RESOLUTION NUMBER 6614

WHEREAS, Congress passed the Clean Water Act in 1972 which regulates water quality; and

WHEREAS, since the adoption of the Clean Water Act, such regulations have become applicable to smaller units of government; and

WHEREAS, the City of Beatrice ("City") became an MS4 Community based on its population in 2003; and

WHEREAS, MS4 Communities must enact measures to detect and eliminate illicit discharges and control construction and post-construction site runoff of stormwater; and

WHEREAS, in 2008, the City adopted Chapter 27 to its City Code, regarding stormwater, which made illicit discharges illegal in the City and requires stormwater detention; and

WHEREAS, Chapter 27 of the Beatrice City Code also mandates that the City adopt requirements which identify best management practices for stormwater detention; and

WHEREAS, the City has become part of the Nebraska H2O group, which is a group of MS4 communities in Nebraska that work together to develop stormwater best management practices; and

WHEREAS, part of Nebraska H2O's efforts has been the development of a drainage criteria manual that is both similar in all eleven (11) Nebraska H2O communities, and also uniquely adapted to each (the "Drainage Criteria Manual"); and

WHEREAS, the City has determined that it is in the best interests of the community to adopt the Drainage Criteria Manual to establish guidelines, standards, and methods for effective planning and design of the stormwater drainage system in our community.

NOW, THEREFORE, BE IT RESOLVED BY THE MAYOR AND CITY COUNCIL OF THE CITY OF BEATRICE, NEBRASKA:

SECTION 1. That the Drainage Criteria Manual, dated August 2020, marked as Exhibit "A", attached hereto and incorporated hereby by reference, be and is hereby adopted.

SECTION 2. That all resolutions or parts of resolutions in conflict herewith are hereby repealed.

RESOLUTION PASSED AND ADOPTED this 8th day of September, 2020.

Attest:

Erin Saathoff, City Clerk

Stan Wirth, Mayor

DRAINAGE CRITERIA MANUAL

FOR THE COMMUNITY OF:

STAKE YOUR CLAIM

BEATRICE

CITY • BOARD OF PUBLIC WORKS

August | 2020

Version 1.0

FELSBURG HOLT & ULLEVIG

connecting & enhancing communities

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1. INTRODUCTION

1.1 Purpose

Providing adequate drainage in urban areas is a necessary component in maintaining the overall health, welfare, and economic well-being of a community. Haphazard growth in an urban setting can result in erratic development of the urban stormwater drainage system. Problems caused by erratic development can include flooding, soil erosion, and pollution, which may manifest themselves in loss of life, property damage, increased stress on municipal budgets, and loss of the natural beauty of a community. Urban drainage and flood control management is a complex issue primarily because it is related to the mobility of the public, water supply, sanitation, aquifer recharge, irrigation, and urban layout. The urban stormwater drainage and flood control system in and of itself is important, but it must also mesh with community growth plans and regional drainage plans.

It is the goal of the City to provide a consistent program of storm drainage and flood control, to protect human life and health, and to minimize property damage resulting from erosion, sedimentation, and flooding.

It is also a goal of the City to plan for urban drainage and flood control to help achieve an orderly, efficient, pleasant, and diverse urban area, which, in turn, will complement other efforts conducive to public health, safety, and welfare.

The purpose of this Drainage Criteria Manual is to provide technical drainage design criteria and guidance to aid in achieving these goals. This manual applies within the corporate limits of the City and its extraterritorial jurisdiction.

1.2 Contents

This manual includes nine technical chapters that provide guidance on the major aspects of urban stormwater management and drainage facility design. The manual is intended to be an effective and practical resource that provides users with accepted engineering approaches and policies.

It is assumed that the user has basic knowledge of hydraulics, hydrology, and stormwater management concepts. For additional design and engineering guidance not specified in this manual, refer to the current issue of the following publications:

City of Lincoln, Nebraska:

- Drainage Criteria Manual

City of Omaha, Nebraska:

- Omaha Regional Stormwater Design Criteria Manual

Federal Highway Administration (FHWA):

- Hydraulic Design Series 5: Hydraulic Design of Highway Culverts (HDS 5)
- Hydraulic Engineering Circular No. 9: Debris Control Structures Evaluation and Countermeasures (HEC 9)
- Hydraulic Engineering Circular No. 13: Hydraulic Design of Improved Inlets for Culverts (HEC 13)
- Hydraulic Engineering Circular No. 14: Hydraulic Design of Energy Dissipators for Culverts and Channels (HEC 14)

