot Plan with Elevations and Drainage Impact Study are formally classified as a Drainage Submittals. As such, the requirements are more substantial as discussed within this section.

3.3.21 Site Grading Best Practices

In addition to consideration of the flood protection elevation, the Lowest Floor (or Lowest Opening) Elevation of a structure shall be set to maintain a minimum ground slope of 1:20 (V:H) from the foundation to a point ten (10) feet from the building (excluding accessible routes and walks at building entrances) and maintain a minimum 1:50 (V:H) from that point to the lot line or top of bank of an overland flow conveyance system wherever feasible and without adversely impacting adjacent properties. The slope from the foundation may be reduced to 1/8-inch per foot across paved surfaces.

More information on best practices for individual lot development site grading is available through other City department sources.

3.3.22 Residential Permits

Typically, standard plot plans will be submitted with residential building permits. The Plot Plan with Elevations is required when the lot has been tagged as a Lot of Primary Concern (LPC). Lots being redeveloped shall submit a standard plot plan with the building permit application unless the lot was previously indicated as an LPC.

3.3.23 Commercial Permits

Commercial building permits will require a standard plot plan or a Plot Plan with Elevations and may additionally require a Drainage Impact Study depending on the size, location, presence of historical drainage issues, complexity of the proposed drainage requirements, and existence of a previous, relevant drainage study. If the commercial building project is on a Lot of Primary Concern (LPC), then a Plot Plan with Elevations is required. All other determinations shall be made by the City Engineer.



3.3.3 Site Improvement Project

Site improvement projects are defined as projects on a privately-owned lot or lots that are not covered by a building permit but are otherwise subject to site work permitting or required review, such as for land clearing as established in the Manhattan Development Code (Code of Ordinances Chapter 26) or for stormwater pollution prevention review (Code of Ordinances Chapter 32, Section 32-196). Site improvement projects include both grading projects and projects that create additional impervious area that are not captured by the building permit process. More formal review procedures are detailed for applicable projects that exceed either 1.0 acre of land disturbance and/or greater than 10,000 square feet of new impervious cover. Nothing within this Criteria shall imply a requirement to submit a project for review unless authorized by the Code of Ordinances.

3.3.4 Public Improvement Project

Public improvement projects are defined as projects that are initiated by the City to improve public infrastructure, ranging from small maintenance-related projects to larger road or infrastructure projects and city buildings. Public improvement projects are generally bid (or other forms of procurement) but also include projects that are constructed internally with City crews. Projects that do not install new, replace, or have the opportunity to replace stormwater infrastructure are exempt.

3.4 Procedures for Review and Approval

The goals of this Drainage Submittal review and approval strategy are to:

- ▶ Foster early understanding of the project
- ▶ Gain earlier opportunities to guide the completion of a drainage submittal.
- ▶ Promote adequacy of required Grading Plans
- ▶ Confirm acceptability of proposed easements earlier in the process

These goals are intended to reduce the adverse consequences of building elevations that are too low, uncontrolled drainage onto adjacent or neighboring properties, easements not wide enough for the underground conveyance or surface drainage path infrastructure, and lack of easements in backyards or for overflow paths and to reduce the amount of drainage complaints received by the City of Manhattan.

An overview of Drainage Submittal requirements is given in Table 3.1. Figures 3.1 through 3.4 present flow charts of the decision-making processes and reviews for each type.



Table 3.1: Drainage Submittal Requirements

Overview			
Type of Project	General Information	Plot Plan w/ Elevations	Drainage Impact Study ¹
Planning Project			
Pre-Application Meeting	R		
50% Design (Recommended)			O
Preliminary (Dev. Plan, Plat)			R
Final (Dev. Plan, Plat)			A
Building Project			
<i>Lot of Primary Concern (Residential or Commercial)</i>			
Building Permit Application		R	
<i>Commercial</i>			
Pre-Application Meeting	R		
50% Design (Recommended)			O
Permit Application			R
Site Improvement Project			
<i>Impervious < 10,000 SF and Grading < 1.0 acre</i>			
Applicable Permit or Review Request		R	
<i>Impervious ≥ 10,000 SF or Grading ≥ 1.0 acre</i>			
Pre-Application Meeting	O		
50% Design			O
Applicable Permit or Review Request			R
Public Improvement Project			
Project Scoping	O		
Concept Submittal			O
50% Field Check			R
90% Office Check			A
Final Check			A

Legend: R-Required, O-Optional, A-As Needed

Note: DIS may include any or all the worksheets as determined by City Engineer through the General Information Worksheet or Project Scoping.

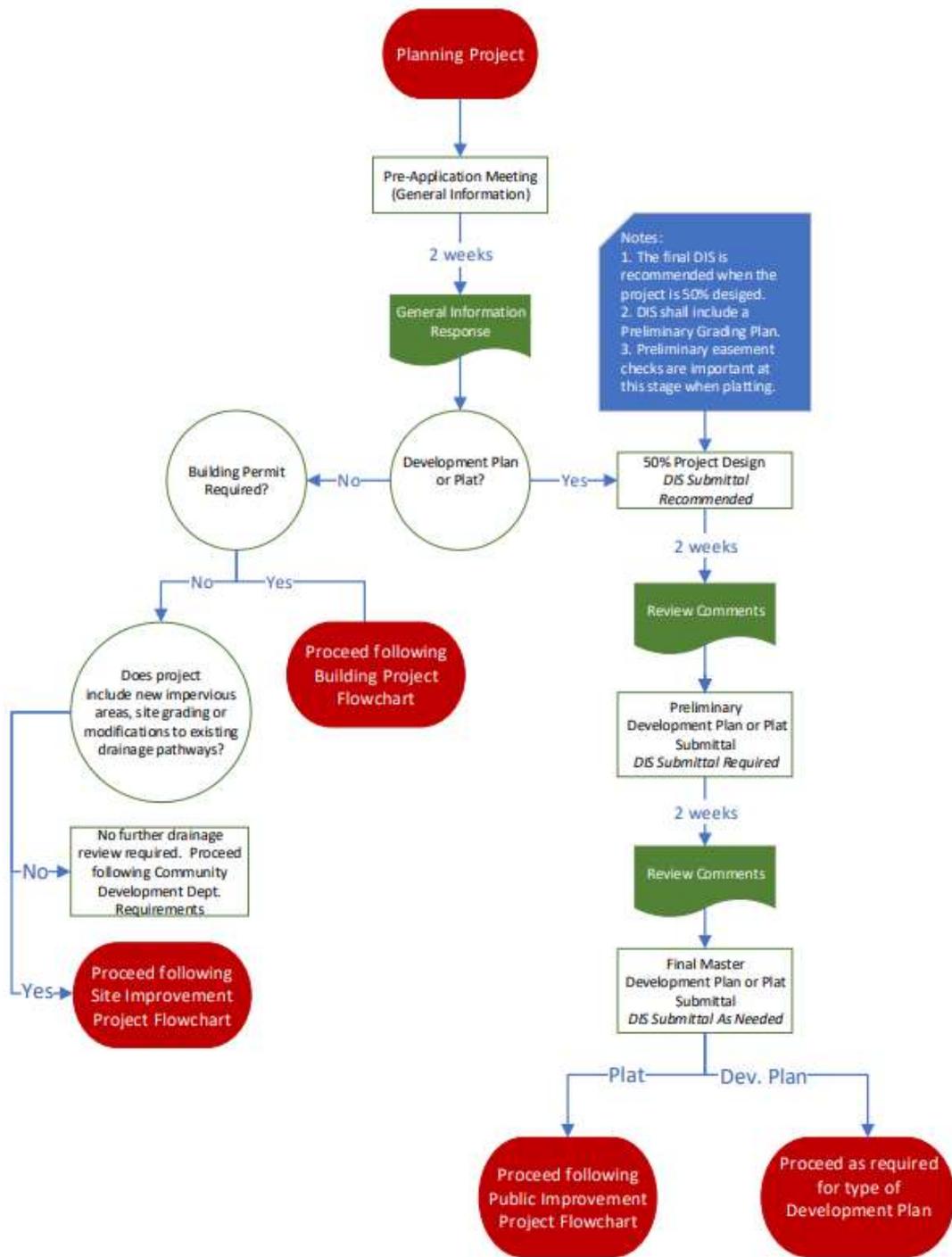


Figure 3.1: Planning Project Flowchart

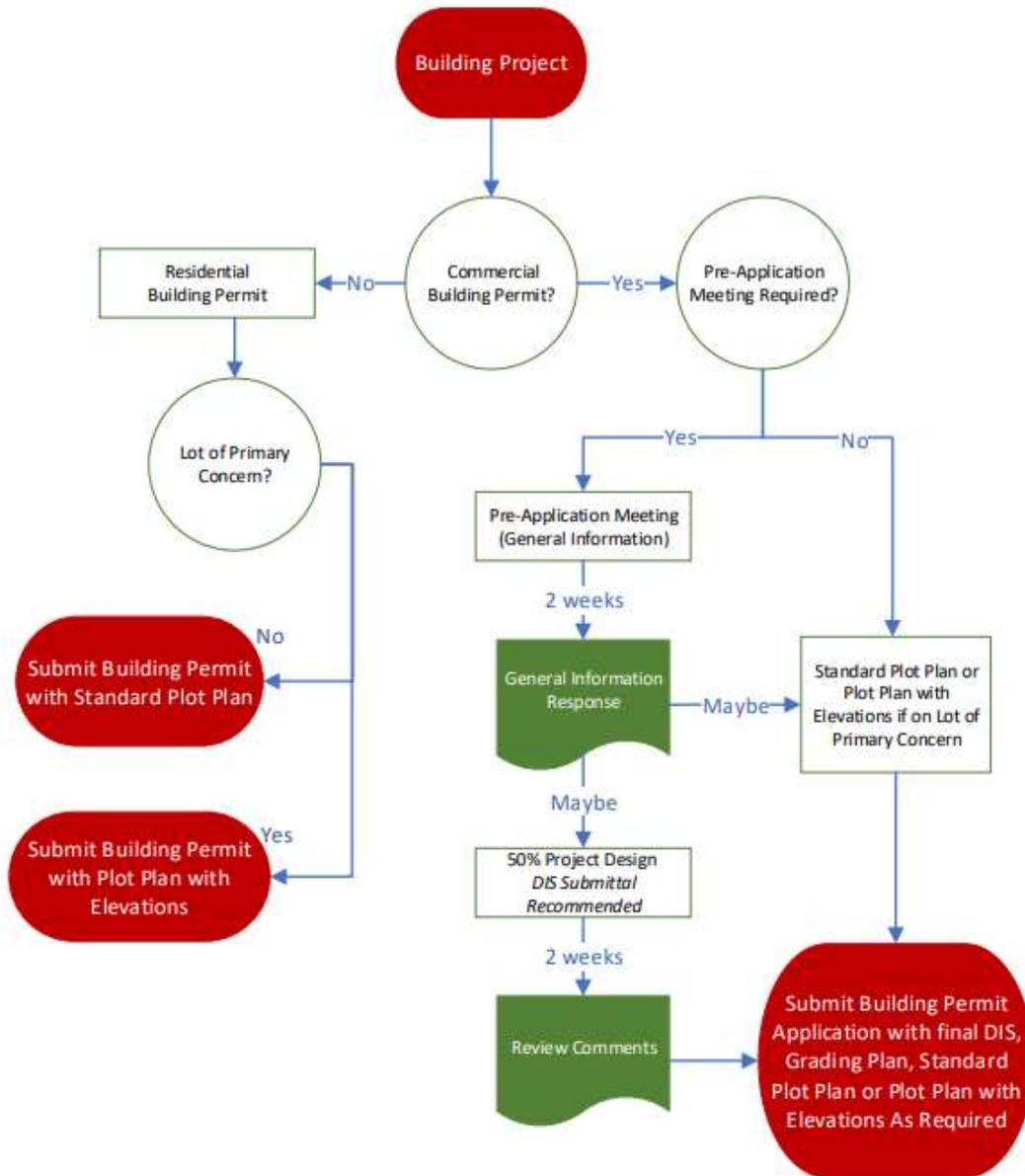


Figure 3.2: Building Project Flowchart

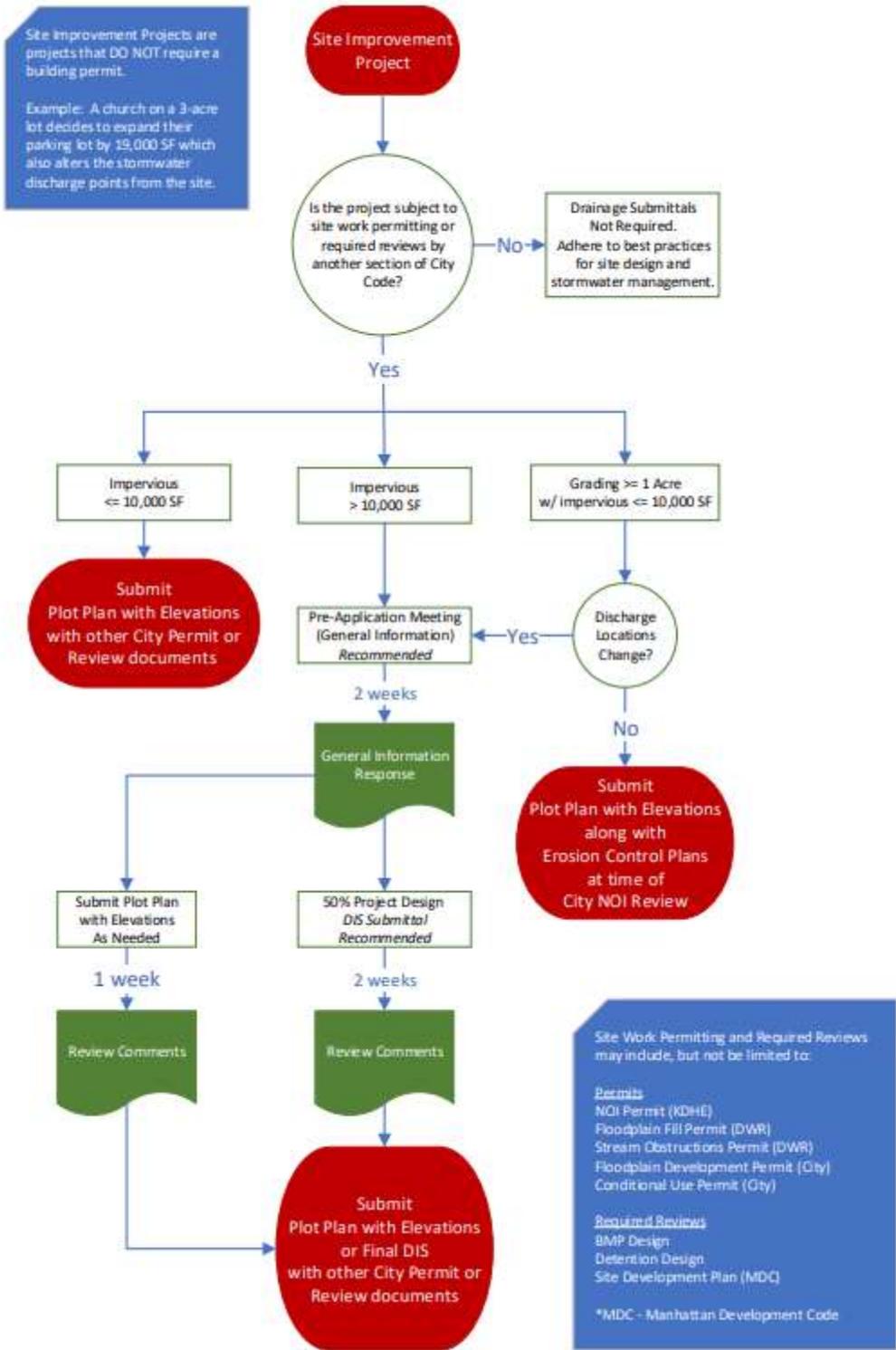


Figure 3.3: Site Improvement Project Flowchart

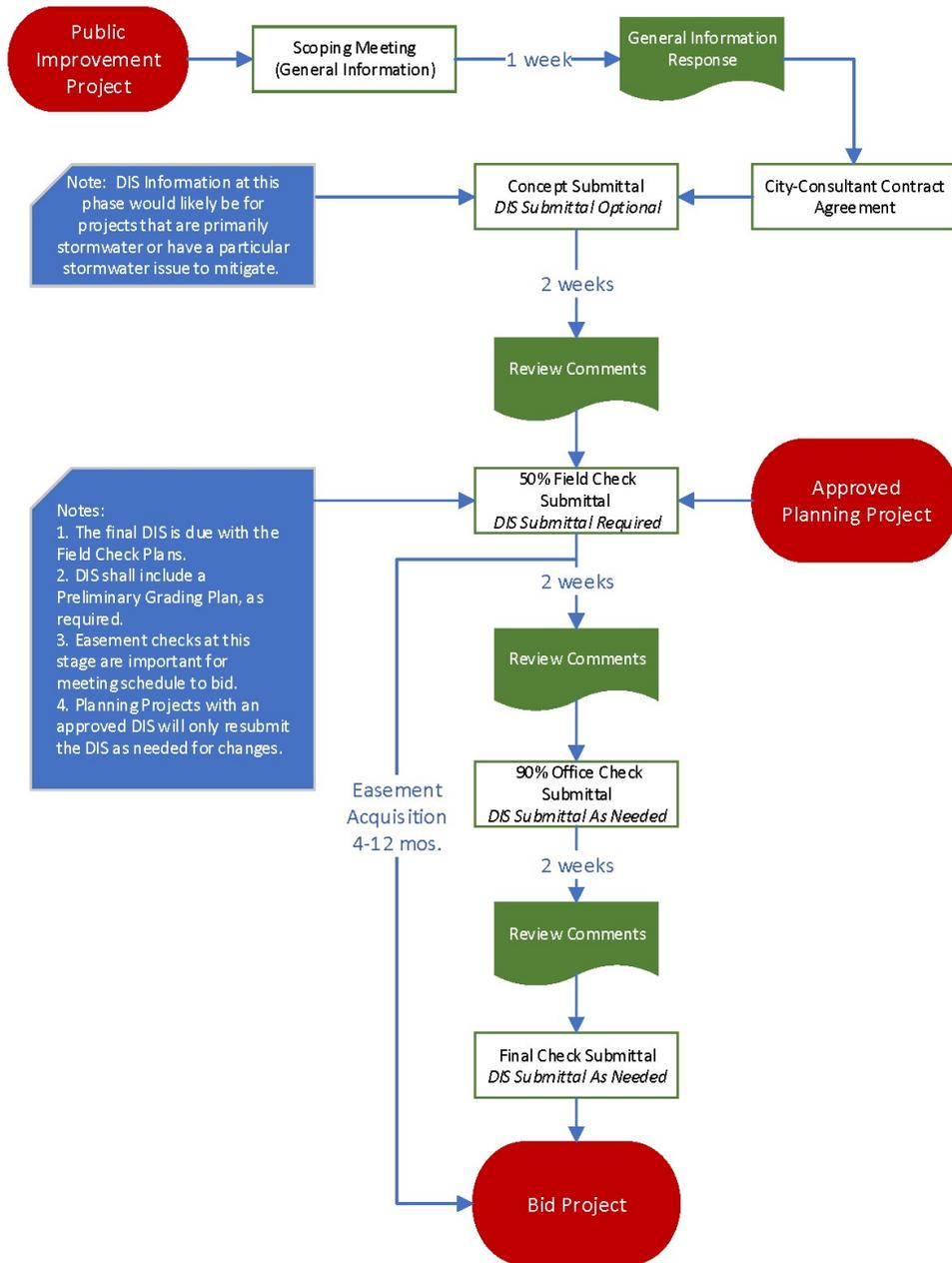


Figure 3.4: Public Improvement Project Flowchart

3.4.1 Study Documentation

The type and format of documentation required is intended to streamline and simplify the process of Drainage Submittals through standardization of information provided and minimization of written reports, allowing maps and tables to primarily tell the story of the drainage for the particular project.

3.4.1.1 General Information

Pre-application meetings may be held for planning projects, commercial building projects and site improvement projects. The Community Development Department and the Risk Reduction Department determine when a pre-application meeting shall be held for planning and building projects, respectively. When a pre-development meeting application is submitted through the City of Manhattan website for a planning or building project, the requirement of the General Information worksheet is fulfilled. Requests for a pre-application meeting for a site improvement project must include the General Information worksheet or equivalent in digital format (xlsx or pdf).

Following the pre-application meeting, Public Works Engineering staff will provide a response. If a drainage submittal is required, the response may include a watershed location map and will include known background information on previous studies or historic stormwater issues, indicate drainage submittal requirements and determine preliminarily what (other) permits may be needed for the project.

Public improvement projects designed by an external consultant will have a scoping meeting(s) and/or communications for the development of a design scope and fee for the project. The General Information worksheet is not required to be submitted by the consultant. However, Public Works Engineering staff may provide the standard General Information worksheet response as part of the scoping collaboration and negotiations.

3.4.1.2 Plot Plan with Elevations

A scalable Plot Plan with Elevations shall be submitted digitally on 8.5"x11" sheet size in pdf format utilizing the checklist in the worksheet. If necessary, 11"x17" sheet size may be used. It shall be included with the building permit or other permit or review requests for applicable site improvement projects, as required.

The final Plot Plan with Elevations submitted for the appropriate permit shall be signed and sealed by a licensed professional engineer, landscape architect or land surveyor registered in the State of Kansas. For Building Projects, the Plot Plan with Elevations must also include the following certification: *"I, [name and professional licensure designation], certify that this Plot Plan with Elevations has been field verified and is in compliance with the approved subdivision Grading Plan unless otherwise noted."*

3.4.1.3 Drainage Impact Study

DIS submittals shall be submitted digitally and include the following:

1.) Technical Memo

A Technical Memo in pdf format to document the date of the submittal, project name and City-assigned number, contents provided, and a brief narrative. The narrative should address any items that the digital workbook may not fully cover and explain any extenuating circumstances for design which will contribute to a better of understanding of the approach taken. The Technical Memo shall serve as a cover  sheet for the DIS and shall be provided with

each submittal, excluding concept submittals. The Technical Memo for each DIS submittal shall be signed and sealed by a Licensed Professional.

2.) DIS Worksheets

The digital workbook for drainage submittals includes the following worksheets that may be included in a DIS.

- General Information (and City's response)
- Hydrology
- Collection
- Conveyance
- Energy Dissipation
- Detention
- Post-Construction Best Management Practices (BMPs)
- Grading Plan – Subdivisions
- Grading Plan – Commercial Building Project

Instructions for the submittal of each type of assessment are included on each worksheet in the digital workbook. Worksheet submittals for the DIS shall be digital (xlsx and/or pdf). Many of the tables may be placed on the required maps if clarity is not compromised. When required, Grading Plans shall be submitted at the time of final Construction Drawings for planning projects and applicable building projects. However, preliminary grading plans are required with a project's DIS and may be part of any preliminary submittal of construction drawings, as appropriate. Maps and Grading Plans must be at an appropriate scale for the project. If full-size digital maps are provided, they must print legibly to half-size.

3.) Computer Program Printouts

Hydrograph or other output printouts from computer programs used to prepare the DIS shall be included, as appropriate, in an appendix. Such printouts shall also include pertinent input data files.

4.) Other Regulatory Agency Determinations

Other regulatory agency determinations relevant to the project, including the Corps of Engineers, Division of Water Resources, FEMA, etc., shall be incorporated in an appendix or by reference. When incorporated by reference, separate copies of such determinations shall be provided to the City Engineer.

5.) Related Studies

Other related studies, such as NRCS Websoil Survey HGS soil maps and other wetlands determinations or stream bank stability studies, shall be incorporated in an appendix or by reference. When incorporated by reference, separate copies of such studies shall be provided to the City Engineer.



3.4.2 Construction Documentation

This section governs the preparation of construction drawings and technical specifications for stormwater system projects.

3.4.21 General

Final conclusions of the DIS and detailed documentation of the proposed stormwater system design shall be shown in the construction drawings. Construction technical specifications shall be in accordance with the City standard specifications and may be supplemented per project as required. Drawings and specifications shall include all information necessary to build and check the design of the proposed stormwater drainage system.

The construction drawings (plan set) and project manual (contract documents and technical specifications) shall be sealed by a Licensed Professional as required and shall be submitted to the City Engineer for review and approval in accordance with Table 3.1 and any professional engineering or developer agreement.

The following subsections specifically address requirements for the construction drawings.

3.4.22 Scale

Drawings shall be drawn at the following minimum scales. Larger scales may be needed to clearly present the design. Bar scales shall be shown on each sheet for each scale.

Hydrology, Grading and other Maps: On-site 1"=200', Off-site 1"=1,000'

Plan: 1" = 50'

Profile: 1" = 5'

Structural Details: ¼" = 1'

3.4.23 Proposed Hydrology Map

Any project that involves hydrology calculations for a proposed stormwater system design that is included in the construction drawings shall also include a proposed hydrology map in accordance with the checklist on the Hydrology worksheet. Existing hydrology maps may be required by the City Engineer to document analysis and confirmation of the existing system for certain projects.

3.4.24 Proposed Hydrology and Detention Tables

Proposed hydrology and detention tables, as specified in the respective worksheets, shall be included in the construction drawings. It is recommended that hydrology and detention tables be placed on the hydrology map. When space is not available or clarity would be compromised, the tables may be included on a separate sheet. The technical methods, as noted on the hydrology worksheet, shall be included in the construction drawings within a separate table or in the notes for the sheet. For detention, both the reservoir routing inputs, as well as routing summary, shall be included in the construction drawings.

3.4.25 Post-Construction BMP Information

Post-Construction BMP information will be added to construction drawings as directed by the City Engineer for completeness of understanding of the proposed design. Larger projects may need to

include certain tables or calculations. Extended detention basins shall include tables similar to standard detention.

3.4.26 Proposed System Conveyance Map

Construction drawings that include a proposed stormwater system design for which hydrology and/or hydraulic calculations have been performed shall include a proposed system conveyance map in accordance with the requirements on the conveyance worksheet. Maintenance projects that remove and replace stormwater system elements without conducting hydrology and/or hydraulic calculations are exempt. The proposed system conveyance map may be combined with the hydraulic map if clarity allows.

3.4.27 Proposed Collection and Conveyance Tables

Proposed collection and conveyance tables, as specified in the respective worksheets, shall be included in the construction drawings. It is recommended that collection and conveyance tables be placed on the conveyance map. When space is not available or clarity would be compromised, the tables may be included on a separate sheet. The technical methods, as noted on the conveyance worksheet, shall be included in the construction drawings within a separate table or in the notes for the sheet.

3.4.28 Grading Plan

Many construction drawings include standard grading plans and should continue to do so as they have historically been done. However, planning projects and building projects shall include stormwater-specific Grading Plans as specified in the checklists in the appropriate worksheet. Notably, proposed critical elevations, building FFEs, and drainage path cross sections at critical locations must be provided on the Grading Plan. Subdivision Grading Plans must indicate Lots of Primary Concern (LPC). The building project may combine standard grading plan elements and stormwater grading plan elements for one sheet if clarity allows. The stormwater grading plan shall be individually sealed and signed by a Licensed Professional.

3.4.29 Plan & Profile Sheets

All proposed stormwater drainage systems shall be drawn in plan and profile view. All parts of the system shall be labeled in accordance with City of Manhattan standard drawing designations. Plan and profile sheets shall contain the following:

Plan View:

- 1.) North arrow and bar scale.
- 2.) Ties to permanent reference points for each system located outside of the street right-of-way, unless otherwise shown on a survey control sheet.
- 3.) Existing survey including such features as buildings, fences, trees, ponds, streams, pipes, culverts, inlets, structures, and utilities. Features should be labeled as necessary.
- 4.) Location of test borings.
- 5.) Existing and proposed right-of-way, property and easement lines.
- 6.) Existing and proposed grade contours at 1-foot intervals unless site conditions warrant otherwise.



- 7.) The 100-year floodplain and dimensions, when appropriate, to illustrate the setback from the top of bank of surface conveyance system to any building.
- 8.) Alignment for the centerline of the proposed underground enclosed or surface conveyance (when warranted) system. The street alignment may be used when street construction is included.
- 9.) A uniform set of symbols subject to approval by the City Engineer.
- 10.) The centerline of existing or proposed surface conveyance system within 50 feet of the of an enclosed drainage system and showing the direction of flow.

Profile View:

- 1.) The proposed storm sewer system along the alignment shall be shown in double lines, illustrating the thickness of the pipe.
- 2.) Station and invert elevations of manholes, junction boxes, inlets or other structures. Inverts shall include the flowline in and out of the structure.
- 3.) Length, size and slope of each underground enclosed or surface conveyance system segment. Slope shall be expressed in percent.
- 4.) Existing and finish surface grade along the centerline of underground enclosed or surface conveyance system in accordance with the alignment. Existing grade above the centerline as a dashed line and proposed finish grade by solid lines.
- 5.) Outlet works (e.g., end sections, headwalls, riprap aprons or other energy dissipation).
- 6.) Each existing utility line crossing the alignment shall be properly located and identified for type, size and material.
- 7.) Test boring information as applicable such as for rock.
- 8.) Headwater elevations for the 10-yr design storm shall be illustrated and labeled at the inlet of each culvert and the inlet of each structure that is part of stormwater drainage system, including a detention pond outlet, along with the hydraulic grade line (HGL) plotted between.
- 9.) Tailwater elevation.

3.4.2.10 Detail Sheets

City of Manhattan standard construction detail sheets shall be included as necessary for the project. Design details for nonstandard structures shall be indicated in the construction drawings. A minimum of one plan view and one sectional view shall be shown for each nonstandard structure. Additional views may be required if necessary to clearly define the design. A reinforcing bar list is not required; however, the grade, type, size and location of the bars shall be clearly indicated.

3.4.2.11 Cross Sections

Cross sections are required for certain stormwater system projects as direction by the City Engineer to provide a full understanding of the scope and magnitude of the project. Surface conveyance systems, particularly large, engineered channels, may require cross sections. Most underground enclosed conveyance systems do not require cross sections and are often illustrated with street construction.



However, large underground enclosed conveyance systems in established urban environments, whether open-trenched, bored or tunneled, may require cross sections.

Drainage Easements

4.1 Description

This section establishes the easement requirements associated with stormwater management. This section also outlines related requirements and land management tools such as stream corridors. Unlike other utilities, drainage ways and related infrastructure take on a variety of forms that include facilities with significant space and orientation requirements. Land dedicated to drainage can also serve multiple functions and have specialized maintenance requirements.

4.2 Easement Types

Easements shall be provided for all drainage system components and natural drainageways at the time of platting or public improvement. Easements shall be dedicated in accordance with the Manhattan Development Code and other guidance as provided by the City Attorney and City Engineer. Where elements of any stormwater collection, conveyance, drainage facility or overflow pathway are contained within rights-of-way dedicated to the public for transportation, separate easements are not required.

All easements shall be dedicated using standard forms and language as approved by the City. The easement types most associated with stormwater projects include:

- ▶ Drainage Easements – used to protect existing drainageways and all stormwater improvements, including surface overflow pathways. This is the primary easement type to be used in stormwater management.
- ▶ Utility Easements – primarily used for other utility facilities, such as water, sewer, gas, electrical, communications, etc. Where a drainage easement and general utility easement are intended to overlap, it will be best practice to designate a “Utility and Drainage Easement” with provisions suitable for both purposes. Overlapping areas should generally be limited to minimized to avoid conflicts. Acceptable overlaps generally include side and back lot lines where storm pipes are smaller than 24-inch diameter, in locations where utilities must cross the drainageway, or along the outer perimeter of stream buffer areas parallel to the flow of larger drainage systems, where there is limited potential for obstruction.
- ▶ Conservation Easements – generally used to conserve open space and natural areas within the City and which often include provisions related to the conservation of natural areas, including natural streams. Where drainage easements and conservation easements overlap, the area will be designated as a “Conservation and Drainage easement” with provisions suitable for both purposes.

- ▶ Maintenance Access Easements – generally used to establish suitable access paths from public rights-of-way to reach drainage facilities when such pathways would extend beyond the limits of other established easements.

4.3 Easement Sizing

Where easements for stormwater drainage and infrastructure are required, such easement shall conform to the following sizing guidance and other provisions. The requirements vary by type of facility and easement purpose. The specific type of easement to be used in each case is dictated by the provisions of Easement Types.

4.3.1 Underground Conveyance and Associated Inlets and Swales

Drainage and related easements shall be sufficiently sized for any underground drainage structure as well as the surface overflow pathway (see next section). Such easements shall have a minimum of 16 feet, or the width of the structures span measured from the outside wall plus 5.0 feet on either side, whichever is greater. This width may also be increased at the direction of the City Engineer to provide for trench safety and temporary spoils placement, particularly for trench depths in excess of 10 feet. Refer to latest OSHA requirements on bury depth and soil conditions (currently OSHA 29 CFR 1926, Subpart P (particularly Appendix F)).

For overlapping drainage and utility easements, the width may need to be expanded further to accommodate all utilities.

4.3.2 Overflow Pathways

All pipe and underground stormwater conveyance systems must be served by a companion overflow pathway system to accommodate flows that exceed the pipe system capacity. Formal designation of the overflow pathways and establishment of appropriate overflow easements shall begin when the cumulative drainage area to the system exceeds 2.0 acres. Overflow pathways may follow along the same alignment as the underground conveyance system, but in certain circumstances the drainage pathway may need to diverge to alternate alignments. Regardless of alignment, the overflow pathway shall be designated in a drainage easement having a minimum width of 10 feet. Such width may be expanded if calculations indicate that additional space is needed to accommodate the anticipated 100-year flow and freeboard, after final grading in the area. . The designation of the formal overflow pathway system may also include sections that run along curbed pavements, roadside ditches, or which cross public streets. In these cases, a separate designation is not required within the public right-of-way, but drainage studies and related calculations shall provide data regarded the anticipated inundation of such public roadways during the 100-year design event.

4.3.3 Engineered Channels

Where an engineered channel is to be constructed, the drainage easement width shall be sufficient to allow for conveyance of the flow and maintenance of the channel. The easement shall be a minimum of 30 feet or to the top of bank plus at least 10 feet on either side, whichever is greater. The top of bank shall have a 10-foot-wide strip on one side for vehicle access, where such area is graded to comply with access pathway requirements. The easement limits shall also be sufficient to contain the 100-year floodplain with a 1-foot freeboard along the facility.



4.3.4 Natural Stream Systems

Where an existing or restored natural stream is to be kept as dedicated means of drainage, the entire stream plus its associated stream buffer will be set aside in a conservation and drainage easement of sufficient size to fully contain the required stream buffer, as defined in Subsection 4.5 Natural Stream Corridors.

4.3.5 Surface Detention Basins

Where a surface detention basin is to be provided, the drainage easement shall extend a minimum of 5 feet clear of any structure and 10 feet clear around the perimeter of the greatest of (i) the top of bank lines, (ii) the 100-year water surface contour, or (iii) 1 foot outside of security fences.

4.3.6 Underground Detention Basins

Where an underground structure is used for detention, the drainage easement shall extend a minimum of 10 feet beyond the perimeter of any underground aggregate storage zone or outside edge of a buried storage pipe, chamber, or similar structure. If the underground basin allows a portion of the detention in the 100-year event to be retained at the surface level, then the drainage easement must also fulfill the criteria for surface detention basins.

4.3.7 Post-Construction Best Management Practices

Where post-construction Best Management Practices (PCBMPs) are provided as part of the system, drainage easements shall be provided. The following principles apply:

1. PCBMPs that are integrated within an enclosed stormwater system, such as hydrodynamic separators, media filter inserts, and baffle boxes, shall be incorporated within the widths established for the enclosed system, with additional width provided at the location of the facility, if needed, to provide for a minimum of 5 feet of width around the entire perimeter of the structure.
2. PCBMPs that are integrated with a stormwater detention system shall be incorporated within the same drainage easement serving the detention, and the outer perimeter extended where necessary to encompass all elements of the water quality facility.
3. PCBMPs not directly integrated with one of the previously listed systems shall be sized in a manner acceptable to the City Engineer and as required to encompass the entire BMP and provide suitable inspection and maintenance access. Additional information may be provided in the technical guidance for each BPCMP. Such PCBMPs may include, but not necessarily be limited to, bio-retention, vegetated swales, filter strips, infiltration trenches, extended dry or wet detention, etc.
4. PCBMPs which rely on, or which are compatible with natural area conservation may be located within a “conservation and drainage easement” with suitable provision to allow necessary maintenance of the PCBMP.
5. Certain types of private individual lot BMPs that are of an isolated nature and do not accept appreciable inflow from offsite properties may be exempted from the requirement to designate a drainage easement. In these instances, covenants may be used to ensure the City’s ability to inspect and enforce maintenance responsibilities as deemed necessary.

4.3.8 Maintenance Access Paths

A suitable access path from public rights-of-way is required to reach to all portions of the stormwater system. Supplemental easements are required when such pathways cannot be contained within the established drainage easement. All access pathways must originate from public right-of-way and must either terminate at another public right-of-way point or contain sufficient space for vehicles to turn around. The maximum length of travel from the public right-of-way to any point on the facility shall not exceed 800 feet. The minimum travel width shall be 10 feet when contained within or adjacent to a drainage easement. For detention basins located near the edge of a property line, a primary or supplemental access pathway must lie between the basin and the property line. Access paths that are not contained within or adjacent to a drainage easement shall allow a minimum 16 feet wide corridor that shall be an “access easement”. The traveling surface of the access pathway shall be graded to keep a longitudinal slope of no more than 12 percent and a maximum cross slope of 3 percent.

For underground enclosed systems, the access pathway may run along the top of pipe and/or the surface overflow swale and within the drainage easement. Private fences are not specifically prohibited within the access pathway provided that a gate or easily removable section is provided and a clear distance of 10 feet is maintained for travel in a direction parallel to the easement.

For natural streams within a conservation and drainage easement, access pathways need only extend to the outer limit of the conservation area. Grading within the conservation area is not generally required. In these cases, however, the location of the access path shall be brought to the edge of the conservation area at a location that would allow for the most reasonable extension and of sufficient intervals should maintenance be required in the future.

4.3.9 Other Features

Sizing requirements for other types of facilities will be determined by the City Engineer, based on similarity to facility types previously listed and any special requirements for operations and maintenance.

4.4 Maintenance Duties within Easements

City ordinance defines the basic assignment of duties for maintenance of areas and facilities within drainage easements. These assignments may be altered pursuant to the specific terms of easements and/or covenants. For new projects designed in accordance with this criterion, the terms of any covenants shall be in accordance with the requirements of the City at the time of development.

4.5 Natural Stream Corridors

Natural stream corridors with adequate buffer zones are preferred as the primary means of storm drainage. Buffer zones adjacent to permanent streams and drainage paths provide numerous environmental protections, flood reduction, and resource management benefits that can include the following:

- Stabilizing stream banks
- Preserving a designated space for the overland conveyance of stormwater
- Providing an overflow path for floodwater when enclosed systems are overwhelmed



- Reducing erosion and sediment entering the stream
- Providing infiltration of stormwater runoff
- Potential recreational opportunity
- Removing pollutants delivered from urban stormwater

In order to function properly, a stream corridor must be of sufficient width to encompass the natural stream channel and an appropriate buffer width.

1. Whenever a natural stream has been designated for preservation and protection, a buffer width shall be established, with widths established as given in Table 4.1.

Table 4.1: Minimum Buffer Widths for Natural Streams

Contributing Drainage Basin Size	Buffer width, from the toe of bank outwards, measured separately in each direction (minimum)
Less than 20 acres 20 acres to 40 acres	20 feet 30 feet
40 acres to 80 acres 80 acres to 160 acres	50 feet 60 feet
160 acres to 320 acres 320 acres to 640 acres	80 feet 100 feet
Greater than 640 acres	120 feet

- a. For the purposes of this chapter, the “toe of bank” is the point where the lowest primary stream bank intersects the bottom plane of the stream. For highly irregular stream shapes the toe is defined as the horizontal location that best fits a simple trapezoidal approximation of the stream channel. See Figure 4.1 for examples on locating the toe of bank. On many channels, the “toe of bank” will be similar or close to the “ordinary high-water mark” as determined under US Army Corps of Engineers guidance.
 - b. The buffer distances here only apply to areas adjacent to a natural stream and may be omitted or modified around the boundary of a pond or lake,
2. The buffer width shall be expanded in locations, if needed, to ensure that the outer edge of the buffer is at least 10 feet away from a point on the ground that would be intercepted by a hypothetical 3:1 (H:V) slope extending from the toe of bank (See Figure 4-2). During the platting process, the City Engineer may also require the buffer to be expanded to address unique geometric or instability concerns of a given channel. In such cases, a special stream bank stability assessment may be added to the requirement of the Drainage Impact Study.
 3. A combination conservation and drainage easement shall be established at a minimum to fully encompass the buffer zone established using the criterial given above. Where the inundation limits for a 100-year design event for a given stream would inundate areas outside the buffer defined above, the excess area can either be  protected as part of a natural area with a

conservation easement, or the excess area would be placed within a drainage easement that otherwise permits more developed use of the area.

4. No construction or disturbance of any type, including clearing, grubbing, stripping, fill, excavation, linear grading, paving, or building should be allowed within the conservation easement, except as required for routine maintenance (i.e., removal of channel blockage and fallen trees) or by permission of the City Engineer. Dense stands of native vegetation should be maintained. Exception may be allowed by the City Engineer for pedestrian trails or low impact recreational features such as benches, signage, etc. Selected recreational amenities including trails and benches may be allowed by permission of the City Engineer. Dedication language on the plat and related covenants should be used to codify these requirements.
5. Designation of the easements on a natural stream and buffer are required whenever a natural stream protection area is being incorporated into a new development or redevelopment plan. For other existing natural streams in previously developed areas, the recommended buffer widths are retained for technical guidance, but formal designation of easements is not necessarily required.
6. A plan for maintenance within stream buffer areas should be outlined at the time of dedication and enforced through appropriate provisions of the easements, covenants, and any associated supplemental maintenance documentation. In order to conserve the natural functions of stream, it is recommended such plans contain the following or similar provisions:
 - ▶ Recommended Maintenance Activities in Conservation Areas for Natural Streams
 - Removal of dead trees/brush and trash
 - Removal of debris that could cause flooding
 - Selective tree trimming or tree removal to mitigate safety hazards or that could cause flooding
 - Selective (spot) chemical spraying for noxious weeds
 - Cutting or mowing of non-woody vegetation or other management practices shown to enhance natural conditions when completed as part of an approved restoration plan.
 - ▶ Discouraged Activities within Conservation Areas for Natural Streams
 - Cutting or mowing of non-woody vegetation beyond that approved as part of a restoration plan
 - Non-selective chemical spraying



Figure 4.1: Defining the Location of Toe of Bank, Example

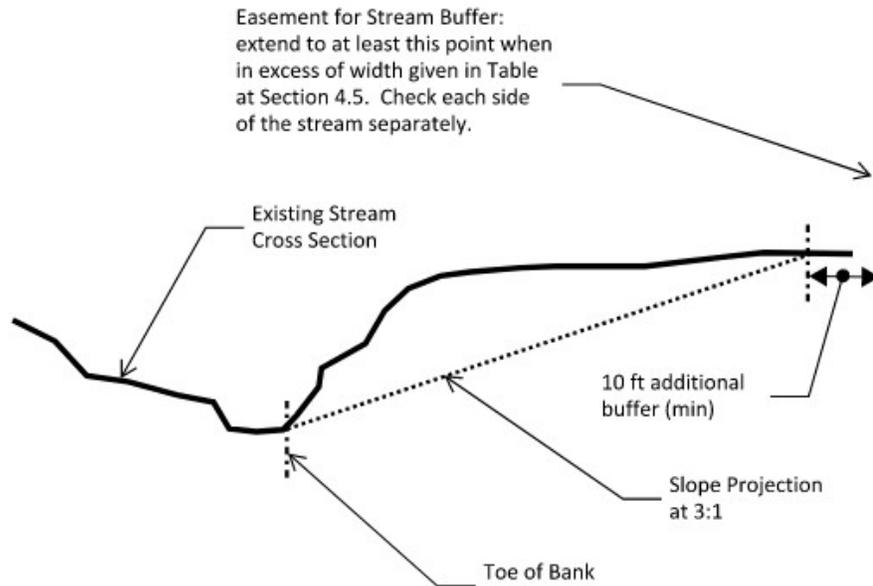


Figure 4.2: Additional Stream Setback for Steep Banks

4.6 Designated Special Flood Hazard Areas

The City is a participant in the National Floodplain Insurance Program (NFIP). As such, the City has adopted floodplain zoning as a means of protecting property and limiting flood-related losses. The Manhattan Development Code contains the floodplain management requirements (currently Article 26-6) for the City. These requirements include the adoption by the City of the latest FEMA adopted Special Flood Hazard Area (SFHA) designations, as well as any supplemental flood-related zoning designations associated with future risks.

All floodplain requirements are in addition to the standards outlined in this technical manual. Nothing contained herein shall be interpreted to minimize or contradict the floodplain management requirements of the City.

Where drainage easements are designated, such easements may be extended to encompass the entire special flood hazard areas, as detailed on the effective floodplain management maps in effect at that time. Such designation is not required for enforcement of floodplain management requirements. Over time, floodplain management maps may change, and easement limits defined by earlier maps may or may not fully contain all hazard areas as later defined.

Hydrology

5.1 Description

This section establishes the hydrologic calculations and assumptions that shall be used to design the stormwater systems. Hydrologic calculations affect the sizing of the stormwater systems. Standardizing assumptions for parameters of the hydrologic calculations promotes consistency in the capacity, materials, and maintenance of the stormwater system, and helps streamline the review process.

As watersheds develop, urban flooding concerns are more frequently related to flash flooding as opposed to the riverine flooding associated with the effective (Federal Emergency Management Agency (FEMA) floodplains. The National Weather Service (NWS) characterizes flash flooding as a quick rise in water level following 3 to 6 hours of heavy rainfall, often from thunderstorms. Urban and suburban areas are more prone to flash flooding than rural areas. This is due to increased impervious surfaces that prevent rainfall from infiltrating into the soil and hydraulically efficient stormwater systems that collect and convey stormwater to the receiving streams. These criteria focus on providing stormwater management related to short, intense rainfall events.

5.2 Runoff Methodologies

Both the Hydrograph Method (the preferred methodology for assessing hydrological conditions for the design of stormwater infrastructure) and the Rational Method, outlined in these criteria, require the designer to determine the composite curve number of each drainage area to compute stormwater runoff.