- Hydraulic Engineering Circular No. 15: Design of Roadside Channels with Flexible Linings (HEC 15)
- Hydraulic Engineering Circular No. 22: Urban Drainage Design Manual (HEC 22)

Natural Resources Conservation Service (NRCS):

- National Engineering Handbook, Part 630 Hydrology

Nebraska Department of Transportation (NDOT):

- Drainage Design and Erosion Control Manual

Mile High Flood District (formerly Urban Drainage and Flood Control District):

- Urban Storm Drainage Criteria Manual

1.3 Objectives

Drainage, flood control, and water quality protection in the City is an integral part of a comprehensive community plan. Drainage represents only one component of a larger urban system. The objectives of the drainage and flood control policies and guidelines outlined in this manual are to:

1. Employ a consistent Stormwater Management Plan for the City, to minimize adverse effects to the environment and to handle storm runoff safely and efficiently.
2. Employ Stormwater Design Criteria that ensures that design of the drainage system is consistent with good engineering practices and minimizes stormwater interference with vehicular traffic.
3. Reduce the exposure of people and property to flood hazards.
4. Systematically minimize the level of flood, sediment, and erosion damage to public and private property.
5. Comply with floodplain regulations as required by the Federal Emergency Management Agency (FEMA) and administered by the Nebraska Department of Natural Resources (NeDNR).
6. Encourage upstream drainage area and flood plain uses which are consistent with approved land use plans for those areas, and coordinate with plans for the total community.
7. Ensure that corrective works are consistent with the overall goals of the city and region and provide an efficient use of public funds.
8. Manage stream and drainage channel corridors to promote environmental diversity and to protect buildings and facilities from damage by channel erosion.
9. Stabilize channels in order to minimize the disruption of existing infrastructure such as bridges and utility lines.
10. Maintain existing natural drainage patterns.

1.4 Criteria Summary

1.4.1 Drainage Design and Technical Criteria

The design criteria presented in this manual are based on accepted engineering practice for drainage and stormwater management. Extensive input from the State of Nebraska Department of Transportation's Drainage Design and Erosion Control Manual, the City of Lincoln Drainage Criteria Manual, and the City of Omaha Regional Stormwater Design Criteria Manual was used in the development of this manual.

The criteria within this manual are intended to establish guidelines, standards, and methods for effective planning and design. Drainage policies, procedures, and guidelines outlined in the manual are subject to amendment by the City as conditions warrant. They are not intended to establish legal standards. Special situations may call for variations from these requirements, subject to approval from the City. The City may set aside these criteria in the interest of the health, safety, order, and general welfare of the community. The proper documentation of drainage decisions is vital for project records and archival purposes.

1.4.2 Minor and Major Drainage Systems

An urban area has two separate and distinct drainage systems, whether or not they are actually planned for and designed. One is the minor system and the other is the major system. The minor system is typically designed to provide public convenience and to accommodate relatively moderate frequent flows. The major system carries more water and operates when the rate or volume of runoff exceeds the capacity of the minor system. To provide for orderly urban growth, reduce costs to taxpayers, and minimize loss of life and property damage, both systems must be planned and properly engineered.

1.4.2.1 Minor Drainage System

The minor drainage system is typically thought of as storm drains and related structures, such as inlets, curbs, and gutters. The minor system is normally designed for floods with return frequencies of 5 years to 10 years, depending on the surrounding land use.

The minor drainage system design will be based on the 5-year (20% annual exceedance probability) design storm for residential areas and the 10-year (10% annual exceedance probability) design storm for downtown and industrial/commercial areas. **During design of the storm sewer system, the hydraulic grade line for all enclosed systems shall be determined to ensure that inlets act as inlets, not outlets.**

The downstream existing conveyance system should be evaluated to ensure that it has sufficient capacity to accept design discharges without adverse backwater impacts on the proposed conveyance system, or downstream impacts such as flooding, streambank erosion, and sediment deposition. Starting tailwater conditions for the major and minor design storm flow should be determined.

1.4.2.2 Major Drainage System

The major drainage system is designed to convey runoff from and to regulate encroachments for large, infrequently occurring events. When development planning and design do not properly account for the major storm flow path, floodwaters will seek the path of least resistance, often through individual properties, thus causing damage. An assured route of passage for major storm floodwaters should always be provided such that public and private improvements are not damaged.

The 100-year return frequency storm (1% annual exceedance probability) shall be the major drainage system design storm for all new developments. Runoff from the 100-year storm event shall pass through a development without flooding buildings, homes, or residential lots. Overland flow routes can be provided using streets, swales, and open space.

Open channels for transportation of major storm runoff are desirable in urban areas and use of such channels is encouraged. Open channel planning and design objectives are best met by using natural, or natural-type channels, which characteristically have slow velocities, and a large width to depth ratio. Optimum benefits from open channels can best be obtained by incorporating parks and greenbelts with the channel layout.

To the extent practicable, open channels shall follow the natural channels and shall not be filled or straightened significantly. Effort must be made to reduce flood peaks and control erosion so that the natural channel features are maintained. Channel improvement or stabilization projects are encouraged to minimize use of visible concrete, riprap, or other hard stabilization materials to maintain the riparian characteristics.

1.4.3 Storm Runoff Computation

The calculation of the storm runoff peaks and volumes is important to the proper planning and design of drainage facilities. Peak runoff values shall be calculated by using either the rational method, NRCS unit hydrograph method, or rational or NRCS methodological software as appropriate.

1.4.4 Detention

Design storms equal to the 2-, 10- and 100-year frequency events shall be used in the design of detention and retention facilities. The NRCS Curve Number method shall be used to develop inflow and outflow hydrographs for the design of storage facilities. The Rational Method or Modified Rational Method shall not be used for design of storage facilities. If a detention or retention facility is used for both water quantity and water quality, it shall also take into account the water quality storm event.

In new or redevelopment areas, post-project peak flow rates shall not exceed existing peak flow rates for the 2-year, 10-year, and 100-year discharges at the project property line and in accordance with other chapters of this Drainage Criteria Manual.

Detention facilities shall be designed with adequate access and sediment storage right-of-way (including sediment forebays) to facilitate maintenance. Unless private maintenance of on-site detention facilities is acceptably performed, necessary maintenance by City forces may be provided. The cost of this service may be allocated to responsible parties.

The owner shall provide record drawings of the storage facility to the City.

1.4.5 Flood Corridor Management

The City participates in the National Flood Insurance Program (NFIP). By ordinance, the City will comply with floodplain regulations as required through the Federal Emergency Management Agency (FEMA) and administered by the Nebraska Department of Natural Resources (NeDNR). Mapped floodplains are present in and around the City.

Projects with construction occurring in a mapped floodplain will require certification that:

- Where construction occurs in Zone A Floodplains, it does not increase, cumulatively, the floodplain base flood elevation more than one foot (1'), and
- Where construction occurs in Floodways, there is no increase in the base flood elevation.

The base flood is defined as the flood having a one percent chance of being equaled or exceeded in magnitude in any given year (100-year event). The base flood elevation is the calculated water surface elevation produced by the base flood.

1.4.5.1 Preservation of Flood Corridor

New development shall preserve a minimum corridor in all channels that drain greater than 40 acres or have a defined bed and bank. The width of minimum flood corridors shall be equal to the greater of:

- The extent of the 100-year floodplain, or
- The channel bottom width, plus 60 feet, plus six times the channel depth

The corridor shall be centered on the channel or aligned such that the corridor follows the natural flow of flood waters. Individual areas of encroachment into the corridor may be permitted for parks, pedestrian/bike trails, recreational uses, and public purposes, provided the encroachments are minimal and the uses are generally consistent with the purpose of the corridor.

1.4.6 NPDES Construction Site Activities

A NPDES "notice of intent" and a Stormwater Pollution Prevention Plan (SWPPP) shall be required before land disturbance or vegetation removal activities occur on any site greater than or equal to one (1.0) acre in size. Approval of the permit will be provided when both the City and State approve the permit application. Structural and non-structural best management practices (BMPs) are required to address erosion and sediment control concerns. The SWPPP shall be prepared by a designated erosion control designer with erosion and sediment control training, experience, and knowledge.

Contractors and developers shall contact the City at least one business day prior to performing land disturbance or vegetation removal on any site greater than or equal to 1.0 acre. Construction sites will be inspected periodically for compliance with submitted SWPPPs.