The composite curve number shall be determined as follows:

1. Delineate drainage areas.
2. Identify and delineate the Hydrologic Soil Group (HSG) within each drainage area per the United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Web Soil Survey.
3. Identify and delineate land use within each drainage area.
4. Determine the composite curve number (CN) of each area delineation based on the land use and hydrologic soil group per Table 5.1. Urban lawn soils are estimated as shown. Soil classifications must be taken from the latest available NRCS Soil Survey (www.websoilsurvey.nrcs.usda.gov)

Table 5.1: Composite CN by Land Use and Soil Group



Land Use	Impervious (%)	Composite CN by Hydrologic Soil Group			
		A	B	C	D
Natural and Agricultural Areas (selected classifications)¹:					
Woods (good condition with underbrush)	0%	30	55	70	77
Woods (poor condition with limited underbrush)	0%	45	66	77	83
Meadows (no grazing)	0%	30	58	71	78
Pasture, Good Condition	0%	39	61	74	80
Pasture, Fair Condition	0%	49	69	79	84
Pasture, Poor Condition	0%	68	79	86	89
Row Crops (good with best practices)	0%	61	70	77	80
Row Crops (poor with least controls)	0%	72	81	88	91
Fallow Ground (Bare Soil)	0%	77	86	91	94
Typical Urban and Developed Areas (with all pervious as urban lawn):					
Impervious Surface	100%	98	98	98	98
Urban Lawn	0%	62	69	74	80
Residential – Single Family/Duplex	35%	75	79	82	86
Residential – 3 to 6 Dwelling Units per building (includes mobile home parks)	60%	84	86	88	91
Residential – More than 6 Dwelling Units per building	80%	91	92	93	94
Public/Semi-Public (Schools, Govt, etc.)	70%	87	89	91	93
Industrial	75%	89	91	92	94
Commercial/Business	85%	93	94	94	95
Central Business District	95%	96	97	97	97

Note:

- (1) CN Values derived from Chapters 7, 8, 9 and 10 of the National Engineering Handbook (NRCS 2002, 2004a, 2004b and 2009).
- (2) For urban lawns, the NRCS method generally assumes that urban lawns are comparable to pasture in good condition in the same HSG. To account for compaction and reduced infiltration from shallow rooted lawns, however, the CN for HSG A and HSG B soils has been increased as shown, reflecting less than good condition. HSG C and HSG D soils are not modified.
- (3) Well-compacted gravel under regular or frequent vehicle traffic will be considered impervious surface. Gravel areas used for storage, pedestrian trails or other less intensive purposes will be considered the equivalent of Fallow Ground (Bare Soil). Incidental gravel used in landscaping beds need not be considered separately from other vegetated areas.
- (4) When there is confidence in the actual proposed layout of impervious structures, including allowance for future infill, it is preferable to use actual impervious percentages instead of these generalized land use ranges to estimate composite CN.

5. Calculate the composite CN of the drainage area. See Table 5.2 and Equation 5.1.

Table 5.2: Example Composite CN Calculation

Drainage Area ID	Area (ac)	Land Use	HSG	CN	CN X Area (ac)
Sub Area 1	5	Pasture, Fair Condition	C	79	395
Sub Area 2	3	Residential – Single Family, Duplex	C	82	246
Sub Area 3	2	Lawn	D	80	160
Total	10 ⁽¹⁾	N/A	N/A	N/A	801 ⁽²⁾
CN_{Composite, DA}	801 / 10 = 80 (rounded)				

Notes:

(1) Use this value as the “Total Area” in Equation 5.1

(2) Use this value as the “Total Product” in Equation 5.1.

$$\text{Equation 5.1: } CN_{Composite,DA} = \frac{\text{Total Product}}{\text{Total Area}}$$

where: $CN_{Composite,DA}$ = Composite CN for the Drainage Area

$Total Product$ = Sum of CN x Area per Table 5.2 (ac)

$Total Area$ = Sum of delineated areas per Table 5.2 (ac)

5.2.1 Hydrograph Method

The Hydrograph Method (NRCS 2007a, HEC 2018) is the preferred methodology for assessing hydrological conditions for the design of stormwater infrastructure. The Hydrograph Method shall be used to determine the peak runoff flowrate, which is the design flowrate, for sizing of stormwater infrastructure with drainage areas less than 1 square mile (640-acres).

For watersheds larger than 1 square mile, the designer shall consider other regional guidance for methodology, design storm, and calibration of results. These other resources include NRCS, USGS, KDOT and available FEMA flood insurance studies. In all cases, if a locally adopted watershed study is available, the estimates provided in those studies should be considered.

Steps for Hydrograph Method (computer analyses):

1. Calculate the time of concentration for the drainage area per Subsection 5.4.
2. Calculate the lag time for the drainage area per Subsection 5.5.
3. Define Loss Method and parameters:
 - Method – SCS Curve Number
 - Curve Number – Composite CN
4. Define Transform Method
 - Method – SCS Unit Hydrograph



- Graph Type – Standard (PRF 484)
 - Lag Time
5. Develop the rainfall hyetograph using the design event duration, distribution, and depth from Subsection 5.3.
 6. Computer Simulation Time Interval: 1 minute
 7. Compute the peak runoff flowrate for the drainage area.

5.2.2 Rational Method

The Rational Method (FHWA 2013) may be used in lieu of the Hydrograph Method for sizing of stormwater collection and conveyance systems with drainage areas less than 300-acres unless a stormwater detention facility is located upstream of the system. If stormwater detention facilities are involved in the analyses area, then Rational Method is not applicable, the Hydrograph Method would be required.

When using the Rational Method, the design flowrate shall be equal to the peak runoff flowrate, calculated per Equation 5.2. The coefficients used for the Rational Method in these criteria differ from those in other references as they have been normalized directly to the composite CN value and have been calibrated to provide consistency with results from the Hydrograph Method using Manhattan area rainfall.

Steps for Rational Method:

1. Calculate the time of concentration for the drainage area per Section 5.4.
2. Determine the Rational Method correction factor (m) from Table 5.3.

Table 5.3: Rational Method Correction for Time of Concentration

Time of Concentration (minutes) (a)	Correction Factor (m)
5-6	0.85
7-8	0.90
9-12	0.95
13+	1.00

3. Determine the Rational Runoff Coefficient (C) from Table 5.4 using the composite CN for the drainage area. If the composite CN is not included in Table 5.4, linearly interpolate between tabular values included in the table to determine the Rational Runoff Coefficient.

Determine the rainfall intensity per the Appendix A1 based on the time of concentration (Tc).

Table 5.4: Rational Runoff Coefficients

Composite CN	Rational Runoff Coefficient (C) by Annual Recurrence Interval (ARI) in years					
	2	5	10	25	50	100
98	0.97	0.98	0.99	0.99	0.99	1.00
92	0.79	0.84	0.87	0.91	0.93	0.94
86	0.58	0.67	0.72	0.78	0.82	0.85
80	0.41	0.51	0.57	0.65	0.70	0.75
74	0.26	0.36	0.43	0.52	0.58	0.63
68	0.14	0.23	0.31	0.40	0.46	0.52
62	0.06	0.13	0.19	0.28	0.35	0.41

Note: Rational Runoff Coefficients were normalized by the City of Manhattan to correspond to the Hydrograph Method results described herein.

4. Compute the peak runoff flowrate for the tributary drainage area per Equation 5.2.

Equation 5.2: $Q = mCiA$

- where:
- Q = Peak runoff flowrate (cfs)
 - m = Rational Method Correction Factor per Table 5.3
 - C = Rational Runoff Coefficient per Table 5.4
 - i = intensity (in/hr) where duration is equal to T_c
 - A = Drainage area (ac)

5.3 Design Event

Design event definition requires assumptions for the rainfall duration, distribution, and depth.

1. **Rainfall Depths & Intensities.** The rainfall depths to be used for hydrograph method are given in Appendix A1. Intensity-duration-frequency curves to be used in the Rational Method are given in Appendix A2.
2. **Duration.** Because the focus of these design criteria is to manage stormwater for the rainfall events affecting the City, which primarily consists of urban and suburban areas concerned with flash flooding, a 6-hour event duration shall be used for design of stormwater management systems and facilities. or drainage areas greater than one square mile, a 24-hour event duration shall be used.
3. **Distribution.** The rainfall distribution in Appendix A3 shall be used for the 6-hour event duration. The latest authorized NRCS 24-hour distribution appropriate for Riley County shall be used for any 24-hour event scenarios (NRCS 2019a). The SCS Type II 24-hour distribution is no longer authorized for use by the NRCS but may be used for legacy calculations with the approval of the City Engineer.

5.4 Time of Concentration

The time of concentration (T_c) shall be equal to the longest travel time for stormwater runoff from the most hydraulically distant point in the tributary drainage area to the point of interest. T_c shall be calculated per the method recommended by the NRCS (2010), as given in Equation 5.3.

$$\text{Equation 5.3:} \quad T_c = T_{sheet} + T_{shallow} + T_{system}$$

where:	T_c	=	Time of concentration (min)
	T_{she}	=	Travel time for sheet flow (min)
	T_{shall}	=	Travel time for shallow concentrated flow (min)
	T_{system}	=	Travel time for the conveyance system (min)

5.4.1 Sheet Flow

Sheet flow is stormwater runoff over plane surfaces, where runoff depths are very shallow and have yet to concentrate (NRCS 2010). Time of sheet flow shall be calculated per Equation 5.4. The maximum length for sheet flow runoff is 100-feet.

$$\text{Equation 5.4:} \quad T_{sheet} = 60 \frac{0.007(nL)^{0.8}}{(P_2)^{0.5}S^{0.4}}$$

where:	T_{sheet}	=	Travel time for sheet flow (min)
	n	=	Manning's roughness coefficient per Table 5.5
	L	=	Flow length (ft); when L is less than or equal to 100 feet
	P_2	=	2-year, 6-hour rainfall depth (in); use 2.56 in, the 2-year, 6-hour rainfall depth from 2014 KDOT Rainfall Depth Tables for Riley County, Kansas (KDOT, 2014)
	S	=	Slope of hydraulic grade line (ft/ft)

Table 5.5: Roughness Coefficients for Sheet Flow

Surface Description	Manning's Roughness Coefficient (n) ¹
Smooth Surfaces ²	0.011
Urban Lawn/Mowed Turf Grasses	0.150
Cultivated Soils, Residual Cover <=20%	0.06
Cultivated Soils, Residual Cover >20%	0.17
Short Grass Prairie	0.15
Dense Native Grasses ³	0.24
Range, Natural	0.13
Woods, Light Underbrush ⁴	0.40
Woods, Dense Underbrush ⁴	0.80

Notes:

- (1) Composite Manning's n values from compiled information. Only for use in Sheet Flow equation 5.4 for depths of flow less than 0.1 foot.
- (2) Smooth surfaces such as concrete, asphalt gravel, or bare soil
- (3) Includes species such as weeping lovegrass, bluegrass, buffalo grass, blue grama grass, and native grass mixtures
- (4) Consider cover to a height of approximately 0.1 feet that would obstruct sheet flow.

5.4.2 Shallow Concentrated Flow

Shallow concentrated flow is the intermediate flow after the sheet flow has ceased and before it enters the stormwater conveyance system (NRCS 2010). Time of shallow concentrated flow shall be calculated per Equation 5.5.

Equation 5.5:
$$T_{shallow} = \frac{L}{60v}$$

where: T_{shall} = Travel time for shallow concentrated flow (min)
 L = Flow length (ft)
 v = Average flow velocity (ft/s) calculated per Velocity Equations provided in Table 5.6 or as shown in Appendix A4.

Table 5.6: NRCS Velocity Equations

Flow Type	Velocity Equation ⁸
Pavement and small upland gullies ¹	$v = 20.328 * S^{1/2}$
Grassed waterways ²	$v = 16.1345 * S^{1/2}$
Nearly bare and untilled (overland flow); and alluvial fans in western mountain regions ³	$v = 9.965 * S^{1/2}$
Cultivated straight row crops ⁴	$v = 8.762 * S^{1/2}$
Short-grass pasture ⁵	$v = 6.692 * S^{1/2}$
Minimum tillage cultivation, contour or strip-cropped, and woodlands ⁶	$v = 5.032 * S^{1/2}$
Forest with heavy ground litter and hay meadows ⁷	$v = 2.516 * S^{1/2}$

Notes:

- (1) Assumes Depth is 0.2 feet and Manning's Roughness Coefficient is 0.025
- (2) Assumes Depth is 0.4 feet and Manning's Roughness Coefficient is 0.050
- (3) Assumes Depth is 0.2 feet and Manning's Roughness Coefficient is 0.051
- (4) Assumes Depth is 0.2 feet and Manning's Roughness Coefficient is 0.058
- (5) Assumes Depth is 0.2 feet and Manning's Roughness Coefficient is 0.073
- (6) Assumes Depth is 0.2 feet and Manning's Roughness Coefficient is 0.101
- (7) Assumes Depth is 0.2 feet and Manning's Roughness Coefficient is 0.202
- (8) Equations all taken from NRCS 2010. A graphical solution to these equations is shown in Appendix A4.

5.4.3 System Flow

System flow describes the conveyance portion either via open channels or within the enclosed system (NRCS 2010). Time of system flow shall be calculated per Equation 5.6.

Equation 5.6:
$$T_{system} = \frac{L}{60v}$$

where: T_{system} = Travel time for the conveyance system (min)
 L = Flow length (ft)
 v = Average flow velocity (ft/s) per Equation 5.7

Equation 5.7:
$$v = \frac{1.49}{n} R^{2/3} S^{1/2}$$

where: v = Average flow velocity (ft/s)
 n = Manning's roughness coefficient (Table 6.2)
 R = Hydraulic radius (ft) per Equation 5.8
 S = Slope of the hydraulic grade line (ft/ft)



Equation 5.8: $R = \frac{A}{P}$

where: $R =$ Hydraulic radius (ft)
 $A =$ Cross-sectional flow area (sf)
 $P =$ Wetted perimeter (ft)

5.5 Lag Time

Lag time is the delay between the center of mass of the excess rainfall to the peak discharge of the runoff hydrograph (NRCS 2010). Lag time shall be calculated per Equation 5.9.

Equation 5.9: $T_{lag} = 0.6 * T_c$

where: $T_{lag} =$ Lag time (min)
 $T_c =$ Time of concentration (min)

5.6 Computer Programs

The following is a list of pre-approved computer programs for analyzing hydrology. Alternate computer programs may be substituted with written approval by the City Engineer.

- ▶ HEC-HMS
- ▶ WinTR-55
- ▶ Autodesk Storm and Sanitary Analysis
- ▶ Autodesk Hydraflow Extensions
- ▶ Bentley OpenFlows CivilStorm
- ▶ Bentley OpenFlows PondPack

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Conveyance

6.1 Description

A Stormwater Conveyance System shall be provided to transport stormwater runoff from one location to another, usually from a project site to a receiving water body such as a natural or naturalized channel or from a project site to the existing municipal separate storm sewer system (MS4). Stormwater may be conveyed either by a surface conveyance system or within an underground enclosed conveyance system.

- ▶ Surface conveyance systems generally include Open Channel Systems, such as:
 - Natural Streams
 - Naturalized Channels
 - Conveyance Swales
 - Engineered Channels
 - Water Quality Channels
- ▶ Underground enclosed conveyance systems generally include:
 - Culverts:
 - Enclosed Systems

Some Stormwater Conveyance Systems concentrate flow, and the discharge of these concentrated flows may threaten the integrity of natural or naturalized channels. This section also covers the energy dissipation and grade control measures to protect natural streams, naturalized channels, and engineered channels.

6.2 Requirements

6.2.1 Underground Enclosed Conveyance System

1. The underground conveyance system shall convey the 10-year annual recurrence interval (ARI) event, the design event such that the water surface elevation at each structure (manhole, junction box, and inlet) is at least 0.5 feet below any inlet opening or rim elevation.
2. The minimum circular pipe diameter for a pipe that is or will be part of the public Stormwater Conveyance System shall be 15 inches.
3. The minimum cover over the underground enclosed conveyance system shall be 18 inches.
4. Pipe materials shall be reinforced concrete in right-of-way and public drainage easements.

- a. Pipe materials other than reinforced concrete which comply with City specifications may be approved in non-paved areas outside of the right-of-way. Requests for alternate pipe materials must be submitted as a request for Waiver in accordance with Section 2.0.
5. The minimum pipe slope for the underground enclosed conveyance system shall be that which maintains a minimum velocity of 3 feet per second (flow full condition), but no less than 0.3%.
 6. Reinforced concrete pipes with slopes greater than or equal to 10% shall have joint connectors at each pipe joint.
 7. For all pipe materials, when pipe slope is greater than or equal to 15%, concrete collars shall be provided to anchor pipe. Pipe anchor spacing shall be per Table 6.1:

Table 6.1: Pipe Anchor Spacing Requirements

Pipe Slope, S (%)	Maximum Anchor Spacing (ft)
15% ≤ S < 20%	100
20% ≤ S < 35%	36
35% ≤ S < 50%	24
50% ≤ S	16

Note: Spacing is measured center to center of anchor.

8. The crown elevation(s) of pipe(s) entering a structure shall be at or above the crown elevation(s) of the pipe(s) exiting a structure.
9. The minimum drop across the invert of manhole, junction box, and inlet structures shall be the following:
 - a. 0.1-feet for a flow angle change less than or equal to 30 degrees
 - b. 0.2-feet for a flow angle change greater than 30 degrees
 - c. 0.3-feet for three or more pipes, all flow angles
10. Outlets from underground conveyance systems into natural or naturalized streams shall meet the following requirements:
 - a. Outlets shall have an invert elevation matching or within 2 feet below the water surface elevation for the 2-year ARI event in the receiving channel when connecting to the bank of an open channel. The outlet invert elevation shall be at least 0.2-feet above the receiving channel bed.
 - b. Outlets should preferably be angled 10-15 degrees downstream from perpendicular to the flow line of the receiving channel.
 - c. Outlet end sections shall be provided to stabilize the surrounding earthen material and/or transition to energy dissipation.
 - d. Pipe slope of outlets shall be less than or equal to 3%.

- e. Drop manhole connections may be used to reduce the slope of the outlet pipe. Drop manholes connections shall be limited to a 5-foot drop, as measured between incoming pipe invert and outgoing pipe invert.
- f. When outlets discharge to a natural stream, if the outlet cannot discharge to the natural stream within 2 feet below the water surface elevation for the 2-year ARI event in the receiving stream and at least 0.2-feet above the receiving stream bed due to cover limitations, the discharge point of the outlet shall be set back from the receiving stream bank a minimum of twice the outfall height plus the length of the required outlet protection and/or energy dissipation.

11. Outlet Protection or Energy Dissipation shall be provided at the outlet from all underground enclosed conveyance systems.

6.2.2 Overflow Pathways

As an integral part of the stormwater drainage system, whether enclosed or open, overflow channels shall be required in all areas in addition to, and above, the 10-year primary conveyance elements.

1. Overflow pathways shall be provided for all underground enclosed conveyance systems to convey the excess flows from the 100-year ARI event not conveyed by the primary 10-year ARI event conveyance system without damage to land or buildings. The pathway may include elements of streets, parking lots and conveyance swales.
2. Overflow pathways shall have a minimum of 1-foot of freeboard between the 100-year ARI water surface elevation and low openings of adjacent habitable structures.
3. See Subsection 7.5 for the allowable depth of overflow at the lowest point of the travelled way (sump).

6.2.3 Conveyance Swales

1. Conveyance swales shall at a minimum convey the 10-year ARI event, the design event, unless the swale is serving as an overflow pathway.
2. Conveyance swales will be trapezoidal in cross-sectional shape with softened, mowable transitions.
3. The minimum bottom width for conveyance swales shall be 4 feet, except as may be required to accommodate side yards or other narrow transitions-
4. Side slopes of conveyance swales shall be no steeper than 4:1 (H:V) .
5. Swale materials shall be mowable. If erosion protection is required in segments, only erosion blankets or turf reinforcing mats will be used.
6. Conveyance swales generally terminate at a stormwater inlet structure or at a point where the companion enclosed system is discharging to a natural stream or engineered channel. Transitions shall be graded smoothly and protected from erosion.

6.2.4 Engineered Channels

1. Engineered channels shall at a minimum convey the 10-year ARI event, the design event, in the main channel, with the extent and impact of the 100-year ARI also considered.
2. Engineered channels shall preferably be trapezoidal in cross-sectional shape.



3. The minimum bottom width for engineered channels shall be 6 feet.
4. Side slopes of engineered channels when trapezoidal shall be no steeper than 2:1 (H:V) unless supported with geotechnical analysis. (Side slopes shall be no steeper than 3:1 for turf grass materials for ease of mowing maintenance.)
5. Engineered channels may be rectangular in cross-sectional shape with vertical side walls; however, walls greater than 3-feet tall must be designed by a structural engineer.
6. The length of materials for engineered channels shall be the entire length of the project extents.
7. Outlet Protection or Energy Dissipation shall be provided at the discharge point from all engineered channels to natural streams, naturalized channels, or into engineered channels that are not lined with concrete.
8. Grade Control shall be provided at the discharge point from all engineered channels discharging to natural channels or naturalized channels if the incoming engineered channel has a bed slope more than 0.5% greater than the receiving stream or channel bed slope. (Example: If the engineered channel bed slope is 1.2% and the receiving channel bed slope is 0.5%, then the difference is 0.7% and grade control is required).
9. Alignment changes shall be achieved by circular curves only having a minimum radius as follows:

Equation 6.1
$$R = \frac{V^2 W}{8D}$$

- where:
- R = Radius on channel centerline (ft)
 - V = Velocity of 10-year design flow (ft/sec)
 - W = Channel width at 10-year water surface elevation (ft)
 - D = Depth of 10-year design flow (ft)

10. Roadside ditches must generally be designed for turf grass lining and be mowable.
11. Channel lining materials shall be designed using the maximum permissible shear stress method as documented in this chapter. Long-term flexible linings are preferred except in locations where the City Engineer has determined that the use of a concrete liner is justified.

6.25 Culverts

1. Culverts shall be designed to convey the 10-year ARI event, the design event, unless the culvert is located beneath public streets classified as “arterials”. If the culvert is located beneath an “arterial” street, the 50-year ARI event shall be the design event.
2. Culverts shall be checked for both inlet control and outlet control conditions, using the procedures given in HDS-5 (FHWA, 2012). Selected inlet and outlet control design charts are given in Appendices B1 through B8.
3. Protection shall be provided at the downstream end of culverts, as needed, using energy dissipation.
4. In streams with a history of instability, grade control may be needed downstream to protect the structure.

5. Natural Stream Conservation: Where culvert crossings are made in natural streams, the following additional design elements should be considered to reduce impacts to the natural environment. Some of these features may also be required by state and federal regulatory agencies as part of various permit reviews.
- a. If possible, culverts should be located at riffles when crossing a natural stream that has typical pool- riffle-reach geomorphology. If not placed at riffles, downstream and upstream grade control may be advisable to isolate impacts of the culvert placement.
 - b. If the design width of the culvert opening significantly exceeds the normal width of the natural stream or naturalized channel, the designer should consider mimicking the primary channel width through the culvert with benching for high flows. This design approach is particularly relevant to larger streams with multi-celled reinforced concrete box culverts.
 - c. Embedment of the main cell culvert floor 6-12” below the natural channel flowline and backfill or natural sedimentation with bed load material to replicate natural channel conditions and improve fish and other aquatic species passage.

6.2.6 Natural Streams

1. Disturbance to natural streams shall be limited and may require additional permits.
2. Below-Grade Stream Crossings by Other Utilities
 - a. Below-grade stream crossings should preferably be located at riffles. Below-grade crossings at riffles shall have at least 3 feet of cover beneath the lowest stream bed elevation at the crossing location.
 - b. If crossing at a riffle is not feasible, then the crossing should be lowered to leave sufficient cover for anticipated scour.
 - c. Below-grade stream crossings should be perpendicular to the natural stream when possible. If perpendicular crossings are not possible, grade control perpendicular to the natural stream should be considered.
 - d. Stream banks at below-grade crossings should be returned to their existing shape and stabilized using vegetative methods, if feasible. If vegetated methods are not feasible, soil bioengineering or hard armor elements may be required.
3. Stream Bank Stabilization
 - a. Stream bank stabilization within natural streams should be limited to circumstances where existing infrastructure or structures are at risk for property damage or as to cause safety issues.
 - b. An engineering assessment shall be performed to determine the failure mechanism: geotechnical failure (slumping of banks due to weak soils in the adjacent slopes) or fluvial failure (erosion of banks caused by stream flows). For geotechnical failure, a slope stability analysis shall be performed by a geotechnical engineer. For fluvial failure, the current phase of channel evolution and meander migration should be considered.

- c. Hard armor elements such riprap and placed stones, as well as vegetated or soil bioengineering methods, or a suitable combination for the given conditions may be utilized. These stabilization measures shall be designed in accordance with Federal Highway Administration, United States Army Corps of Engineers, and Natural Resources Conservation Service requirements.
 - d. Materials shall be keyed into the bed and banks with allowance for scour along the toe and the structure should have adequate foundations.
 - e. Stabilization shall begin and end at stable locations along the bank. The existing cross-sectional shape and areas of the natural stream should be maintained.
 - f. Grade control shall be considered both upstream and downstream of the stabilization extents to isolate it from the surrounding natural stream and protect the foundation from undercutting.
 - g. In-stream stability structures may be allowed at the discretion of the City Engineer to focus flow, control grade, dissipate energy and selectively lower near-bank stress. Stream barbs, weirs, guide vanes, vegetative sills, and longitudinal peak stone toe protection (LPSTP) are among the more commonly considered in-stream structures.
4. Natural streams are complex and variable; care and adequate specialized qualifications are necessary when designing engineering works in the stream environment.

6.2.7 Outlet Protection and Energy Dissipation

1. Energy dissipation is a critical feature in outlet design to protect downstream channels from the erosive effects of high velocity flow. The following structure types listed in *HEC-14 (FHWA 2006)* are approved for use to fulfill energy dissipation requirements, pending limitations and design requirements of each energy dissipator described in that document:
 - a. Riprap Basin
 - b. Outlet Weir
 - c. USBR Type III Stilling Basin
 - d. USBR Type VI Stilling Basin
 - e. Contra Costa Basin
2. Riprap Aprons (as distinguished from Riprap Basins referenced above) are also approved for use as an energy dissipator from smaller pipe and RCB discharges, within the specified limits, using an alternate design procedure described in Subsection 6.3.
3. The City's standard drawings include riprap apron and riprap basin details. Other structures would be project specific, requiring structural engineering. Base CADD files may be available from the City Engineer for some of these structure types.

6.2.8 Grade Control Requirements

1. For receiving channel bed slope less than or equal to 2%, a Newbury Loose Rock Structures designed per *Part 654 of the National Engineering Handbook (NEH)* and *Technical Supplement 14G (TS14G) (NRCS 2007b)*, shall be provided.



- For receiving channel bed slope greater than 2%, a Rigid Drop Structures designed per the same reference shall be provided.

6.3 Design Procedures

6.3.1 System Capacity

The following procedure shall be used to calculate conveyance system capacity, preferably using approved hydraulic conveyance models instead of manual calculations.

- Identify the design rainfall event to be conveyed within the Stormwater Conveyance System.
- Calculate the design flowrate per Section 5.0 Hydrology.
- Determine the system parameters to convey the design flowrate, assuming appropriate full or partial flow conditions in the conveyance system. Use Manning’s Equation, Equation 6.2, to calculate the conveyance system capacity.

Equation 6.2:
$$Q = \frac{1.486}{n} AR^{2/3} S^{1/2}$$

where:	$Q =$	System capacity (cfs)
	$n =$	Manning’s Roughness Coefficient per Table 6.2
	$A =$	Cross-sectional flow area (sf)
	$R =$	Hydraulic radius (ft)
	$S =$	Slope of the hydraulic grade line (ft/ft)

- Demonstrate that system capacity equals or exceeds the design flowrate. Document calculations as indicated in the Drainage Submittal Workbook.
- Determine the water surface elevation for the design event at each structure (inlet, manhole, junction box) per Equation 6.3.

Equation 6.3
$$WSEL = Inv_{out} + H_{out} + k * \left(\frac{v_{out}^2}{2g} \right)$$

where:	$WSEL =$	Water surface elevation (ft)
	$Inv_{out} =$	Invert elevation of outgoing pipe (ft)
	$H_{out} =$	Height of outgoing pipe (ft)
	$k =$	Head loss coefficient (dimensionless) per Table 6.3
	$v_{out} =$	Velocity of flow in outgoing pipe (fps)
	$g =$	Acceleration of gravity (ft/s ²)

- Demonstrate that the water surface elevation at each structure meets freeboard requirements. Document calculations as indicated in the Drainage Submittal Worksheet.



Table 6.2: Manning’s Roughness Coefficients

Description	n ⁽¹⁾
Underground Conveyance System	
Reinforced Concrete Pipe (RCP), Reinforced Concrete Boxes (RCB), and Reinforced Concrete Elliptical Pipe	0.013
Vitrified Clay Pipe	0.013
Corrugated Metal Pipe (CMP):	
2⅔ x ½ inch Annular or Helical Corrugations unpaved – plain	0.024
2⅔ x ½ inch Annular or Helical Corrugations paved invert	0.021
3 x 1 inch Annular or Helical Corrugations unpaved – plain	0.027
3 x 1 inch Annular or Helical Corrugations paved invert	0.023
6 x 2 inch Annular or Helical Corrugations unpaved – plain	0.033
6 x 2 inch Annular or Helical Corrugations paved invert	0.028
High Density Polyethylene (HDPE) or PVC Pipe (Smooth Inner Wall)	0.011 ⁽²⁾
Open Channels, Overflow Pathways	
Street Curbing	0.014
Concrete Trowel Finish	0.013
Concrete Float Finish	0.015
Concrete Unfinished	0.017
Concrete, bottom float finished, with sides of Dressed Stone	0.017
Concrete, bottom float finished, with sides of Random Stone	0.020
Concrete, bottom float finished, with sides of Cement Rubble Masonry	0.025
Concrete, bottom float finished, with sides of Dry Rubble or Riprap	0.030
Gravel bottom, with sides of Random Stone	0.023
Gravel bottom, with sides of Riprap	0.033
Riprap	0.035
Grouted Riprap	0.030
Earthen channel, straight and uniform	0.027
Earthen channel, winding and sluggish	0.035
Unlined channel, not maintained, weeds & brush uncut	0.090
Natural Stream, Clean, straight	0.030
Natural Stream, Clean, winding, some pools and shoals, some weeds and stones	0.045 ⁽³⁾
Natural Stream, Stream with pools, sluggish reaches, heavy underbrush	0.100
Flood Plains, Grass, no brush	0.030
Flood Plains, With some brush	0.090
Flood Plains, Trees, heavy stand of timber, few down trees, little undergrowth, flow below branch	0.100 ⁽³⁾
Flood Plains, Trees, heavy stand of timber, few down trees, little undergrowth, flow into branches	0.120 ⁽³⁾

Notes:

(1) All values from APWA 5600 Table 5603-1 (KC-APWA, 2011) except as noted

(2) Value from the NRCS National Engineering Handbook Part 634 Hydraulics Figure 4-3 , assuming that HDPE with smooth inner walls has equivalent manning’s roughness coefficient as PVC

(3) Value from HEC-RAS 6.0 Hydraulic Reference Manual Table 3-1 (HEC 2021)

Table 6.3: Head Loss Coefficients

Description	k ⁽¹⁾ (2)
Manholes, Junction Boxes, and Inlets with Shaped Inverts	
Thru Flow Only	0.15
Junctions Boxes	0.40
Inlets (when <50% inflow enters from the surface opening)	0.40
Inlets (when >50% inflow enters from the surface opening)	1.00
Contraction Transition	0.10
Expansion Transition	0.20
Bends: 45° < Angle ≤ 90°	0.40
Bends: Angle ≤ 45°	0.30
Culvert Inlets: Pipe, Concrete	
Projecting from fill (no headwall), Socket end of pipe (groove end)	0.20
Projecting from fill (no headwall), Square cut end of pipe	0.50
Headwall or headwall and wingwalls, Socket end of pipe (groove end)	0.20
Headwall or headwall and wingwalls, Square cut end of pipe	0.50
Headwall or headwall and wingwalls, Round end (radius = 1/12 barrel)	0.20
Mitered to conform to fill slope	0.70
Standard end section	0.50
Beveled edges, 33.7° or 45° bevels	0.20
Side or slope-tapered inlet	0.20
Culvert Inlets: Pipe, or Pipe-Arch, Corrugated Metal	
Projecting from fill (no headwall)	0.90
Headwall or headwall and wingwalls, Square cut end of pipe	0.50
Mitered to conform to fill slope	0.70
Standard end section	0.50
Beveled edges, 33.7° or 45° bevels	0.20
Side or slope-tapered inlet	0.20
Culvert Inlets: Box, Reinforced Concrete	
Headwall parallel to embankment (no wingwalls), Square edged on 3 edges	0.50
Headwall parallel to embankment (no wingwalls), Rounded on 3 edges (radius = 1/12-barrel dimension) or Beveled edges on 3 edges	0.20
Wingwalls at 30° to 75° to barrel, Square edged at crown	0.40
Wingwalls at 30° to 75° to barrel, Rounded at crown (radius = 1/12-barrel dimension)	0.20
Wingwalls at 10° to 25° to barrel, Square edged at crown	0.50
Wingwalls parallel (extension of sides), Square edged at crown	0.70
Wingwalls parallel (extension of sides), Side or slope-tapered inlet	0.20

Notes:

(1) All values from APWA 5600 Table 5603-2 (APWA, 2011)



6.3.2 Channel Lining Materials

The following procedure shall be used to determine appropriate channel lining materials and calculate material extents.

6.3.2.1 Channel Lining Resistance

1. Calculate the flowrate in the channel at the discharge point for the 10-year ARI event per Section 5.0 Hydrology.
2. Determine the maximum depth of flow in the channel for the design event.
3. Calculate the applied shear stress for the maximum depth of flow in the channel per Equation 6.4.

$$\text{Equation 6.4: } \tau_d = F\gamma_w dS$$

where:

- τ_d = Applied shear stress in channel at maximum depth (psf)
- F = Factor of safety, 1.5 (dimensionless)
- γ_w = Unit weight of water (62.4 pcf)
- d = Maximum depth of flow in the channel section (ft)
- S = Slope of the hydraulic grade line (ft/ft)

4. Determine the type of channel material such that the permissible shear stress (Table 6.4) is not exceeded by the applied shear stress. For well-vegetated natural channels without supplemental lining, the permissible shear stress is a function of the Retardance Class of the vegetation, as shown on Table 6.5. For channels to be lined with riprap or rock aggregate lining, the detailed procedures in HEC-15 should be followed to determine rock size and other requirements.

6.3.2.2 Channel Lining Material Extents

1. The minimum lining height shall be the design flow depth (y) in the 10-year ARI event, plus at least 0.5-foot freeboard.
2. Along the outer side of horizontal curves, the lining shall be increased to a height at least 25% greater than the design flow depth. The transition to the increased lining height shall be uniform, beginning at a point at least 10 times the design flow depth upstream of the point of curvature. The transition back to standard depth after the bend shall begin at the point of tangency and proceed uniformly of a distance 30 times the design flow depth.

6.3.3 Riprap Apron Outlet Protection

1. Overview:
 - a. Match the actual outlet condition to the closest experimental conditions described in the design charts (Omaha 2014), both in terms of outlet flow conditions and receiving channel tailwater. [Charts are based on experimental results for circular pipes flowing full. For



stormwater pipes flowing partially full or for box culverts, adjust input variables per the design procedure before using the charts. Design charts are given in Appendices C1 and C2 for Minimum and Maximum Tailwater conditions.

- ▶ Minimum Tailwater applies when the outflow is relatively unconstrained and can dissipate in part by spreading laterally. Riprap Aprons in this instance will be short but flare out to widen quickly and require heavier stone.
 - ▶ Maximum Tailwater applies when outflow is into a highly constricted channel or a channel under frequently high backwater. In this case, the backwater provides some dissipation, but the flow does not spread out as quickly. These aprons must be longer but widen less abruptly and generally do not require as heavy stone.
- b. Limitation: Based on the range of values given in the design charts and to avoid extreme or uneconomical designs, energy dissipators other than Riprap Aprons should be used when any of the following conditions are exceeded:
- ▶ outlet velocities greater than 20 feet per second (fps).
 - ▶ pipe diameters greater than 60 inches or RCB rise heights greater 5 feet;
 - ▶ stone requirements larger than KDOT Light Series Riprap;
 - ▶ apron lengths greater than 8 times the pipe diameter or box rise.

2. Calculation Sequence:

- a. Specify outlet structure type and flow condition in the 10-year ARI or other design event. For pipes flowing full, use the depth of flow, d , equal to pipe diameter (D_o). Use the discharge rate (Q) or corresponding full flow outlet velocity (v) directly.
- b. For pipes flowing partially full and box culverts, use the uniform depth of flow in the pipe as “ d ” and the actual uniform velocity in the pipe as “ v ”. Find the intersecting point on the design chart. (Do not use the discharge capacity (Q) scale on the bottom of the chart).
- c. Specify the tailwater condition. If the tailwater is less than one-half the depth of flow ($TW < d/2$), treat the condition as Minimum Tailwater. If the tailwater is greater than one-half the depth of flow, treat as Maximum Tailwater.
- d. Enter the lower half of the appropriate design chart with the proper combination of D_o and Q (or d and v), interpolating as needed. Find the riprap median diameter d_{50} from the scale on the right-of-the lower half of the chart. Then, from the d and v intersection point on the lower chart, move vertically to the upper curve until intersecting for the correct flow depth, d , and find the minimum apron length (L_a) from the scale on the left of the upper half of the chart.
- e. Specify an appropriate grade of KDOT-approved riprap stone or aggregate ditch lining stone, based on the d_{50} obtained.
- f. Complete the design of the basin shape using the layout given in the Standard Details, based on scaling parameters and expansion flare rates consistent with the requirements of this design method.



- g. If tailwater conditions are uncertain, the riprap diameter shall be the larger of the values given for the minimum and maximum condition, and the length and shaping of the apron modified to protect the channel under both conditions.

6.3.4 Energy Dissipation

An energy dissipator per HEC-14, most current version, shall be provided for discharge points that do not meet the requirements for riprap apron outlet protection in Subsection 6.3.3 with the following considerations:

1. The Froude Number shall be calculated in accordance with HEC-14 and must be within allowable range of the proposed Energy Dissipator.
2. The immediate downstream channel conditions shall be evaluated to determine the hydrologic and hydraulic conditions for the design event as a part of the Energy Dissipator design process.
3. The Energy Dissipator selection shall be appropriate for the channel conditions and nature of the discharge. The proposed discharge velocities from the dissipation zone shall not exceed that which the downstream channel can convey in a stable manner.

Table 6.4: Permissible Shear Stresses for Lining Materials

Lining Category	Lining Type	Permissible Shear Stress (lbs/ft ²) ¹
General	– Erosion Control Blankets	1.55 - 2.35
	– Turf Reinforcing Mats ²	2.0 – 8.0
	– Geosynthetic Materials	3.0
	– Cellular Containment	8.1
	– Woven Paper Net	0.15
	– Jute Net	0.45
	– Straw with Net	1.45
	– Curled Wood Mat	1.55
	– Synthetic Mat	2.00
Vegetative	– Class A (see Table 6.7)	3.70
	– Class B (see Table 6.7)	2.10
	– Class C (see Table 6.7)	1.00
	– Class D (see Table 6.7)	0.60
	– Class E (see Table 6.7)	0.35
Riprap and Aggregate Lining	– Use FHWA HEC-15 for Sizing and Design	Varies

Note:

- (1) See KC-APWA 2011 and FHWA HEC-15 (2005) for reference.
- (2) For Turf Reinforcing Mats, use established specifications (such as KDOT's) and manufacturers' recommended values for specific products and installations in lieu of values above when derived from adequate test results.



Table 6.5: Retardance Classification of Vegetal Covers

Class	Cover	Condition ⁽¹⁾
A	<ul style="list-style-type: none"> - Weeping Love Grass - Yellow Bluestem Ischaemum 	<ul style="list-style-type: none"> - Excellent stand, tall (average 30") - Excellent stand, tall (average 36")
B	<ul style="list-style-type: none"> - Bermuda Grass - Native Grass Mixture ⁽²⁾ - Grass Mixture ⁽³⁾ - Smooth Bromegrass - Alfalfa - Weeping Love Grass - Tall Fescue - Blue Gamma 	<ul style="list-style-type: none"> - Good stand, tall (average 12") - Good stand, unmowed (average 20") - Good stand, uncut (average 20") - Good stand, mowed (12"-15") - Good stand, uncut (average 11") - Good stand, unmowed (average 13") - Good stand (average 18") - Good stand, uncut (average 12")
C	<ul style="list-style-type: none"> - Tall Fescue - Bermuda Grass - Common Lespedeza ⁽⁴⁾ - Grass-Legume Mixture ⁽⁵⁾ – Summer - Kentucky Bluegrass 	<ul style="list-style-type: none"> - Good stand (8"-12") - Good stand, mowed (average 6") - Good stand, uncut (average 12") - Good stand, uncut (6"-8") - Good stand, headed (6"-12")
D	<ul style="list-style-type: none"> - Bermuda Grass - Common Lespedeza ⁽⁴⁾ - Buffalo Grass - Grass-Legume Mixture ⁽⁵⁾ – Fall, Spring - Tall Fescue 	<ul style="list-style-type: none"> - Good stand, cut to height of 2.5" - Excellent stand, uncut (average 5") - Good stand, uncut (3"-6") - Good stand, uncut (4"-6") - Good stand, cut (3"-4")
E	<ul style="list-style-type: none"> - Bermuda Grass - Bermuda Grass 	<ul style="list-style-type: none"> - Good stand, cut to height of 2" - Burned stubble

Notes:

(1) Stands are based on stem density per square foot, with Excellent Stand as 300-665 and Good Stand as 200-400. This table follows HEC 15 (FWHA, 2005) with some modifications appropriate to north-central Kansas and the Manhattan region.

(2) Little bluestem, big bluestem, blue gamma, and other long and short Midwest grasses

(3) Timothy, smooth bromegrass, orchard grass

(4) Common Lespedeza (*Lespedeza striata*) is also known as Japanese Clover (*Kummerowia striata*), but differs from *Lespedeza sericea*, which is classified as a noxious weed in the State of Kansas.

(5) Orchard grass, redbud, Italian ryegrass, and common lespedeza6.

6.3.5 Grade Control

Grade control shall be designed per NRCS technical guidance manual previously reference in Subsection 6.2.

6.4 Computer Programs

The following is a list of pre-approved computer programs for analyzing conveyance systems. Alternate computer programs may be substituted with written approval by the City Engineer.

- ▶ Hydrologic Engineering Center, HEC-RAS (Open Channel)
- ▶ FHWA, HY-8 Culvert Hydraulic Analysis Program (Culverts)
- ▶ EPA, SWMM 5 (Enclosed, Open Channel)
- ▶ Autodesk, Hydraflow Storm Sewers Extension (Enclosed)
- ▶ Autodesk, Storm and Sanitary Analysis (Enclosed, Open Channel)
- ▶ Bentley, OpenFlows FlowMaster (Enclosed, Open Channel)
- ▶ Bentley, OpenFlows SewerGEMS (Enclosed, Open Channel)

Collection

7.1 Description

Stormwater collection is the interception of stormwater runoff at specific locations. Stormwater collection is most often associated with stormwater inlets, which collect stormwater from roadways, streets, parking lots, and other runoff generating surfaces and discharge the collected stormwater to the stormwater conveyance system.

7.2 Allowable Inlet Types

Type “A” Curb Inlets, per Manhattan Standard Drawings, are the preferred inlets to be used.

Type “B” Curb Inlets, per Manhattan Standard Drawings, are only allowed when site constraints inhibit the use of Type “A” Curb Inlets.

Area Inlets should be specified and constructed per Manhattan Standard Drawings.

7.3 Design Method

The design method differs between on-grade and sump inlets. Design tables are provided for the designer to utilize when developing the storm sewer design and layout. Reference Appendices D2 through D14 for the inlet design tables.

7.3.1 On-Grade Inlets

For an inlet with an on-grade condition, where runoff is collected at points along the natural grade, capacity calculations are based on empirical assumptions. A summary of these calculations is included in the design tables and further explained in Appendix D14. The inlet charts include a 10% capacity reduction for clogging when on-grade.

7.3.2 Sump Inlets in Street

For an inlet with a sump condition in the street, capacities will be determined using the inlet charts in the Appendices, where capacities were determined by calculations following the procedures outlined in Hydraulic Engineering Circular No. 22 (HEC-22) Urban Drainage Manual (FHWA, 2013). A summary of these calculation assumptions is included in the design tables. The inlet charts include a 20% capacity reduction for clogging when in sump conditions.

7.3.3 Area Inlets

For area inlets in yard or paved areas, capacities will be determined using the inlet charts in the Appendices, if available, or from independent calculations following the procedures in HEC-22. The calculations method generally involves checking the inlet for weir or orifice control, with suitable deductions for effective opening area and configurations. A 20% capacity reduction for clogging shall be used.



7.4 Inlet Locations

Inlet placement shall be dictated by hydraulic design criteria, geometric controls, or both.

Inlets shall be placed at sump locations. On-grade inlets within streets shall be placed at suitable intervals that is governed by the allowable spread for the 10-year annual recurrence (ARI) interval.

Examples of curb inlet placement dictated by geometric controls includes the following:

- ▶ Immediately upstream of intersections, cross walks, median breaks, or where water could flow onto the travel way.
- ▶ Immediately upstream and downstream of bridge
- ▶ Immediately upstream before superelevated sections of roadway

7.5 Allowable Gutter Depth & Spread

Inlet placement is dependent upon flow depth in the gutter and spread of flow along the pavement. Guidelines for gutter depth and spread are as follows:

1. Allowable depth of flow for a 10-year ARI event shall not overtop the curb height and shall incorporate allowable gutter spread requirements.
2. Allowable gutter spread in roadway sections in the 10-year ARI shall be based on number of travel lanes, as described in Table 7.1: Allowable 10-Year Gutter Spread by Street Type
3. Allowable depth of flow for a 100-year ARI for crossing the roadway at sump during an overflow event shall not exceed 6 inches above the crown at the lowest point of the travelled way (sump).

Table 7.1: Allowable 10-Year Gutter Spread by Street Type

Number of Travel Lanes, (Total)	Allowable Gutter Spread, T_{allow} (ft)
1	7.5
2	7.5
3	13.5

Notes:

- (1) Gutter Width = 1.5 feet
- (2) Gutter Spread, as measured from vertical face of curb for composite curb and gutter section (FHWA, 2013)
- (3) Allowable Gutter Spread pertains to both sides of the travel direction.
- (4) Street typology for reference only. Allowable spread for any given roadway is dictated by number of travel lanes.