1.4.7 Post Construction Stormwater Quality

Structural and nonstructural BMPs that address long-term stormwater quality enhancement are required for new or redevelopment projects that disturb more than one acre. Effective, reasonable, and cost-effective BMPs should be selected for implementation on a site-specific basis and in a manner that is consistent with existing basin plans. Water quality guidelines are outlined in Chapter 9 of this manual. The following is a list of structural BMP types that may be considered:

- Create temporary ponding areas on parking lots and in landscaped or turfed open areas of building sites.
- Reduce the amount of impervious area directly connected to the storm drain system.
- Intentionally create longer vegetated drainage paths for minor storm events.
- Develop multipurpose extended detention facilities.
- Use retention facilities (wet ponds) where feasible.

The following is a list of non-structural BMP types that may be considered:

- Use appropriate vegetation to reduce the need for fertilizer and pesticides.
- Preserve environmentally sensitive areas to protect them from development or other disruption.
- Set aside more open space.
- Preserve or re-establish riparian vegetation.
- Implement staged grading of developments to minimize the amount of land disturbed at one time.

1.4.8 Drainage Easements

All easements for storm drain pipe should be a minimum of 20 feet wide. In situations where the engineer can clearly demonstrate that an easement less than 20 feet is adequate, the City may consider such a request. Easements for surface water flow shall be used where a drainageway must be maintained to carry stormwater flow in excess of the storm drain pipe capacity. The easement cross-section shall accommodate the depth and width of flow from the 100-year storm. The width must also be designed to allow for access of maintenance equipment during the major storm.

Drainage easements should also be provided at all areas of ponding or backwater near inlets, culverts, and levees. Easements at these locations should be sized to cover the entire ponding or backwater area for the 100-year storm.

1.5 Submittals

The City requires submittals of drainage reports, hydrologic and hydraulic calculations, and drainage plans when a project changes the land use or drainage patterns of an area. Additional, specific submittal requirements for post-construction stormwater BMPs for development disturbing one acre or more are detailed in Chapter 9 of this manual. Submittal of drainage documentation and data must be coordinated with the City.

1.6 Software

Drainage design software accepted by the City may be used. The City should be consulted to determine if software is acceptable prior to its use. Any software used for design in the City must be capable of utilizing and meeting the design criteria found in this manual. Software available from the Federal Highway Administration such as HY-8 or Hydraulic Toolbox, the U.S. Army Corps of Engineers such as HEC-RAS or HEC-HMS, or state agencies such as the Nebraska Department of Transportation's Rational Method RMA Calculator are generally acceptable in their most recent versions, for example.

1.7 References

- City of Lincoln Public Works and Utilities Department, 2004. *Drainage Criteria Manual.*
- City of Omaha Environmental Quality Control Division, 2014. *Omaha Regional Stormwater Design Manual.*
- Federal Highway Administration, 2009. *Hydraulic Engineering Circular No. 22, Third Edition, Urban Drainage Design Manual.*
- Nebraska Department of Transportation, 2006. *Drainage and Erosion Control Manual.*
- Mile High Flood District (formerly Urban Drainage and Flood Control District), 2016. *Urban Storm Drainage Criteria Manual.*

2. HYDROLOGY

2.1 Overview

Hydrology is the study of the movement and distribution of water. Runoff is the drainage that leaves an area as surface flow or pipeline flow. Hydrologic analysis is necessary to estimate the peak runoff rate and volume of runoff that a drainage structure will be required to convey or control. Methods for computing peak rates of runoff and criteria for determining design storm frequencies are included in this section. Because these methods only estimate runoff, stream gage or other historical flood data should be used by designers (when available) to calibrate or correlate calculated estimates of runoff.

2.1.1 Hydrologic Method Selection

Several hydrologic methods have been developed for estimating peak runoff quantities. This section presents the two methods recommended for computing peak runoff; the rational method and the Natural Resources Conservation Service (NRCS) unit hydrograph method. It is recommended that each of the two methods be limited to use within a given drainage basin size, as detailed below. If a drainage basin greater than the recommended size for the NRCS unit hydrograph method is encountered, NDOT regression equations are recommended for computing peak runoff per the most recent version of the NDOT Drainage Design and Erosion Control Manual.

The rational method can only be used to estimate the peak runoff of a drainage basin. This is its only use; the rational method cannot be used to derive a runoff hydrograph or for the design of a storage facility.