Gutter spread in roadway sections shall be determined using Appendix D1. This is based on a simplified street and curb section with uniform cross slope and calculated using Izzard’s Formula, Equation 7.1.

$$\text{Equation 7.1} \quad Q = \frac{(0.56)(Z)(S^{0.5})(D^{2.67})}{n}$$

- where:
- Q = Gutter capacity (cfs)
 - Z = Reciprocal of the average cross slope (ft/ft), including gutter section
 - S = Longitudinal street grade (ft/ft)
 - D = Depth of flow at curb face (ft)
 - n = Manning’s n (typically use 0.014 for gutters and pavement)

7.5.1 Street Inlet System Calculation

1. Locate inlets first based on the geometry of the street and overflow system and estimate the location of any intermediate inlets needed to limit spread in the street. Identify the runs of inlets that contribute or collect bypass from each other and organize calculations in upstream to downstream order.
2. For the first inlet in the system, calculate the total discharge Q (Q_{new}) from the tributary area to that inlet. Also calculate the gutter spread and the inlet capture based on inlet type, using the tables in the Appendices.
3. For inlets located “on-grade”, any excess flow not captured is designated “bypass” (Q_{bypass}) from that inlet and flows to the next inlet in the system.
4. At that next inlet, calculate the new discharge from its own tributary area and then add all bypasses from upstream inlets (called the “carryover” to estimate the total discharge to be handled at that inlet. (i.e., $Q_{\text{total}} = Q_{\text{new}} + Q_{\text{carryover}}$, where carryover flow is the sum of all upstream bypasses directed to that inlet).
5. Check the gutter spread and inlet capture at this second inlet based on Q_{total} . The excess not captured becomes bypass to the next inlet. Continue the calculation in this manner for all subsequent inlets in the system until reaching the sump, adjusting on-grade inlet locations (and associated drainage area calculations, as needed).
6. At the sump inlet, calculate Q_{total} as before, where the carryover component may likely include bypass flows from multiple directions. Flow will not bypass the sump inlet, so calculate the depth of ponding (i.e., head) at the sump necessary to convey the total discharge into the inlet.
7. Repeat this procedure for all inlets (on-grade and sumps) in the system.
8. Check the gutter spreads, depths of accumulation and inlet efficiencies for all inlets in the system. Adjust placement of any inlets if necessary to meet criteria and optimize design. Recalculate using the same procedures until reaching a final design. It is helpful to organize these calculations in a table, per the Drainage Submittal Workbook.
9. Following the inlet calculation, verify that the underlying pipe flow calculations are still accurate based on final inlet placement and bypasses. Verify that no inlets are surcharging, as this would invalidate the inlet capacity tables.

10. In many cases, the pipe portion of the system will be sized as if no surface bypass of an inlet has occurred, regardless of the actual inlet bypass. This is generally conservative and easier to analyze. When examining the performance of an existing pipe network, however, it may be necessary to account for inlet bypasses and carryovers more specifically.
11. Once the 10-year primary design system is completed, check the 100-year overflows, depths in gutters, system capacities and overflow path capacities. Further adjustments may be necessary to oversize the primary system if the overflow system requirements cannot be met.

Detention

8.1 Description

Whenever there is a change in the cover description (e.g., increase in impervious area) or manner in which stormwater flows across or discharges from a site, there is a potential to adversely impact adjacent and/or downstream properties. Detention helps to mitigate these average drainage-related impacts. Detention facilities temporarily delay stormwater from entering the stormwater system, maintaining capacity during and immediately following a rainfall event. Detention-based stormwater management facilities help protect the downstream community from localized flooding due to limited capacity in the existing system. Detention also helps protect the integrity of receiving streams by limiting discharge flow rates along with water velocities of concentrated stormwater flows to the downstream system.

8.2 Requirements

Stormwater detention shall be provided for all development sites 0.4 acres and larger, including subdivisions and infill projects, when there is an increase in the total impervious surface area. The stormwater detention shall be provided such that post-project peak discharge rates from detention facilities shall not exceed either the pre-development peak flow or the allowable release rates for the 2-, 10-, and 100-year annual recurrence interval (ARI) events described in this section, whichever is less. This requirement is regardless of the site's location within the watershed. In certain cases, a fee-in-lieu program may be utilized.

8.2.1 Allowable Release Rates

Post-project peak discharge rates from areas of new development shall not exceed the allowable release rates expressed in discharge rate per tributary area for the design events provided in Table 8.1. When the area of new development is perfectly aligned with the tributary area of the detention facility, this table will set the release rate for the detention facility. When complicating factors such as bypass, pass-thru or redevelopment are present, the adjustment methods described in this Section will be used to adjust the design release rate for the outflow from the actual facility.

Table 8.1: Allowable Release Rate by Design Event

Design Event by ARI	Release Rate (cfs/ac)
Water Quality Volume (WQv)	QWQ ⁽¹⁾
2-year	0.5
10-year	1.5
100-year	3.0

Notes: The Water Quality Outflow Rate (QWQ) applies when extended dry detention or extended wet detention is incorporated into the detention facility as a proposed stormwater quality BMP. See Section 9. If the pre-development peak flow rate would give a lower discharge, use that instead.

8.2.2 Above-Ground Detention

Above-ground detention facilities shall meet the following requirements:

1. Side slopes of vegetated detention basins shall be no steeper than 4:1 (H:V) unless supported with geotechnical analysis. (Side slopes shall be no steeper than 4:1, regardless of geotechnical analysis, for turfgrass vegetation for ease of mowing maintenance).
2. Care must be taken to ensure that all intended inflow can be routed into the detention basins, including surface overflows not contained in the primary storm sewer.
3. Detention inundation extents for the 100-year ARI shall be contained within easements meeting the criteria given in Section 4.0.
4. For the 100-year event, freeboard, as measured from the top of the embankment (not the invert of the spillway) to the 100-year water surface elevation, shall be provided per Table 8.2

Table 8.2: Freeboard Requirements

100-Year Storage Volume	Freeboard (feet)
Less than or equal to 0.5 acre-feet	0.5
Greater than 0.5 acre-feet, but less than or equal to 5.0 acre-feet	1.0
Greater than 5.0 acre-feet, but less than or equal to 25.0 acre-feet	2.0
Greater than 25 acre-feet	3.0

5. An overflow spillway shall also be provided for that is capable of independently conveying an additional unattenuated flow rate equal to 50% of the 100-year discharge while leaving at least one-half of the required freeboard. Flow across the spillway must be routed to the toe of embankment and into the receiving channel along an adequately stabilized drainageway.
6. Basins with a storage volume greater than 5.0 acre-feet shall be designed in accordance with Technical Release TR-60 (NRCS 2019b). If a surface detention basin is of a size that it is regulated state of Kansas dam safety regulations, then those standards apply instead.
7. A maintenance route shall be provided that allows for vehicular access to all detention basin components, including inlet structure(s), outlet structure(s) and vegetation. The path shall meet the criteria given in Section 4.0.

8.23 Underground Detention

Underground detention facilities may be allowed at the discretion of the City Engineer. Underground detention shall consist of perforated or non-perforated storage pipe, pre-manufactured chambers with clean granular backfill, or other system acceptable to the City Engineer.

Underground detention shall meet the following requirements:

1. A location for sediment and debris collection and removal shall be provided.
2. When the inflowing pipes are not carrying the entire design inflow, a surface inlet capable of capturing the additional runoff and routing it into the underground detention must be provided.
3. A minimum of two (2) primary access points shall be strategically located within the system for maintenance and inspection activities.
4. Secondary access points for maintenance activities should be provided as needed to adequately maintain the underground detention facility and appurtenances, such as at opposite ends of the system, and horizontal bends in the alignment greater than 45 degrees.
5. Access points shall be sized accordingly for maintenance and inspection activities.
6. Primary access points shall be equipped with 24-inch diameter (min.) castings.
7. Secondary access points shall be at least 6 inches in all dimensions (width and length or diameter) when connected by 45-degree vertical bends.
8. Secondary access points shall be at least 8 inches in all dimensions (width and length or diameter) when connected by 90-degree vertical bends.
9. A maintenance route shall be provided that allows for vehicular access to all detention basin components, including inlet structure(s), outlet structure(s) and underground storage chambers. The path shall meet the criteria given in Section 4.0.
10. On the surface above the detention basin, a continuous overflow pathway sized to convey 50% of the unattenuated 100-year ARI inflowing discharge shall be provided from the inlet of the detention basin to the first inlet in-line but downstream of the underground basin. This overflow pathway provides protection in the event the underground basins is clogged or otherwise fails.

8.24 Outlet Structure

The detention outlet structure shall meet the following requirements:

1. Outlet structures shall be designed to meet the allowable release rate requirement and be “non-clogging” such as a reverse-slope pipe, hooded orifice, or opening protected by trash rack, grate, or other debris-screening feature.
2. The minimum opening dimension in any direction for a single opening shall be 4 inches.
3. An orifice plate with minimum 1-inch diameter orifices may be used if the calculated orifice size necessary to meet allowable release rate requirements is smaller than 4 inches.
4. The trash rack, grate or other debris-screening device shall have a minimum opening area of 4-times the opening area of the orifice, unless a larger opening area is otherwise required per the PCBMP Manual when the detention facility also provides extended wet detention or extended dry detention.

8.2.5 Fee In Lieu of Detention

Fee in lieu of detention may be utilized in specific watersheds when authorized by the City Commission. A “fee in lieu of” detention program enables a property owner to contribute to a designated stormwater fund for future improvements in lieu of constructing a detention facility to meet all or part of the City’s detention requirements. The “fee” shall be determined per the current policy of the City.

8.3 Design Procedures

The following procedure shall be used to design detention facilities.

8.3.1 Establish Release Rate for the Base Condition

The base condition occurs when the tributary area to the detention basin is perfectly aligned with site boundary of the development. In that circumstance, the allowable discharge is per Equation 8.1.

$$\text{Equation 8.1: } Q_{\text{allowable}} = A_{\text{tributary}} * q_{\text{allowable}}$$

where:

$Q_{\text{allowable}}$ = Allowable discharge (cfs)

$A_{\text{tributary}}$ = Tributary area to the detention facility (ac)

$q_{\text{allowable}}$ = Allowable release rate (cfs/ac) from Table 8.1

8.3.2 Release Rates for Special Conditions

Site topography and development preference often dictates variations from the base condition for detention. The following methods are used to apply adjustments to detention basin release rates appropriate to those conditions. This subsection includes a general procedure for establishing a modified detention release rate, as well as several short-cut methods suitable for common scenarios. When the required detention area and the actual detention basin tributary area differ by less than 1%, no adjustments are required.

8.3.2.1 Comparable Hydrographs Method.

The primary method of establishing modified release rates is to create two or three models for side-by-side comparison. The subbasin delineation should be the same (or as close as possible) in each model to allow for direct comparisons. The models represent these conditions:

- ▶ Proposed Conditions Model - the first model is structured to match the actual proposed conditions, with subareas divided as needed to delineate the original site, any pass-thru contributions, and/or any bypass areas. The nearest point immediately downstream of the development that reflects the main drainageway with bypass flows recombined is identified as the point of common comparison.
- ▶ Hypothetical Conditions Model – the second model is structured so that the entire area required for detention is shown as if directed into a hypothetical detention basin that was designed to



meet the allowable release rate given at Table 8.1. The hypothetical simple detention basin should have a realistic storage and outflow design.

Pre-Project Conditions Model – a third model, if necessary, can be created to document the discharge conditions that existing pre-project, prior to either development or new detention. In general, the use of the allowable release rates approach means this model is typically not necessary, but there may be circumstances where the information is useful. The outflow at the common point of reference is compared for the hypothetical and proposed conditions model. Peak outflow from the proposed model must be equal or lower at the point of common comparison that modeled in the hypothetical model. Other results, such as hydrograph shape and total detention volume should reasonably match, to conserve the over-detention benefit to the entire system. Due to timing and hydrograph shape mismatches, it is not acceptable to simply add peaks from an onsite requirement and a pass-thru area flow model. Results shall be reported in the Drainage Submittal Workbook.

8.3.2.2 Shortcut Method for Small Bypasses

In some cases, there will be areas of a site that cannot be reasonably captured and drained to the onsite detention basin. This can include perimeter areas, driveway aprons, or steep transition slopes that drain away from the main body of the site. The preferred method for offsetting the bypass would be to capture an equivalent or slightly larger area of similar offsite pass-thru flow, if possible, so that the net tributary area to the detention basin is equivalent or slightly larger than the development.

Where this is not feasible and the bypass area is less than 10% of the development area, a reasonable compensation can be made by restricting the flow rate from the main basin. The factor to reduce the detention release rate will be 1.5 times the percentage of tributary area bypassed.

Example: A 2-acre convenience store and shopping area is planned. Due to steep grades and driveway arrangements, there will be 0.2 acres that bypasses the underground detention basin., with the remaining 1.8 acres being directed to the detention basin. The 100-year allowable release rate from the detention basin was first set to 6.0 cfs, per Table 8.1 (2 acre * 3.0 cfs/acre). To offset the impact of bypass, a 15% deduction is imposed (i.e., 1.5 factor * 10% bypass area), giving an allowable release rate is 5.1 cfs (6.0 cfs * 85%) from the actual detention basin. The 2-year and 10-year modified release rates are calculated similarly.

8.3.2.3 Shortcut Method for Small Pass-Thru Areas

In some cases, there are adjacent offsite areas that may be directed into a new development's onsite drainage system. Instead of separating the flows, the engineer may choose to allow the offsite areas to "pass-thru" the detention basin without incurring a significant penalty on design. For pass-thru conditions that would not enlarge the tributary area to the detention basin by more than 20% of the project area, the release rate may be increased by the same 1.5 factor on the pass-thru area percentage.

Example: A 10-acre site is being developed from pasture to residential subdivision. An adjacent subdivision adds 2.0 acres of flows to the site, so that 12 acres is directed to the onsite detention basin. If only the site had been captured, the peak basin release rate for the 100-year storm would be 30.0 cfs (10 acres of project site * 3 cfs/acre). The additional pass thru area represents 20% of the project area so the release rate from the detention basin may be increased 30% (a 1.5 factor increase).

The modified detention basin release rate



would be 39.0 cfs (30.0 cfs * 1.30). The 2-year and 10-year modified release rates are calculated similarly.

8.3.2.4 Short-cut Method for Redevelopment

Where a site is undergoing redevelopment, the intent is to detain runoff consistent with the increase in site usage, while giving credit for the pre-existing developed area. It can be difficult to precisely separate a small site into the existing and new components, especially if the previously existing impervious areas are included in the demolition.

In such cases, the allowable release rate may be established as a weighted average of the undetained peak flow rate for the full site after redevelopment and the target release rate of the base condition.

The weighting factors are the relative amounts of pre-existing impervious area versus the additional net new imperviousness, expressed as shares of the total impervious area of the completed site. This method of weighting has the effect of allocating remaining pervious area in a balanced manner to both the pre-existing and net new site elements and assigning both elements the same time of concentration, representing the total site response.

This method retains a proportional share of the “over-detention” benefit from the net new impervious area.

Example: A 4.0-acre site with HSG B soils was originally 35% impervious and will be 65% impervious after redevelopment. All pre-existing features are being demolished and there is no simple demarcation between the original and new components. For the 100-year design storm, the undetained peak from the redeveloped site is estimated as 30.2 cfs (from the hydrograph model), while the target release rate of the entire site had it been developed from greenfield (i.e., the base condition) is 12 cfs, per Table 8.1 (3.0 cfs/acre * 4 acres). The existing imperviousness represents 53.8% of the site’s total final impervious area (35%/65%), while the net new element represents 46.1% (30%/65%). The allowable release rate is:

$$Q_{\text{release,100-yr}} = (53.8\% * 30.2 \text{ cfs}) + (46.1\% * 12 \text{ cfs}) = 21.8 \text{ cfs}$$

The 2-year and 10-year modified release rates are calculated similarly.

8.3.2.5 Sites Divided into Multiple Watersheds

When a site consists of multiple watersheds, the intent is to provide suitable protection to each downstream receiving system. Each distinct watershed should be analyzed separately and have its own detention facility. Exceptions may be made when the separate discharge would recombine within a reasonably short distance downstream from the site and there is a determination of no adverse localized impact from leaving one outlet undetained prior to recombining. In that case, the Comparable Hydrographs Method is used to establish the required release rate from the detained outlet, with the recombination point as the point of common comparison.

8.3.3 Outlet Structures

Provide outlet structure(s) to meet the allowable discharge requirements. The most common outlet components and suitable design equations are listed below. For more complex conditions, use the



design methods outlined in *Hydrologic Engineering Circular No. 22* (HEC-22, 2013) or other approved reference.

Discharge over a sharp crested weir shall be calculated per Equation 8.2 (assumes unsubmerged sharp crested weirs with no end contractions. Flow over the top of a detention riser shall be treated as flow over a sharp crested weir with no end constrictions.)

$$\text{Equation 8.2: } Q = C_{SCW} * L * H^{1.5}$$

where: Q = Discharge over unsubmerged weir (cfs)

L = Length of weir, perpendicular to direction of flow over weir (ft)

H = Head above weir crest (ft)

C_{SCW} = Sharp Crested Weir Coefficient (in English Units), use 3.2

Discharge over a broad crested weir (including emergency overflow spillways and roadway embankments) shall be calculated per Equation 8.3.

$$\text{Equation 8.3: } Q = C_{BCW} * L * H^{1.5}$$

where: Q = Discharge over weir (cfs)

L = Length of weir, measured perpendicular to direction of flow (ft)

H = Head above weir crest (ft)

C_{BCW} = Broad Crested Weir Coefficient (in English Units), use 2.7.

Discharge through a v-notch weir shall be calculated per Equation 8.4.

$$\text{Equation 8.4: } Q = C_V * \left(\tan \left(\frac{\theta}{2} \right) \right) * H^{2.5}$$

where: Q = Discharge through weir (cfs)

θ = Angle of v-notch (degrees)

H = Head above lowest elevation of weir (ft)

C_V = V-Notch Weir Coefficient (2.5 in English Units)

Discharge through an orifice shall be calculated per Equation 8.5.

$$\text{Equation 8.5: } Q = C_o * A_o * (2 * g * H_o)^{0.5}$$

where: Q = Discharge through orifice (cfs)

A_o = Area of orifice (ft²)

g = Gravitational acceleration (32.2 ft/s²)



H_o = Effective head , measured from the centroid of the opening (ft)

C_o = Orifice Coefficient (in English Units) per Table 8.3

Table 8.3: Orifice Coefficients

Orifice Type	C_o
Square Edge	0.80
Round Edge	0.95
Sharp Edge	0.60
Projecting Sharp Edge	0.50

Determine the detention facility Peak Discharge, Maximum Stage, and Maximum Storage Volume for each design event using the Hydrograph Method described in Section 5.0 Hydrology.

Provide a summary of detention facility performance including the allowable discharge, peak discharge, maximum stage, and maximum storage volume, in a format as indicated in the Drainage Submittal Workbook.

8.4 Computer Programs

The following is a list of pre-approved computer programs for analyzing detention facilities. Alternate computer programs may be substituted with written approval by the City Engineer.

- ▶ HEC-HMS
- ▶ Autodesk Storm and Sanitary Analysis
- ▶ Autodesk Hydraflow Hydrographs (not permitted for interconnected pond routing or multi-stage outlet structures)
- ▶ Bentley OpenFlows CivilStorm
- ▶ Bentley OpenFlows PondPack

Post-Construction Stormwater BMPs

9.1 Description

Post-construction stormwater best management practices (PCBMPs) provide water quality benefits by capturing the “first flush” stormwater runoff, the runoff with the highest concentrations of sediment, nutrients, bacteria, and other constituents, before that runoff enters the municipal separate storm sewer system (MS4).

9.2 Requirements

Post-construction stormwater BMPs are required per Code of Ordinances Article IV Stormwater Management System Section 32-193. They shall be provided for all new development and redevelopment projects, that disturb greater than or equal to one acre, including projects less than one acre that are part of a larger common plan of development or sale, to capture and treat the water quality volume (WQv). Implementation of post-construction stormwater BMPs shall be evaluated and designed per the City of Manhattan’s Post-Construction Stormwater BMP Manual.

9.3 Design Procedures

Post-construction stormwater BMPs shall be designed to capture and treat the WQv per the City of Manhattan’s Post-Construction Stormwater BMP Manual.

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Appendices



Appendix A1 - Riley County Rainfall Depths by Recurrence Interval

Annual Recurrence Interval (years)	6-Hour Event Depth (inches)	24-Hour Event Depth (inches)
1	2.19	2.87
2	2.56	3.35
5	3.23	4.18
10	3.83	4.90
25	4.74	5.94
50	5.50	6.79
100	6.31	7.67
200	7.18	8.61
500	8.42	9.90

Note: The rainfall depth values presented were extracted from the KDOT Rainfall Depth Tables for Riley County, Kansas (KDOT 2014).

Appendix A2 - Intensity-Duration-Frequency Values

Duration (H:MM)	Rainfall Intensity (inches/hour) by ARI (years)						
	1	2	5	10	25	50	100
0:05	4.92	5.79	7.26	8.53	10.37	11.85	13.38
0:06	4.55	5.35	6.71	7.89	9.58	10.95	12.36
0:07	4.25	5.00	6.27	7.37	8.95	10.23	11.55
0:08	4.00	4.71	5.90	6.94	8.43	9.63	10.88
0:09	3.79	4.46	5.59	6.57	7.98	9.12	10.30
0:10	3.60	4.24	5.31	6.25	7.59	8.67	9.79
0:11	3.44	4.04	5.07	5.96	7.24	8.27	9.34
0:12	3.29	3.86	4.85	5.70	6.92	7.91	8.93
0:13	3.15	3.71	4.65	5.47	6.65	7.59	8.57
0:14	3.04	3.57	4.48	5.26	6.40	7.31	8.25
0:15	2.93	3.44	4.32	5.08	6.17	7.05	7.96
0:16	2.84	3.34	4.19	4.93	5.99	6.84	7.72
0:17	2.76	3.25	4.08	4.79	5.82	6.65	7.51
0:18	2.69	3.16	3.97	4.67	5.67	6.47	7.31
0:19	2.62	3.09	3.87	4.55	5.53	6.31	7.13
0:20	2.56	3.01	3.78	4.44	5.40	6.16	6.96
0:21	2.50	2.94	3.69	4.34	5.27	6.02	6.80
0:22	2.44	2.88	3.61	4.24	5.15	5.89	6.65
0:23	2.39	2.81	3.53	4.15	5.04	5.76	6.50
0:24	2.34	2.75	3.46	4.06	4.94	5.64	6.37
0:25	2.29	2.70	3.39	3.98	4.84	5.53	6.24
0:26	2.25	2.64	3.32	3.90	4.74	5.42	6.12
0:27	2.20	2.59	3.25	3.83	4.65	5.31	6.00
0:28	2.16	2.54	3.19	3.75	4.56	5.21	5.89
0:29	2.12	2.49	3.13	3.68	4.48	5.12	5.78
0:30	2.08	2.44	3.07	3.61	4.39	5.02	5.68
0:31	2.04	2.40	3.02	3.55	4.32	4.94	5.58
0:32	2.01	2.36	2.97	3.49	4.25	4.86	5.49
0:33	1.97	2.32	2.92	3.43	4.18	4.78	5.41
0:34	1.94	2.28	2.87	3.38	4.11	4.71	5.32
0:35	1.91	2.25	2.82	3.32	4.05	4.63	5.24
0:36	1.88	2.21	2.78	3.27	3.98	4.56	5.16
0:37	1.85	2.18	2.73	3.22	3.92	4.49	5.09



0:38	1.82	2.14	2.69	3.17	3.86	4.42	5.01
0:39	1.79	2.11	2.65	3.12	3.80	4.36	4.94
0:40	1.77	2.08	2.61	3.07	3.75	4.30	4.87
0:41	1.74	2.05	2.57	3.03	3.69	4.23	4.80
0:42	1.72	2.02	2.53	2.98	3.64	4.17	4.73
0:43	1.69	1.99	2.49	2.94	3.59	4.12	4.67
0:44	1.67	1.96	2.46	2.90	3.54	4.06	4.61
0:45	1.64	1.93	2.42	2.86	3.49	4.00	4.54
0:46	1.62	1.90	2.39	2.82	3.44	3.95	4.48
0:47	1.60	1.88	2.36	2.78	3.39	3.90	4.43
0:48	1.58	1.85	2.32	2.74	3.35	3.85	4.37
0:49	1.55	1.82	2.29	2.70	3.31	3.80	4.31
0:50	1.53	1.80	2.26	2.67	3.26	3.75	4.26
0:51	1.51	1.78	2.23	2.63	3.22	3.70	4.21
0:52	1.49	1.75	2.20	2.60	3.18	3.66	4.16
0:53	1.48	1.73	2.17	2.57	3.14	3.61	4.11
0:54	1.46	1.71	2.15	2.53	3.10	3.57	4.06
0:55	1.44	1.69	2.12	2.50	3.06	3.52	4.01
0:56	1.42	1.67	2.09	2.47	3.03	3.48	3.96
0:57	1.40	1.65	2.07	2.44	2.99	3.44	3.92
0:58	1.39	1.63	2.04	2.41	2.95	3.40	3.87
0:59	1.37	1.61	2.02	2.38	2.92	3.36	3.83
1:00	1.35	1.59	2.00	2.36	2.89	3.32	3.78

Note: The rainfall intensity values were extracted from the 2014 KDOT Rainfall Intensity Tables for Riley County, Kansas (KDOT, 2014).

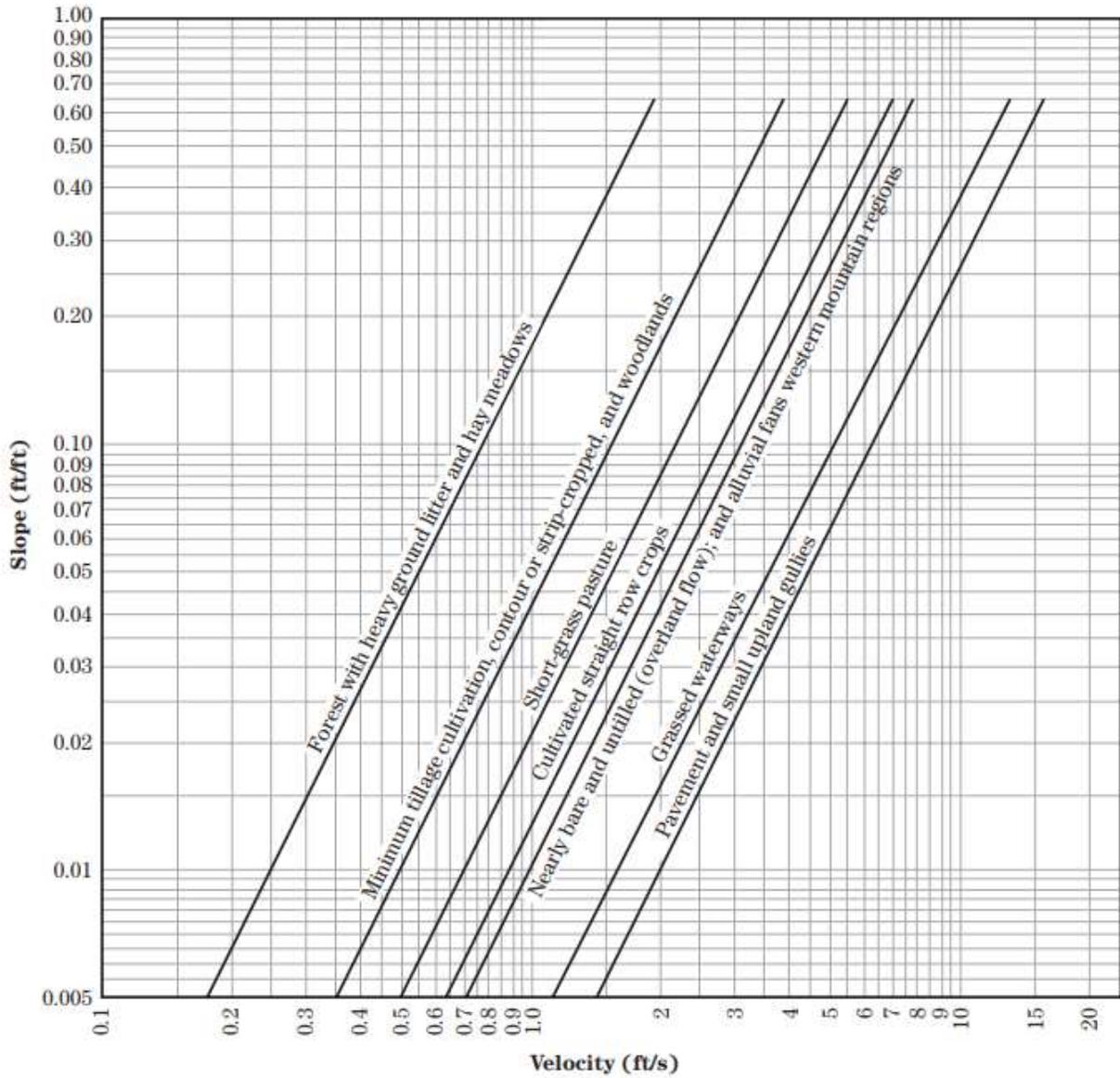
Appendix A3 - Manhattan, Kansas 6-hour Dimensionless Rainfall Distribution

Time (hr)	Cumulative Rainfall (decimal)	Time (hr)	Cumulative Rainfall (decimal)
0.0	0.00000	3.0	0.42580
0.1	0.00411	3.1	0.63024
0.2	0.00833	3.2	0.69661
0.3	0.01266	3.3	0.74681
0.4	0.01712	3.4	0.77785
0.5	0.02171	3.5	0.80417
0.6	0.02643	3.6	0.82183
0.7	0.03130	3.7	0.83745
0.8	0.03634	3.8	0.85153
0.9	0.04154	3.9	0.86438
1.0	0.04694	4.0	0.87624
1.1	0.05254	4.1	0.88638
1.2	0.05837	4.2	0.89586
1.3	0.06444	4.3	0.90477
1.4	0.07078	4.4	0.91319
1.5	0.07743	4.5	0.92117
1.6	0.08521	4.6	0.92798
1.7	0.09340	4.7	0.93447
1.8	0.10206	4.8	0.94067
1.9	0.11124	4.9	0.94662
2.0	0.12104	5.0	0.95233
2.1	0.13247	5.1	0.95783
2.2	0.14480	5.2	0.96313
2.3	0.15823	5.3	0.96824
2.4	0.17303	5.4	0.97320
2.5	0.18959	5.5	0.97799
2.6	0.21418	5.6	0.98265
2.7	0.24260	5.7	0.98717
2.8	0.27700	5.8	0.99156
2.9	0.33389	5.9	0.99584
		6.0	1.00000

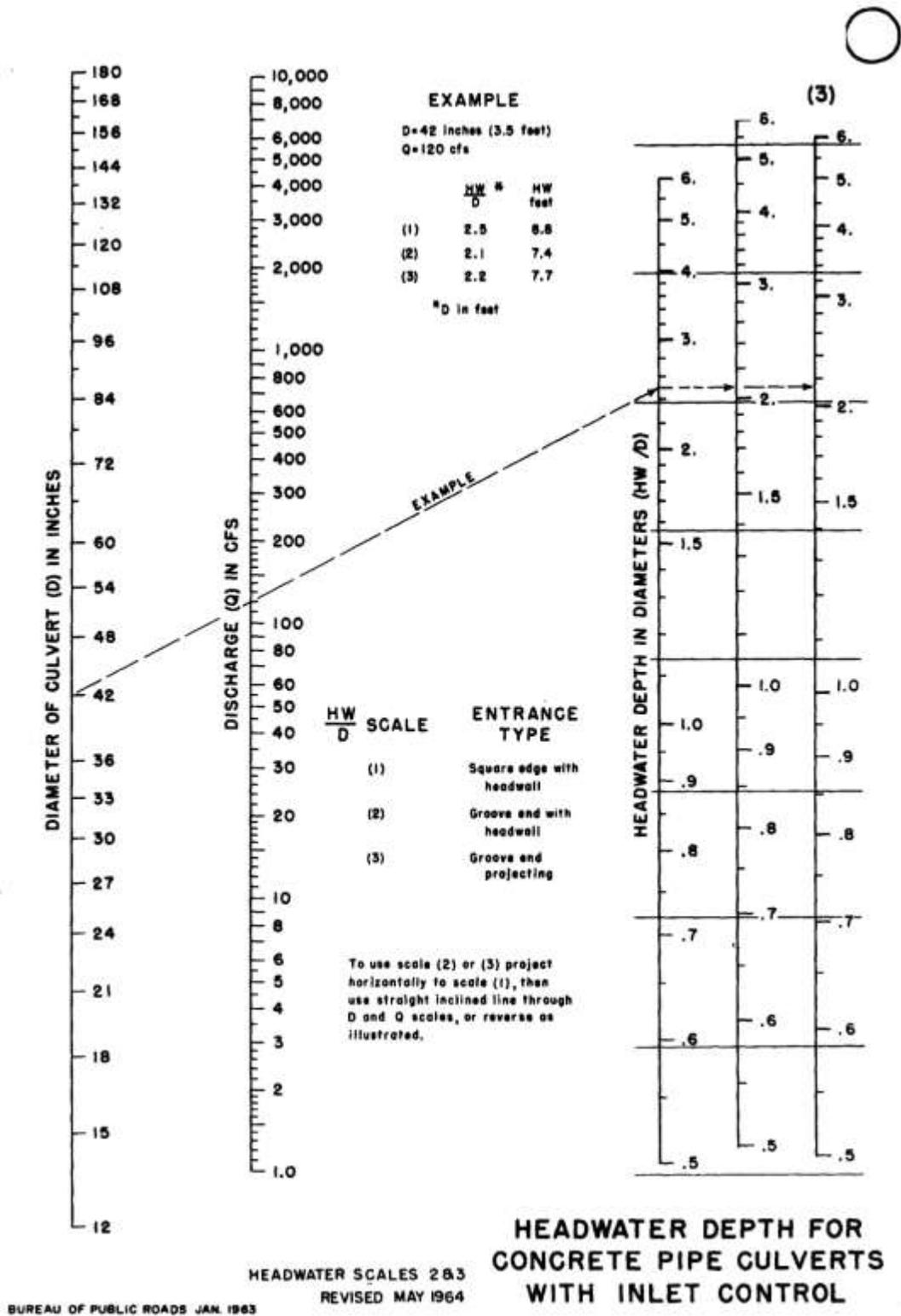
Note: The rainfall distribution was developed by the City of Manhattan using Intensity-Duration-Frequency Values for Riley County, per NOAA Atlas 14 (KDOT 2014 and NOAA 2013) and the frequency-based storm distribution model in HEC-HMS (HEC 2018).

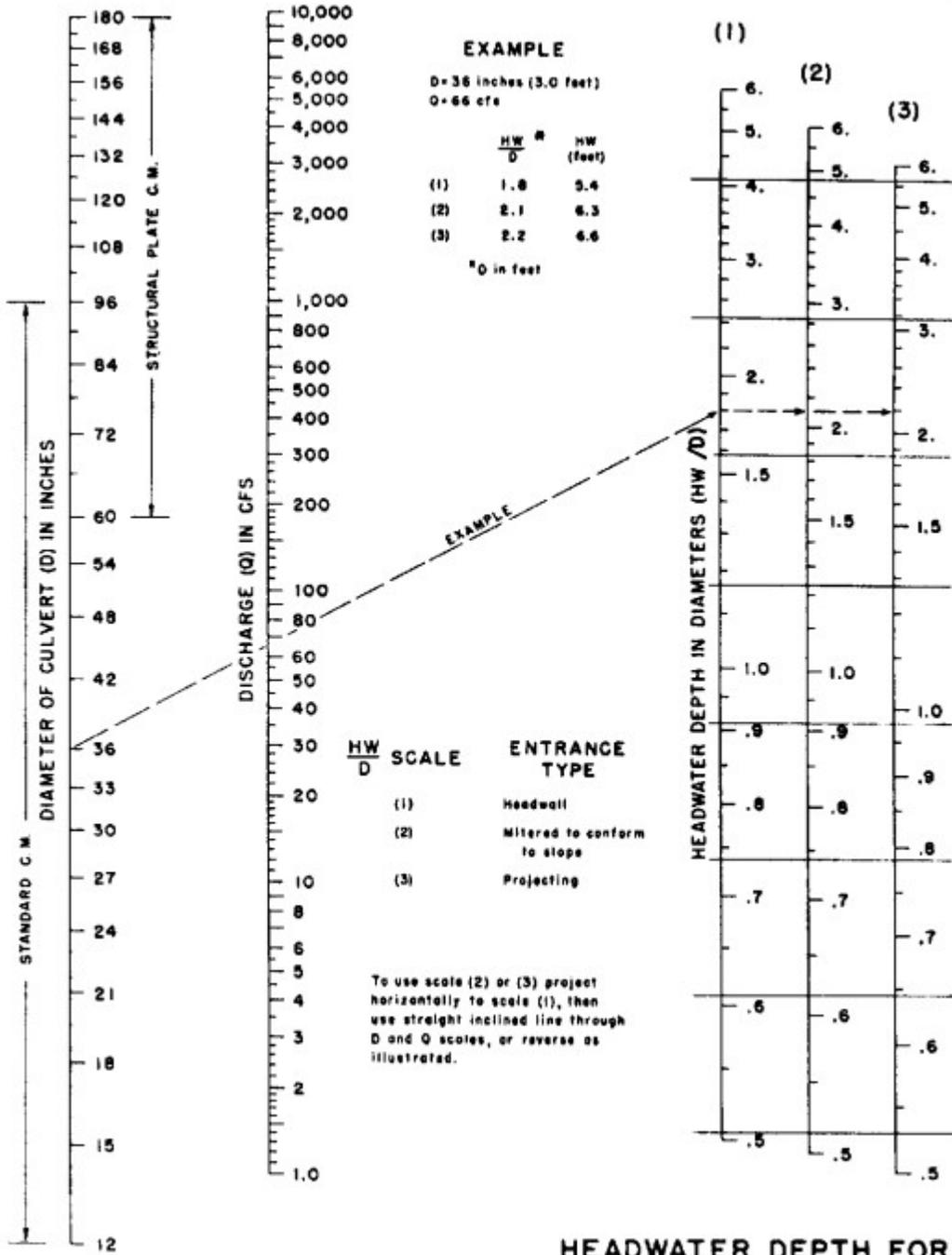


Appendix A4 – Velocity vs Slope for Shallow Concentrated Flow



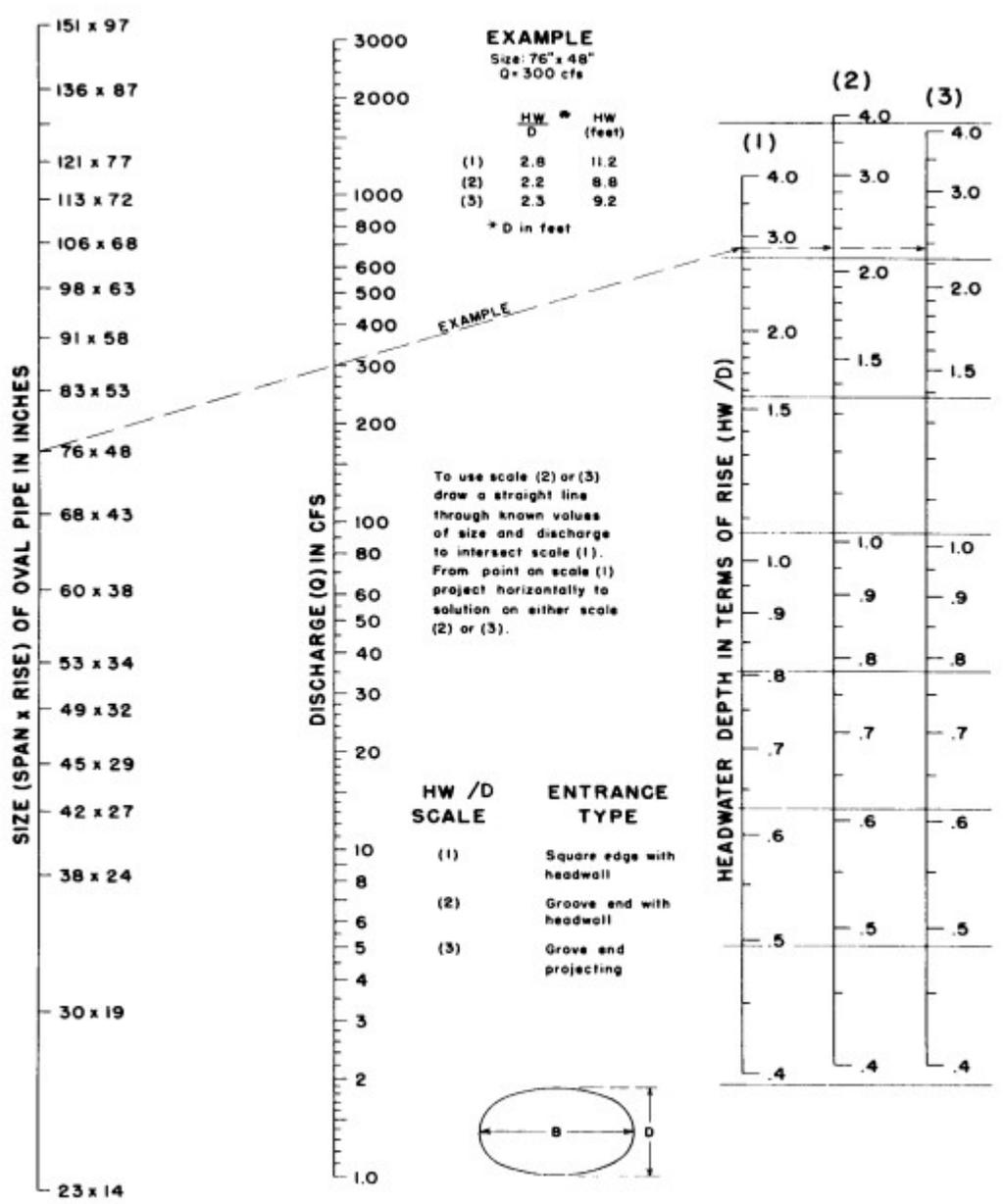
Note: Assumptions for this chart match those discussed in Equation 5.5 and Table 5.6 in Chapter 5. This chart is taken from Figure 15-4 of the NRCS (2010) handbook on Time of Concentration calculations.





HEADWATER DEPTH FOR C. M. PIPE CULVERTS WITH INLET CONTROL

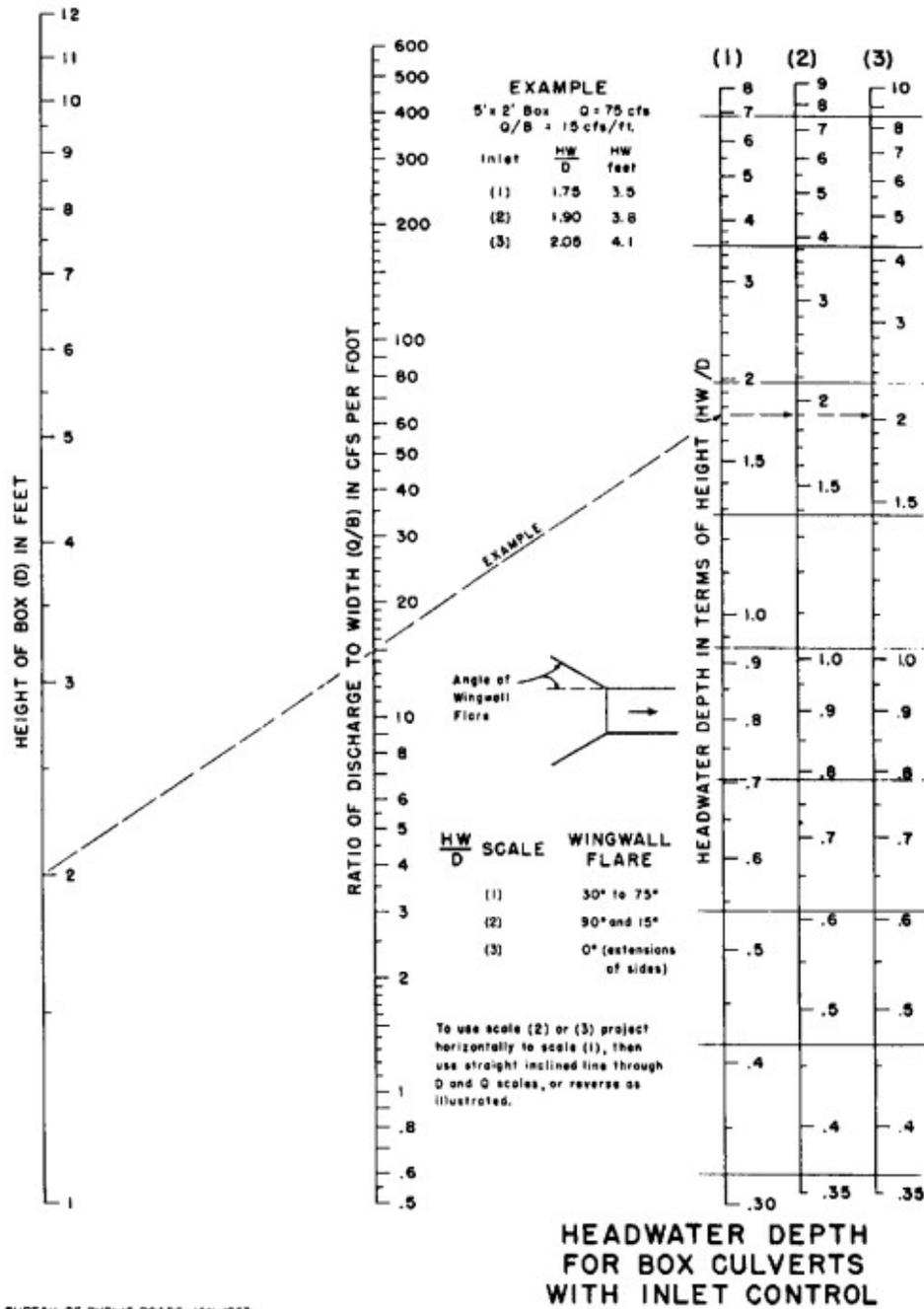
BUREAU OF PUBLIC ROADS JAN. 1963



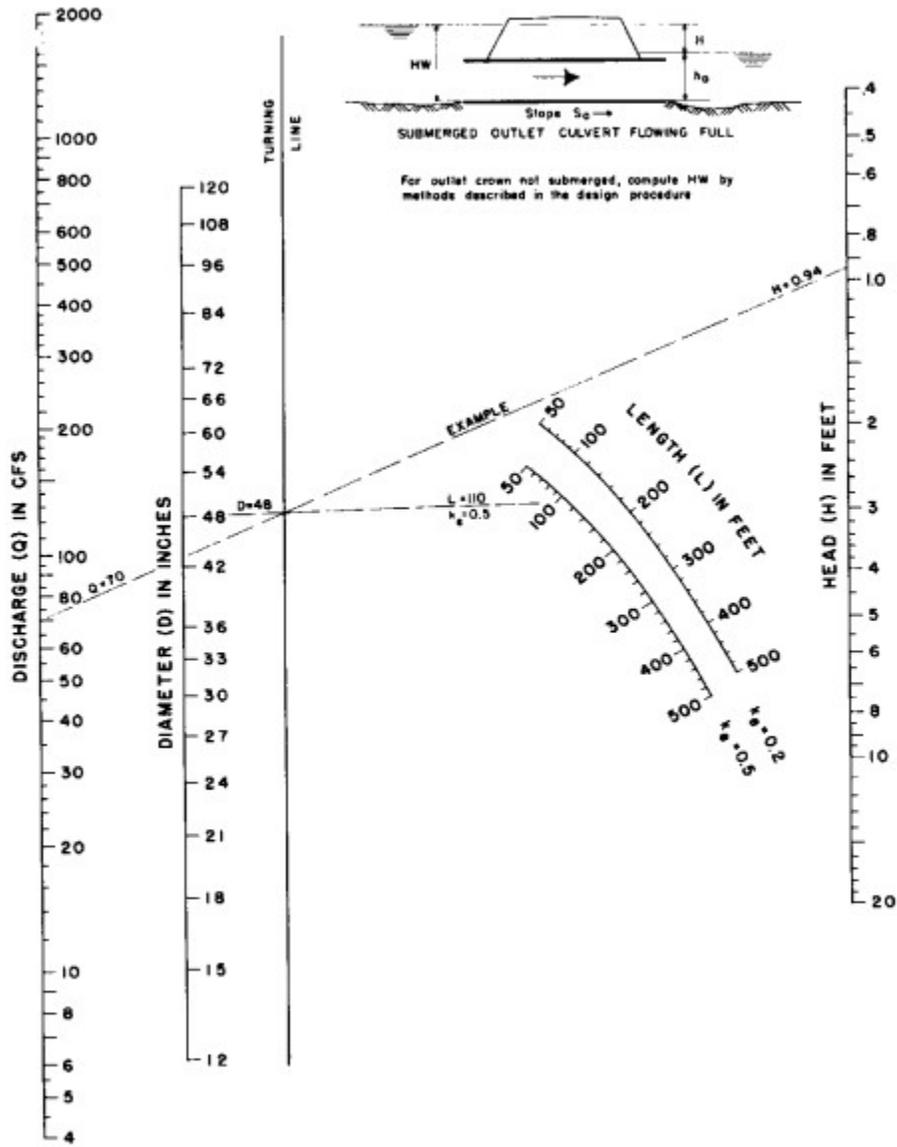
HEADWATER DEPTH FOR OVAL CONCRETE PIPE CULVERTS LONG AXIS HORIZONTAL WITH INLET CONTROL