Table 2-1. Recommended Hydrologic Methods

Method	Size Limitations[1]	Comments
Rational	0 to 200 Acres	Method can be used for estimating peak flow only. Method shall not be used for the design of storage facilities (See NRCS Method below for storage facility design).
NRCS[2] Unit Hydrograph	200 Acres to 10 Square Miles	Method can be used for estimating peak flow and developing hydrographs. Method shall be used for the design of all storage facilities regardless of sub-basin size.
NDOT Regression Equations	Greater Than 10 Square Miles	Refer to the most recent version of the NDOT Drainage Design and Erosion Control Manual for all design criteria for regression equations.

[1] Size limitations refer to the sub-basin size to the point where the stormwater management facility (i.e., culvert, inlet) is located.

[2] The NRCS was previously called the Soil Conservation Service (SCS), and many of the methods detailed by the NRCS are still commonly referred to as SCS Methods. For the purposes of this manual, all methods will be referred to as NRCS methods.

2.1.2 Frequency Design Criteria

Since it generally is not economically feasible to design a structure for the maximum runoff a watershed is capable of producing, design frequency criteria must be established. The design frequency criteria for common stormwater management facilities is summarized in Table 2-2.

Table 2-2. Design Frequency Criteria

Stormwater Management Facility	Design Frequency
Pavement Drainage/Inlets/Storm Sewer	10 Year Commercial/Industrial, 5 Year Residential
Culverts/Pavement Cross Drainage (Major System)	50 Year
Culverts (Minor System[1])	10 Year
Open Channels (Major System)	100 Year
Open Channels (Minor System[1])	10 Year
Storage Facilities	2, 10 & 100 Year
Temporary Facilities[2]	2 Year

[1] Culverts and open channels for the minor system run parallel to the roadway and are used to drain the roadway in lieu of a storm sewer system. No culvert that crosses a public roadway is considered to be part of the minor system.

[2] These facilities shall remain in place no longer than two years.

In some cases, particularly in municipalities located in extremely flat terrain, the 10-year commercial/industrial and 5-year residential design frequency for storm sewer may be impractical to obtain. In these cases, consideration may be given for design frequencies as low as 2-years. City approval must be obtained in these cases.

2.2 Rational Method

The rational method is the most commonly used method to estimate the peak runoff of a drainage basin. It can be used to estimate the peak runoff for areas as large as 200 acres.

2.2.1 Concept and Equation

The rational method estimates the peak rate of runoff at any location in a watershed as a function of the drainage area, runoff coefficient, and mean rainfall intensity for a duration equal to the time of concentration. The rational method is based on the following formula:

$$Q = CIA$$

Where:

$Q = Discharge\ Occurring\ at\ the\ Time\ of\ Concentration, cfs$
$C = Runoff\ Coefficient$
$I = Average\ Rainfall\ Intesity\ for\ a\ Duration$
$Equal\ to\ the\ Time\ of\ Concentration, in/hr$
$A = Drainage\ Area, acres$

2.2.2 Application

Peak runoff estimated using the rational formula is very sensitive to the parameters that are used. The designer must use good engineering judgment in assigning values to these parameters. Each parameter used in the rational method is discussed below.

2.2.2.1 Time of Concentration

The time of concentration (Tc) is the time required for water to flow from the hydraulically most remote point of the drainage area to the design point. The duration of rainfall is set equal to the Tc and is used to estimate the rainfall intensity. In some cases, for a basin with highly impervious areas, several different Tc's must be calculated to determine the governing design flow. No matter how small a drainage area may be, the time of concentration shall not be shorter than five minutes. See Section 2.2.3 Common Errors and Limitations.

For a storm sewer system, the Tc consists of the inlet time plus the time of flow in a pipe or open channel to the design point. The velocity method from the NRCS is recommended for computing Tc.

The total Tc is:

$$Tc = T_i + T_p$$

Where:

$Tc = Time\ of\ Concentration$
$T_i = Inlet\ Time$
$(Sheet\ Flow\ Plus\ Shallow\ Concentrated\ Flow\ Times, See\ Below)$
$T_p = Time\ in\ Pipe\ or\ Channel$

2.2.2.1.1 Inlet Time

Inlet time is the time required for runoff to flow over the surface to the nearest inlet and is primarily a function of the length of overland flow, the slope of the land and surface cover. Overland flow includes sheet flow and shallow concentrated flow and the total inlet time can be estimated by summing these two components.

Sheet flow time is based on the following formula:

$$T_{sf} = \frac{0.42(nl)^{0.8}}{(P_2)^{0.5}S^{0.4}}$$

Where:

$T_{sf} = Sheet\ Flow\ Time, minutes$
$n = Manning's\ Roughness\ Coefficient$
$l = Sheet\ Flow\ Length, feet$
$P_2 = 2 - Year, 24 - Hour\ Rainfall, inches$
$S = Slope\ of\ Land\ Surface,\ ft/ft$

To avoid inaccurate estimations of sheet flow time, the sheet flow length should be limited according to the following formula, with a maximum sheet flow length of 300 feet. Maximum sheet flow lengths for common surfaces can be found in Table 2-3.

$$l = \frac{100\sqrt{S}}{n}$$

Where:

$l = Limiting\ Length\ of\ Flow, feet$
$n = Manning's\ Roughness\ Coefficient$
$S = Slope, ft/ft$

Table 2-3. Maximum Sheet Flow Lengths

Surface Description	n Value	Slope, ft/ft	Length, ft
Smooth Surface (Concrete, Asphalt, Gravel, Bare Soil)	0.011	0.01	300
Range	0.13	0.01	77
Dense Grass	0.24	0.01	42
Woods (Dense)	0.80	0.01	12.5
Smooth Surface (Concrete, Asphalt, Gravel, Bare Soil)	0.011	0.05	300
Range	0.13	0.05	172
Dense Grass	0.24	0.05	55
Woods (Dense)	0.80	0.05	28

Table 2-4. Manning's Roughness Coefficients for Sheet Flow

Surface Description	n Value
Smooth Surface (Concrete, Asphalt, Gravel, Bare Soil)	0.011
Fallow (No Residue)	0.05
Cultivated Soils:	
Residue Cover < 20%	0.06
Residue Cover > 20%	0.17
Grass:	
Short-Grass Prairie	0.15
Dense Grasses[1]	0.24
Bermudagrass	0.41
Range (Natural)	0.13
Woods[2]	
Light Underbrush	0.40
Dense Underbrush	0.80

[1] Includes species such as weeping lovegrass, bluegrass, buffalo grass, blue grama grass, and native grass mixtures.

[2] When selecting n, consider cover to a height of about 0.1feet. This is the only part of the plant cover that will obstruct sheet flow.

After a maximum of 300 feet, sheet flow usually becomes shallow concentrated flow with a depth of 0.1 feet to 0.5 feet. The average velocity for shallow concentrated flow can be estimated from the following formulas and shallow concentrated flow time can be determined by dividing the flow length by the average velocity.

Table 2-5. Velocity Equations for Shallow Concentrated Flow

Surface Description	Velocity Equation[1]
Pavement and Small Upland Gullies	$V = 20.328(S)^{0.5}$
Grassed Waterways	$V = 16.135(S)^{0.5}$
Nearly Bare and Untilled Soil	$V = 9.965(S)^{0.5}$
Cultivated Straight Row Crops	$V = 8.762(S)^{0.5}$
Short Grass Pasture	$V = 6.962(S)^{0.5}$
Minimum Tillage Cultivation, Contour or Strip-Cropped and Woodlands	$V = 5.032(S)^{0.5}$
Forest with Heavy Ground Litter and Hay Meadows	$V = 2.516(S)^{0.5}$

[1] $V = Average\ Velocity, ft/s$ $S = Slope\ of\ Land\ Surface, ft/ft$

2.2.2.1.2 Pipe and Open Channel Flow Time

The average velocity for pipe and open channel flow can be estimated from the hydraulic properties of the conduit or channel by using Manning's equation. Pipe and open channel flow time can be determined by dividing the flow length by the average velocity. See Chapters Three and Four for additional discussion on flow in pipes and open channels.

2.2.2.2 Rainfall Intensity

The rainfall intensity is the average rainfall rate (inches per hour) ***for a duration equal to the Tc*** for a selected return period. The rainfall intensity shall be determined from Intensity-Duration-Frequency (IDF) curves shown on Figure 2-1 or the tabular data in Table 2-6. All rainfall intensity data provided was obtained from the National Oceanic and Atmospheric Administration (NOAA) Atlas 14 Point Precipitation Frequency Estimates.