BUREAU OF PUBLIC ROADS JAN. 1963

Appendix B4 – Inlet Control Nomograph, RCB (Box) Culverts



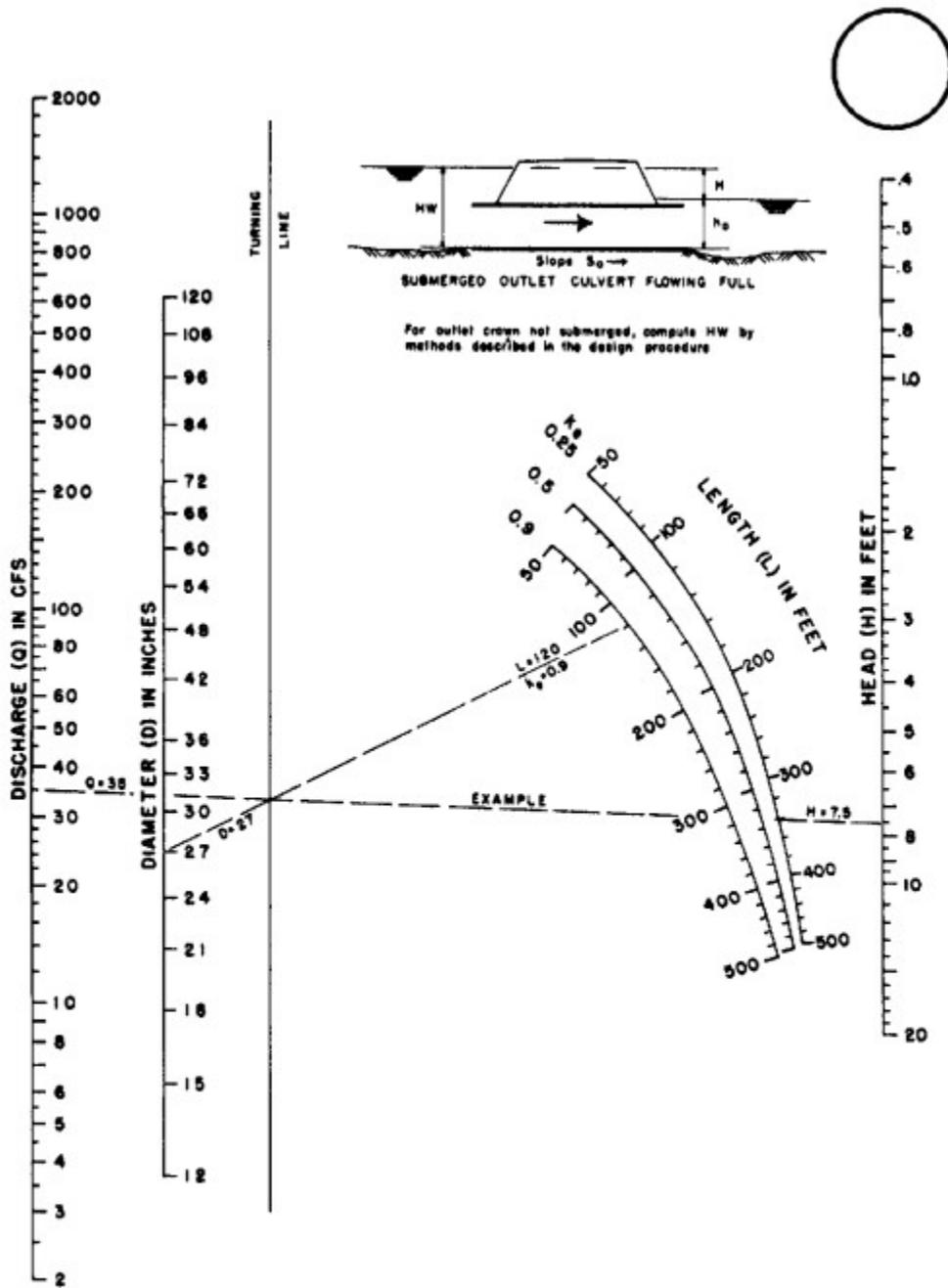
BUREAU OF PUBLIC ROADS JAN. 1963



**HEAD FOR
 CONCRETE PIPE CULVERTS
 FLOWING FULL
 n = 0.012**

BUREAU OF PUBLIC ROADS JAN. 1963

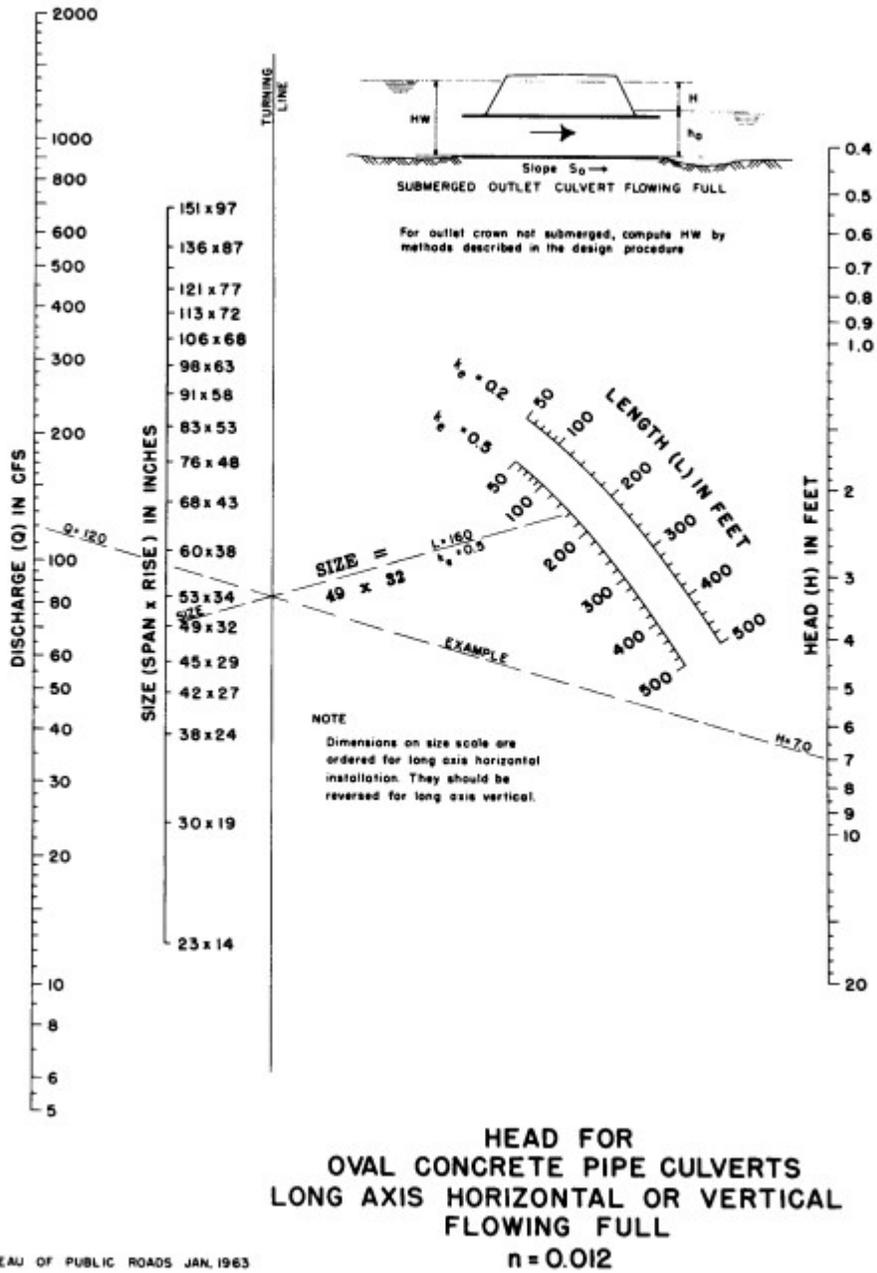
Appendix B6 – Outlet Control Nomograph, CMP Culverts



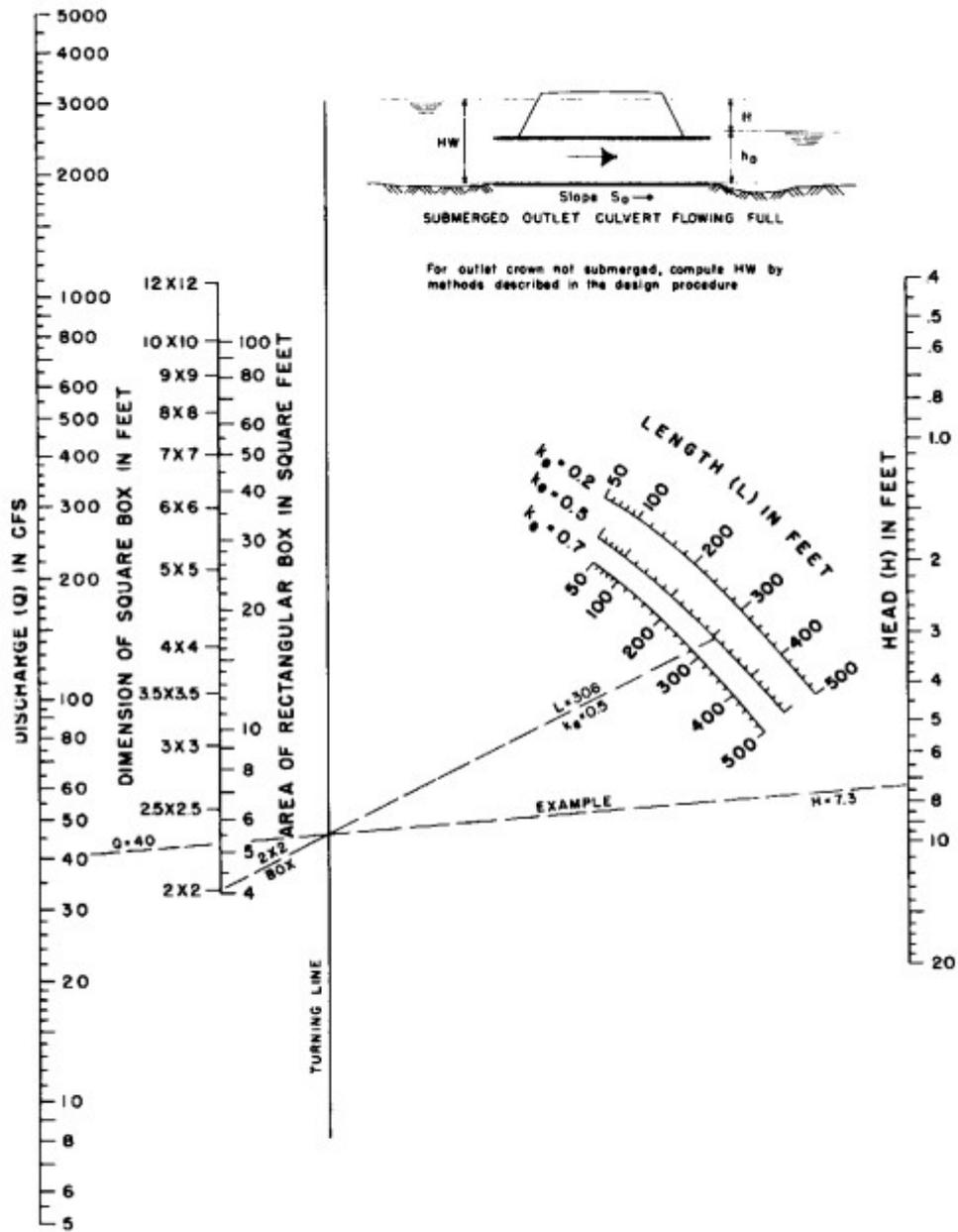
HEAD FOR
STANDARD
C. M. PIPE CULVERTS
FLOWING FULL
 $n = 0.024$

BUREAU OF PUBLIC ROADS JAN. 1963

Appendix B7 – Outlet Control Nomograph, RCPHE Culverts



Appendix B8 – Outlet Control Nomograph, RCB (Box) Culverts



HEAD FOR
CONCRETE BOX CULVERTS
FLOWING FULL
 $n = 0.012$

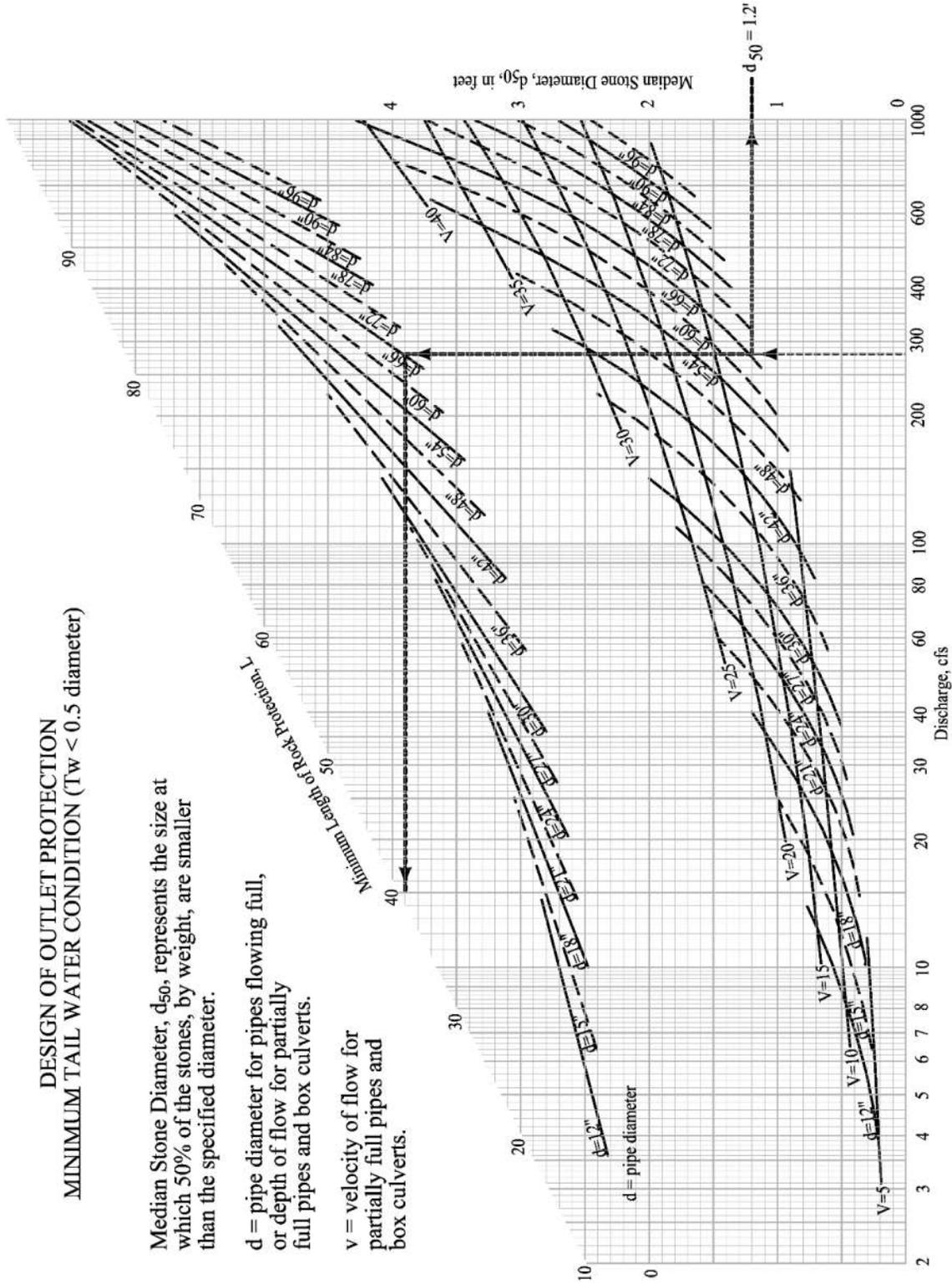
Appendix C1 - Riprap Apron Outlet for Minimum Tailwater

**DESIGN OF OUTLET PROTECTION
MINIMUM TAIL WATER CONDITION ($T_w < 0.5$ diameter)**

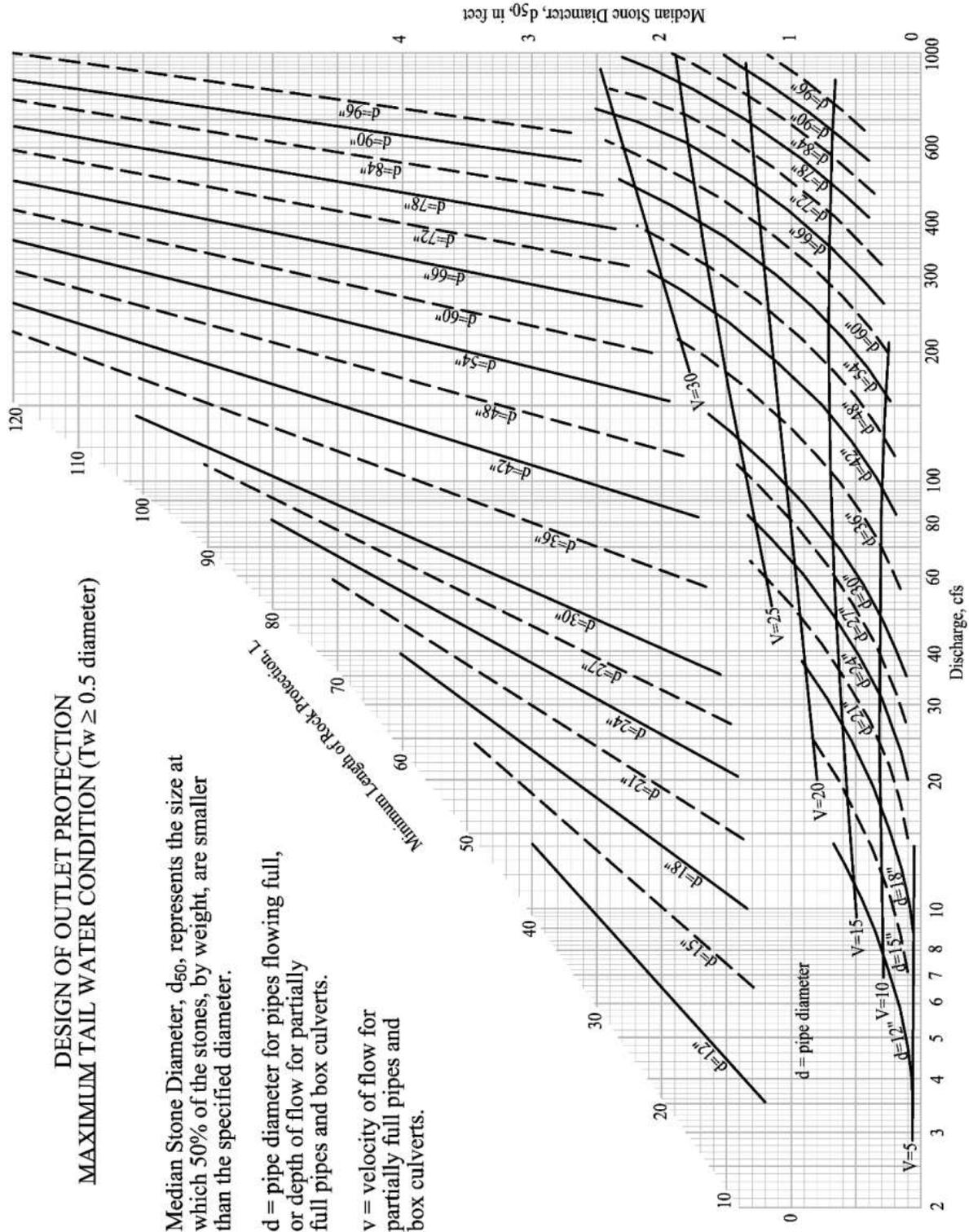
Median Stone Diameter, d_{50} , represents the size at which 50% of the stones, by weight, are smaller than the specified diameter.

d = pipe diameter for pipes flowing full, or depth of flow for partially full pipes and box culverts.

v = velocity of flow for partially full pipes and box culverts.