Figure 2-1. Intensity-Duration-Frequency Curves

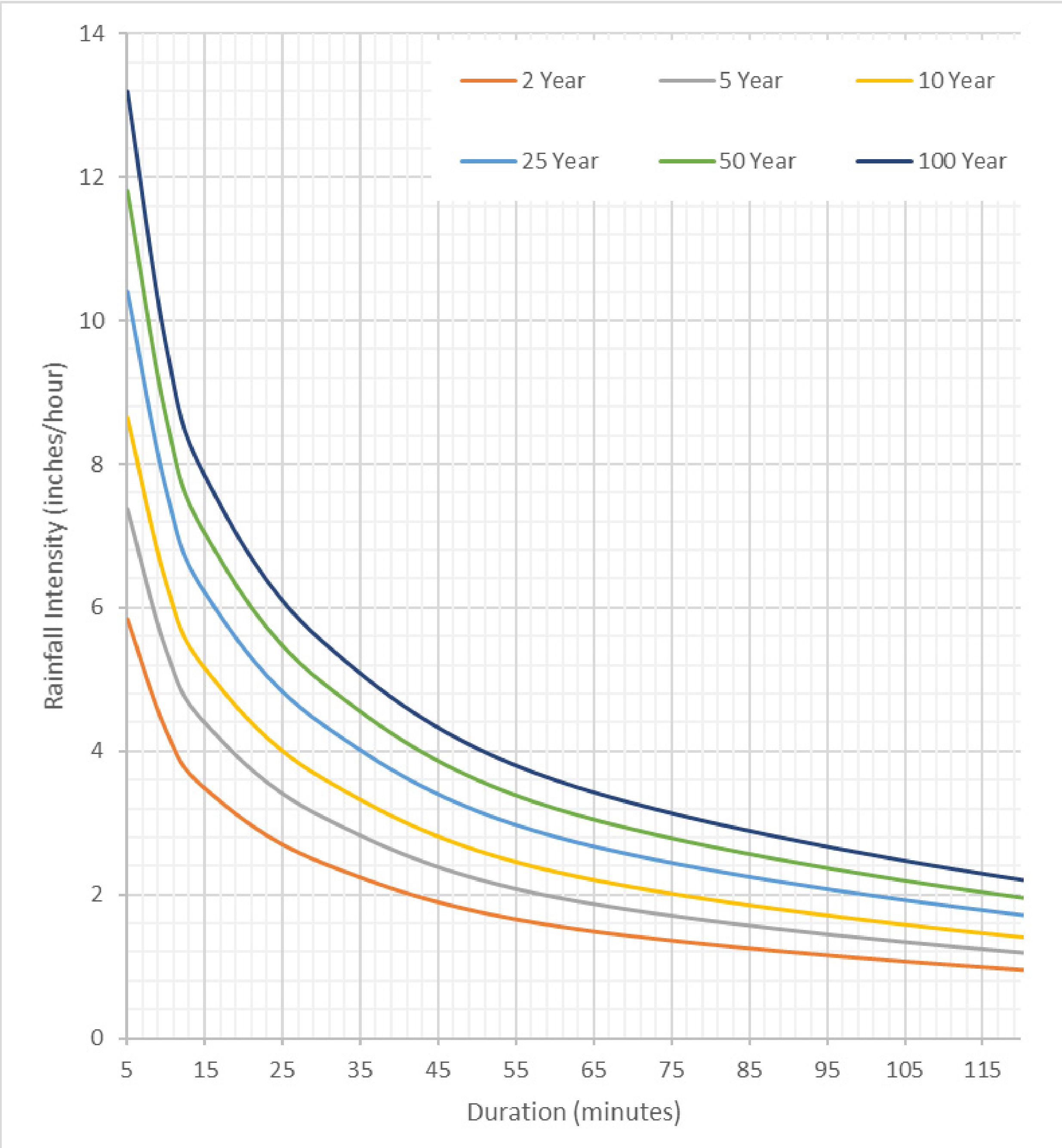


Table 2-6. Rainfall Intensity Tabular Data

Duration	2 Year	5 Year	10 Year	25 Year	50 Year	100 Year
5 Minutes	5.83	7.37	8.65	10.4	11.8	13.2
10 Minutes	4.27	5.4	6.34	7.63	8.63	9.64
15 Minutes	3.47	4.39	5.15	6.20	7.02	7.83
30 Minutes	2.44	3.09	3.63	4.38	4.96	5.54
60 Minutes	1.56	1.97	2.32	2.81	3.20	3.60
2 Hours	0.949	1.20	1.41	1.72	1.96	2.21
3 Hours	0.695	0.875	1.03	1.26	1.44	1.64
6 Hours	0.402	0.502	0.593	0.726	0.837	0.954
12 Hours	0.227	0.281	0.331	0.407	0.47	0.537
24 Hours	0.128	0.159	0.188	0.23	0.265	0.303