Source: USDA NRCS, 2004



Source: USDA NRCS, 2004

Appendix D1 - Spread Width for Gutter Flow on Grade^{1,2}

Gutter Flow, Q _g (in cfs) for Given Longitudinal Slope, S _o (%) in Street											
Spread, T (ft)	0.5%	1%	2%	3%	4%	5%	6%	8%	10%	12%	Depth at Curb, H (inches)
2	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.10	0.12	0.13	0.5
3	0.08	0.11	0.15	0.19	0.22	0.24	0.27	0.31	0.35	0.38	0.7
4	0.17	0.24	0.33	0.41	0.47	0.53	0.58	0.67	0.75	0.82	1.0
5	0.30	0.43	0.60	0.74	0.86	0.96	1.05	1.21	1.35	1.48	1.2
6	0.5	0.7	1.0	1.2	1.4	1.6	1.7	2.0	2.2	2.4	1.4
8	1.1	1.5	2.1	2.6	3.0	3.4	3.7	4.2	4.7	5.2	1.9
10	1.9	2.7	3.8	4.7	5.4	6.1	6.7	7.7	8.6	9.4	2.4
12	3.1	4.4	6.3	8	9	10	11	13	14	15	2.9
14	5	7	9	12	13	15	16	19	21	23	3.4
16	7	10	13	17	19	21	23	27	30	33	3.8
18	9	13	18	23	26	29	32	37	41	45	4.3

Notes:

- (1) Spread calculated by Izzard's formula - per FHWA HEC-22 (English units)
- (2) Standard conditions assume a 2% Cross Slope (S_x) and a Manning n=0.014
- (3) Spread (T) and depth (H) calculated per Hydraulic Engineering Circular No. 22 (HEC-22) Urban Drainage Manual (FHWA, 2013)

Appendix D2 – Capacity of A-5 Non-Setback Curb Inlet On Grade ^{1,2,3}

Captured Discharge, Qc (cfs), for Given Longitudinal Slope, So (%) in Street										
Q Total (cfs)	0.5%	1%	2%	3%	4%	5%	6%	8%	10%	12%
0	-	-	-	-	-	-	-	-	-	-
0.5	0.45	0.45	0.45	0.44	0.44	0.44	0.44	0.44	0.44	0.44
1	0.9	0.8	0.8	0.8	0.8	0.8	0.8	0.7	0.7	0.7
1.5	1.2	1.2	1.1	1.1	1.0	1.0	1.0	0.9	0.9	0.8
2	1.5	1.4	1.3	1.3	1.2	1.1	1.1	1.0	1.0	0.9
3	2.1	1.9	1.7	1.6	1.4	1.3	1.2	1.1	1.0	1.0
4	2.5	2.2	1.9	1.7	1.5	1.4	1.3	1.2	1.1	1.0
6	3.0	2.6	2.0	1.8	1.6	1.4	1.3	1.2	1.1	1.0
8	3.4	2.7	2.1	1.9	1.6	1.4	1.3	1.2	1.1	1.0
10	3.6	2.8	2.1	1.9	1.6	1.4	1.3	1.2	1.1	1.0
12	3.7	2.9	2.2	1.9	1.6	1.4	1.3	1.2	1.1	1.0
14	3.8	2.9	2.2	1.9	1.6	1.4	1.3	1.2	1.1	1.0
18	3.8	2.9	2.2	1.9	1.6	1.4	1.3	1.2	1.1	1.0
For reference⁴										
Qo (cfs)	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Qa (cfs)	4.3	3.2	2.4	2.1	1.8	1.6	1.5	1.3	1.2	1.1

Notes:

- (1) See Manhattan Standard Detail Sheet 2410
- (2) See Appendix D14 for capacity calculation description and background.
- (3) A 10% capacity reduction is included to account for clogging.
- (4) The values of Qo and Qa used in the calculation are listed for reference.

Appendix D3 – Capacity of A-7.5 Non-Setback Curb Inlet On Grade ^{1,2,3}

Captured Discharge, Qc (cfs), for Given Longitudinal Slope, So (%) in Street										
Q Total (cfs)	0.5%	1%	2%	3%	4%	5%	6%	8%	10%	12%
0	-	-	-	-	-	-	-	-	-	-
0.5	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45
1	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
1.5	1.3	1.3	1.3	1.2	1.2	1.2	1.2	1.2	1.2	1.2
2	1.7	1.6	1.6	1.6	1.5	1.5	1.5	1.5	1.5	1.4
3	2.3	2.3	2.1	2.1	2.0	2.0	2.0	1.9	1.9	1.8
4	2.9	2.8	2.6	2.5	2.4	2.3	2.3	2.2	2.1	2.1
6	3.8	3.6	3.2	3.0	2.9	2.7	2.7	2.5	2.4	2.3
8	4.4	4.1	3.6	3.3	3.1	3.0	2.8	2.7	2.5	2.4
10	4.9	4.5	3.8	3.5	3.2	3.1	2.9	2.7	2.6	2.5
12	5.3	4.7	4.0	3.6	3.3	3.1	3.0	2.8	2.6	2.5
14	5.5	4.9	4.0	3.7	3.4	3.1	3.0	2.8	2.6	2.5
18	5.9	5.1	4.1	3.7	3.4	3.2	3.0	2.8	2.6	2.5
For reference: ⁴										
Qo (cfs)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Qa (cfs)	6.9	5.9	4.6	4.1	3.8	3.5	3.4	3.1	2.9	2.8

Notes:

- (1) See Manhattan Standard Detail Sheet 2410
- (2) See Appendix D14 for capacity calculation description and background.
- (3) A 10% capacity reduction is included to account for clogging.
- (4) The values of Qo and Qa used in the calculation are listed for reference.

Appendix D4 - Capacity of A-10 Non-Setback Curb Inlet On Grade ^{1,2,3}

Captured Discharge, Qc (cfs), for Given Longitudinal Slope, So (%) in Street										
Q Total (cfs)	0.5%	1%	2%	3%	4%	5%	6%	8%	10%	12%
0	-	-	-	-	-	-	-	-	-	-
0.5	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45
1	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
1.5	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
2	1.7	1.7	1.7	1.7	1.7	1.7	1.6	1.6	1.6	1.6
3	2.5	2.4	2.4	2.3	2.3	2.3	2.3	2.2	2.2	2.2
4	3.1	3.1	2.9	2.9	2.8	2.8	2.7	2.7	2.6	2.6
6	4.2	4.1	3.8	3.7	3.6	3.5	3.5	3.3	3.3	3.2
8	5.1	4.9	4.5	4.3	4.1	4.0	3.9	3.7	3.6	3.5
10	5.8	5.5	5.0	4.7	4.5	4.3	4.2	4.0	3.8	3.7
12	6.4	6.0	5.3	4.9	4.7	4.5	4.4	4.2	4.0	3.8
14	6.8	6.4	5.6	5.1	4.9	4.7	4.5	4.3	4.1	3.9
18	7.5	6.9	5.9	5.4	5.1	4.8	4.6	4.3	4.1	4.0
For reference: ⁴										
Qo (cfs)	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Qa (cfs)	9.5	8.5	6.9	6.2	5.8	5.5	5.3	4.9	4.6	4.4

Notes:

- (1) See Manhattan Standard Detail Sheet 2410
- (2) See Appendix D14 for capacity calculation description and background.
- (3) A 10% capacity reduction is included to account for clogging.
- (4) The values of Qo and Qa used in the calculation are listed for reference.

Appendix D5 - Capacity of A-5S Setback Curb Inlet On Grade ^{1,2,3}

Captured Discharge, Qc (cfs), for Given Longitudinal Slope, So (%) in Street										
Q Total (cfs)	0.5%	1%	2%	3%	4%	5%	6%	8%	10%	12%
0	-	-	-	-	-	-	-	-	-	-
0.5	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45
1	0.9	0.9	0.9	0.9	0.9	0.9	0.8	0.8	0.8	0.8
1.5	1.3	1.3	1.2	1.2	1.2	1.2	1.1	1.1	1.1	1.1
2	1.6	1.6	1.5	1.5	1.4	1.4	1.4	1.3	1.3	1.2
3	2.3	2.2	2.0	1.9	1.8	1.7	1.6	1.5	1.4	1.4
4	2.8	2.6	2.3	2.2	2.0	1.9	1.8	1.7	1.5	1.4
6	3.7	3.3	2.8	2.6	2.2	2.1	1.9	1.7	1.6	1.5
8	4.3	3.7	3.0	2.7	2.3	2.1	2.0	1.8	1.6	1.5
10	4.7	3.9	3.1	2.8	2.4	2.1	2.0	1.8	1.6	1.5
12	5.0	4.1	3.2	2.8	2.4	2.1	2.0	1.8	1.6	1.5
14	5.3	4.2	3.2	2.8	2.4	2.1	2.0	1.8	1.6	1.5
18	5.5	4.3	3.2	2.9	2.4	2.1	2.0	1.8	1.6	1.5
For reference: ⁴										
Qo (cfs)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Qa (cfs)	6.5	4.9	3.6	3.2	2.6	2.4	2.2	2.0	1.8	1.7

Notes:

- (1) See Manhattan Standard Detail Sheet 2410
- (2) See Appendix D14 for capacity calculation description and background.
- (3) A 10% capacity reduction is included to account for clogging.
- (4) The values of Qo and Qa used in the calculation are listed for reference.

Appendix D6 - Capacity of A-7.5S Setback Curb Inlet On Grade ^{1,2,3}

Captured Discharge, Qc (cfs), for Given Longitudinal Slope, So (%) in Street										
Q Total (cfs)	0.5%	1%	2%	3%	4%	5%	6%	8%	10%	12%
0	-	-	-	-	-	-	-	-	-	-
0.5	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45
1	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
1.5	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
2	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.6	1.6	1.6
3	2.5	2.5	2.4	2.3	2.3	2.3	2.3	2.2	2.2	2.2
4	3.2	3.1	3.0	2.9	2.8	2.8	2.7	2.7	2.6	2.6
6	4.3	4.2	3.9	3.7	3.6	3.5	3.4	3.3	3.2	3.1
8	5.3	5.0	4.5	4.3	4.1	4.0	3.8	3.7	3.5	3.4
10	6.0	5.6	5.0	4.7	4.4	4.2	4.1	3.9	3.7	3.5
12	6.7	6.1	5.4	5.0	4.7	4.4	4.3	4.0	3.8	3.6
14	7.2	6.5	5.6	5.2	4.8	4.6	4.4	4.1	3.9	3.7
18	7.9	7.1	5.9	5.4	5.0	4.7	4.5	4.2	3.9	3.7
For reference: ⁴										
Qo (cfs)	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Qa (cfs)	10.4	8.8	7.0	6.2	5.7	5.3	5.0	4.7	4.4	4.2

Notes:

- (1) See Manhattan Standard Detail Sheet 2410
- (2) See Appendix D14 for capacity calculation description and background.
- (3) A 10% capacity reduction is included to account for clogging.
- (4) The values of Qo and Qa used in the calculation are listed for reference.

Appendix D7 - Capacity of A-10S Setback Curb Inlet On Grade ^{1,2,3}

Captured Discharge, Qc (cfs), for Given Longitudinal Slope, So (%) in Street										
Q Total (cfs)	0.5%	1%	2%	3%	4%	5%	6%	8%	10%	12%
0	-	-	-	-	-	-	-	-	-	-
0.5	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45
1	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
1.5	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
2	1.8	1.8	1.8	1.8	1.8	1.7	1.7	1.7	1.7	1.7
3	2.6	2.6	2.5	2.5	2.5	2.5	2.5	2.5	2.4	2.4
4	3.3	3.3	3.2	3.2	3.2	3.1	3.1	3.1	3.0	3.0
6	4.7	4.6	4.4	4.3	4.2	4.2	4.1	4.0	4.0	3.9
8	5.8	5.7	5.4	5.2	5.1	5.0	4.9	4.7	4.6	4.5
10	6.8	6.6	6.1	5.9	5.7	5.5	5.4	5.3	5.1	5.0
12	7.7	7.3	6.7	6.4	6.2	6.0	5.9	5.6	5.4	5.3
14	8.4	8.0	7.2	6.8	6.6	6.3	6.2	5.9	5.7	5.5
18	9.6	9.0	8.0	7.4	7.1	6.8	6.6	6.2	6.0	5.8
For reference: ⁴										
Qo (cfs)	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
Qa (cfs)	14.3	12.7	10.3	9.3	8.7	8.2	7.9	7.4	7.0	6.7

Notes:

- (1) See Manhattan Standard Detail Sheet 2410
- (2) See Appendix D14 for capacity calculation description and background.
- (3) A 10% capacity reduction is included to account for clogging.
- (4) The values of Qo and Qa used in the calculation are listed for reference.

Appendix D8 - Capacity of B-3 and B-3S Curb Inlets On Grade ^{1,2,3,4}

Captured Discharge, Qc (cfs), for Given Longitudinal Slope, So (%) in Street							
Q Total (cfs)	0.5%	1%	2%	4%	6%	8%	10%
0	-	-	-	-	-	-	-
0.5	0.3	0.3	0.3	0.3	0.3	0.3	0.3
1	0.6	0.6	0.6	0.6	0.6	0.6	0.6
1.5	0.8	0.8	0.8	0.8	0.8	0.8	0.8
2	1.0	1.0	0.9	0.9	1.0	1.0	1.0
3	1.4	1.3	1.3	1.3	1.3	1.3	1.3
4	1.8	1.6	1.5	1.5	1.6	1.6	1.6
6	2.3	2.1	2.0	2.0	2.1	2.1	2.2
8	nd	2.6	2.5	2.5	2.5	2.6	nd
10	nd	nd	2.9	2.9	2.9	3.0	nd
12	nd	nd	3.3	3.3	3.3	nd	nd
14	nd	nd	nd	3.6	3.7	nd	nd
18	nd	nd	nd	4.3	nd	nd	nd

Notes:

- (1) See Manhattan Standard Detail Sheet 2420
- (2) Capacity of Type B was estimated by Neenah for Deeter #2047 castings, per correspondence with City Aug 2020.
- (3) A 10% capacity reduction is included to account for clogging.
- (4) Capacity of Type B in setback is assumed similar to non-setback conditions, assuming grate is the control.
- (5) No calculation data is available for conditions marked "nd"

Appendix D9 - Capacity of B-6 and B-6S Curb Inlets On Grade ^{1,2,3,4}

Captured Discharge, Qc (cfs), for Given Longitudinal Slope, So (%) in Street							
Q Total (cfs)	0.5%	1%	2%	4%	6%	8%	10%
0	-	-	-	-	-	-	-
0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4
1	0.8	0.8	0.7	0.7	0.7	0.7	0.7
1.5	1.2	1.1	1.0	1.0	1.0	0.9	0.9
2	1.5	1.4	1.3	1.2	1.2	1.2	1.2
3	2.1	2.0	1.8	1.7	1.6	1.6	1.6
4	2.8	2.5	2.3	2.1	2.0	2.0	2.0
6	3.9	3.5	3.1	2.9	2.7	2.7	2.7
8	nd	4.4	3.9	3.5	3.4	3.3	3.3
10	nd	nd	4.6	4.2	4.0	3.9	3.8
12	nd	nd	5.3	4.7	4.5	4.4	4.3
14	nd	nd	nd	5.3	5.0	4.9	4.8
18	nd	nd	nd	6.2	6.0	5.8	5.7

Notes:

- (1) See Manhattan Standard Detail Sheet 2420
- (2) Capacity of Type B was estimated by Neenah for Deeter #2047 castings, per correspondence with City Aug 2020.
- (3) A 10% capacity reduction is included to account for clogging.
- (4) Capacity of Type B in setback is assumed similar to non-setback conditions, assuming grate is the control.
- (5) No calculation data is available for conditions marked "nd"

Appendix D10 - Capacity of B-9 and B-9S Curb Inlets On Grade ^{1,2,3,4}

Captured Discharge, Qc (cfs), for Given Longitudinal Slope, So (%) in Street							
Q Total (cfs)	0.5%	1%	2%	4%	6%	8%	10%
0	-	-	-	-	-	-	-
0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4
1	0.9	0.8	0.8	0.8	0.8	0.8	0.8
1.5	1.3	1.2	1.2	1.1	1.1	1.1	1.1
2	1.7	1.6	1.5	1.5	1.4	1.4	1.4
3	2.4	2.3	2.2	2.1	2.0	1.9	1.9
4	3.2	3.0	2.8	2.6	2.5	2.4	2.4
6	4.7	4.4	4.0	3.7	3.5	3.4	3.3
8	nd	5.6	5.1	4.6	4.4	4.2	4.1
10	nd	nd	6.2	5.5	5.2	5.0	4.8
12	nd	nd	7.2	6.4	6.0	5.7	5.6
14	nd	nd	nd	8.0	6.7	6.4	6.2
18	nd	nd	nd	nd	8.1	7.7	7.5

Notes:

- (1) See Manhattan Standard Detail Sheet 2420
- (2) Capacity of Type B was estimated by Neenah for Deeter #2047 castings, per correspondence with City Aug 2020.
- (3) A 10% capacity reduction is included to account for clogging.
- (4) Capacity of Type B in setback is assumed similar to non-setback conditions, assuming grate is the control.
- (5) No calculation data is available for conditions marked "nd"

Appendix D11 – Capacity of Curb Inlets in Roadway Sags ^{1,2,3}

Inlet Capacity, Qc (cfs) for Given Configuration										
Reference Gutter Flow Depth, H, (in) 4	T, SPREAD, IF Sx=2%	A-5 5	A-7.5 5	A-10 5	A-5S 5	A-7.5S 5	A-10S 5	B-3 & B-3S 6	B-6 & B-6S 6	B-9 & B-9S 6
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.5	2.1	0.1	0.2	0.2	0.2	0.3	0.3	0.1	0.2	0.2
1.0	4.2	0.3	0.4	0.6	0.6	0.7	0.9	0.3	0.5	0.7
1.5	6.3	0.5	0.8	1.1	1.1	1.3	1.6	0.6	1.0	1.3
2.0	8.3	0.8	1.2	1.6	1.6	2.0	2.4	1.0	1.5	2.0
2.5	10.4	1.1	1.7	2.3	2.3	2.9	3.4	1.4	2.1	2.7
3.0	12.5	1.5	2.3	3.0	3.0	3.8	4.5	1.8	2.7	3.6
3.5	14.6	1.9	2.8	3.8	3.8	4.7	5.7	2.3	3.4	4.5
4.0	16.7	2.3	3.5	4.6	4.6	5.8	6.9	2.8	4.2	5.5
4.5	18.8	2.8	4.1	5.5	5.5	6.9	8.3	3.3	5.0	6.6
5.0	20.8	3.2	4.8	6.5	6.5	8.1	9.7	3.9	5.8	7.7
5.5	22.9	3.7	5.6	7.4	7.0	9.3	11.2	4.5	6.7	8.9
6.0	25.0	4.2	6.4	8.5	7.3	10.6	12.7	5.1	7.6	10.2
6.5	27.1	4.8	7.2	9.6	7.6	11.4	14.4	5.6	8.6	11.5
7.0	29.2	5.3	8.0	10.7	7.9	11.9	15.9	5.8	9.6	12.8

Notes:

- (1) See Manhattan Standard Detail Sheets 2410 & 2420
- (2) Capacity is calculated as minimum of weir (Cw=3.0) or orifice (Co=0.67) flow, per FHWA HEC-22, 3rd ed (2013)
- (3) A 20% capacity reduction is included to account for clogging.
- (4) H represents the elevation where the standard street slope would project to face of curb. Throat on A-Series inlet is typically depressed 2.5 inches below H
- (5) Weir length for Type A is the face of inlet opening. Calculations for weir length on setback inlets adds 5 feet total to account for transition
- (6) On B-Series inlets, the weir length is based on 3 sides of grate and neglects curb opening. Orifice flow assumes grate is 32% open, and a 4" of grate width is added to estimate capacity of curb opening.

Appendix D12 - Capacity of Type 1 Area Inlet ^{1,2,3,4}

Captured Discharge, Qc (cfs) for given configuration				
Ponding Depth, H, (ft) ⁵	Type I, 4 ft x 4 ft, ⁶	Area Inlet, 4.5 ft x 4.5 ft, ⁶	Area Inlet, 5.5 ft x 4.5 ft, ⁶	Area Inlet, 7.5 ft x 4.5 ft, ⁶
0.00	0	0	0	0
0.17	2.0	2.3	2.6	3.3
0.33	5.5	6.5	7.4	9.2
0.50	10	12	14	17
0.75	19	22	25	31
1.00	23	32	38	48
1.25	26	35	45	66

Notes:

- (1) See Manhattan Standard Detail Sheet 2430
- (2) Capacity is calculated as minimum of weir (k=3.0) or orifice (Cd=0.67) flow.
- (3) Net opening for orifice flow is assumed at 60% based on rounded bars.
- (4) A 20% capacity reduction is included to account for clogging.
- (5) H is measured in feet above the rim of the inlet.
- (6) Dimensions are to outside of structure, per detail.

Appendix D13 - Capacity of Type 2, 3 and 4 Area Inlets ^{1,2,3,4}

Ponding Depth, H, (ft)	Captured Discharge, Qc (cfs) for given configuration		
	Type 2 or Type 3 (Standard Grate) ⁵	Type 2 or Type 3 (ADA Grate) ⁶	Type 4 (Beehive Grate) ^{7,8,9}
0.00	0.0	0.0	0.0
0.17	1.0	1.0	0.7
0.33	2.7	1.9	1.9
0.50	3.3	2.3	2.8
0.67	3.9	2.6	2.9
0.83	4.3	3.0	3.5
1.00	4.7	3.2	4.0
1.17	5.1	3.5	4.5
1.33	5.5	3.7	4.9
1.50	5.8	4.0	5.3

Notes:

(1) See Manhattan Standard Detail Sheet 2300

(2) Capacity is calculated as minimum of weir (k=3.0) or orifice (Cd=0.67) flow.

(3) H is measured in feet above the rim of the inlet.

(4) A 20% capacity reduction is included to account for clogging.

(5) Standard inlet based on Deeter #1930 grate with 24" diameter inside ring, with a net free opening of 35% of base area (160 sq inches)

(6) Deeter #1930A is an ADA-compliant version of the standard #1930, with a smaller net free opening of 24% of base area (107 sq. inches)

(7) For Deeter #4495 Beehive, the diameter at base is 21-7/8 inches, the dome height (Z) is 9-15/16", and an actual opening of approximately 35% of dome area.

(8) For calculation, the beehive is approximated as weir flow up to 4", special orifice only above 6", and transitional in between. The weir length is reduced by 30% for obstruction.

(9) For special orifice flow on the beehive inlet, the area of orifice is treated as a flat surface, raised 4" above the rim, and with an effective opening of 40% of the base area.

Type A Inlets, On Grade

Type A inlet design was adapted from inlets studied as part of various K-Trans research projects using lab-scale physical models. The basic inlet studied was the KDOT Type 22 (McEnroe, Wade & Smith 1999). The lab results were fitted to the following equation of curb inlet performance:

Equation:
$$Q_c = \begin{cases} Q_t & \text{for } Q_t \leq Q_o \\ Q_o + (Q_a - Q_o) \left\{ 1 - \exp \left[- \left(\frac{Q_t - Q_o}{Q_a - Q_o} \right) \right] \right\} & \text{for } Q_t > Q_o \end{cases}$$

where:

- Q_t = Total discharge (cfs)
- Q_o = Largest discharge captured completely (cfs)
- Q_a = Upper limit on the captured discharge

Q_o and Q_a vary by specific inlet configuration and longitudinal slope in the street and were determined experimentally for 5 feet and 10 feet long inlets on street slopes between 0.5% and 5%. Values for Q_o and Q_a were estimated for steeper slopes and for the intermediate 7.5 feet long inlet.

For MSD 2410 Type A non-setback curb inlets on-grade, the capacity of the inlets is estimated to perform equivalently to a KDOT Type 22 style inlet. Design charts from KDOT’s Design Manual (KDOT 2016) were consulted for basic values. All calculations assumed that the KDOT charts for a street cross slope of 3.1% were adequate, since no testing was made on the more typical 2% cross slope used in Manhattan.

For Type A setback curb inlets on-grade, the capacity of inlets is based on a separate study. KDOT’s study did not examine inlets in a setback configuration, but a similar set of model studies for setback inlets used in Johnson County, KS was conducted by McEnroe & Wade (1998) under a separate KDOT-funded grant. The Johnson County inlets have substantially deeper throat depressions and setback widths than those used for the Manhattan Type A setback inlet. An intermediate set of values for Q_o and Q_a was estimated by increasing the Q_o and Q_a values of the non-setback condition by 50%. In the absence of further model testing this provided a modest boost in estimated inlet performance.

Type B Inlets, On Grade

The standard casting used is a Deeter #2047 manufactured by Neenah Enterprises, Inc (www.groupnei.com and www.deeter.com), or equivalent. The manufacturer supplied the city with calculations to estimate inlet capture for the three standard configurations (3 ft, 6 ft and 9 ft) used. Based on the operation of grate inlets, there was no estimated increase in capacity when used in a setback configuration. Capacity of was estimated by Neenah for Deeter #2047 castings, per correspondence with the City in August 2020. The capacity results include a 10% reduction to account for clogging.