2.2.2.3 Runoff Coefficient

The runoff coefficient value in the rational formula is the fraction of rainfall intensity, expressed as a decimal, which contributes to the peak discharge, occurring at the time of concentration. It does not represent how much of the rain becomes runoff. Runoff coefficients vary based on land use, soil type, imperviousness, watershed slope and rainfall intensity/duration. Runoff coefficients should be selected from Table 2-7 or Table 2-8, depending on the land use. Where a drainage area consists of several land uses, a weighted runoff coefficient should be developed to represent the entire area.

Table 2-7. Runoff Coefficients for Developed Areas

Cover Description	Runoff Coefficients for Return Period					
	2	5	10	25	50	100
Asphalt	0.73	0.77	0.81	0.86	0.90	0.95
Concrete/Roof	0.75	0.80	0.83	0.88	0.92	0.97
Grass Areas (Lawns, Parks, etc.)						
Poor Condition (Grass Cover < 50%)						
Flat, 0-2%	0.32	0.34	0.37	0.40	0.44	0.47
Average, 2-7%	0.37	0.40	0.43	0.46	0.49	0.53
Steep, Over 7%	0.40	0.43	0.45	0.49	0.52	0.55
Fair Condition (Grass Cover 50% to 75%)						
Flat, 0-2%	0.25	0.28	0.30	0.34	0.37	0.41
Average, 2-7%	0.33	0.36	0.38	0.42	0.45	0.49
Steep, Over 7%	0.37	0.40	0.42	0.46	0.49	0.53
Good Condition (Grass Cover > 75%)						
Flat, 0-2%	0.21	0.23	0.25	0.29	0.32	0.36
Average, 2-7%	0.29	0.32	0.35	0.39	0.42	0.46
Steep, Over 7%	0.37	0.40	0.42	0.46	0.49	0.53

Cover Description	Runoff Coefficients for Return Period					
	2	5	10	25	50	100
Urban Districts:						
Commercial and Business (85% Impervious)[1]	0.68	0.73	0.76	0.81	0.85	0.89
Industrial (72% Impervious)[1]	0.62	0.67	0.70	0.74	0.78	0.83
Residential Districts by Average Lot Size:						
1/8 Acre or Less (Town Houses) (65% Impervious)[1]	0.59	0.63	0.66	0.71	0.75	0.79
1/4 Acre (38% Impervious)[1]	0.46	0.50	0.53	0.58	0.61	0.65
1/3 Acre (30% Impervious)[1]	0.43	0.46	0.49	0.54	0.57	0.61
1/2 Acre (25% Impervious)[1]	0.41	0.44	0.47	0.51	0.55	0.59
1 Acre (20% Impervious)[1]	0.38	0.42	0.45	0.49	0.52	0.56
2 Acres (12% Impervious)[1]	0.35	0.38	0.41	0.45	0.48	0.52

[1] The average percent impervious shown was used to develop the composite runoff coefficients. Other assumptions are as follows: impervious areas are directly connected to the drainage system, impervious areas are considered equivalent to concrete/roof, and pervious areas are considered equivalent to grass areas in good condition with an average slope.

Table 2-8. Runoff Coefficients for Undeveloped Areas

Cover Description	Runoff Coefficients for Return Period					
	2	5	10	25	50	100
Cultivated Land						
Flat, 0–2%	0.31	0.34	0.36	0.40	0.43	0.47
Average, 2–7%	0.35	0.38	0.41	0.44	0.48	0.51
Steep, Over 7%	0.39	0.42	0.44	0.48	0.51	0.54
Pasture/Range						
Flat, 0–2%	0.25	0.28	0.30	0.34	0.37	0.41
Average, 2–7%	0.33	0.36	0.38	0.42	0.45	0.49
Steep, Over 7%	0.37	0.40	0.42	0.46	0.49	0.53
Forest/Woodlands						
Flat, 0–2%	0.22	0.25	0.28	0.31	0.35	0.39
Average, 2–7%	0.31	0.34	0.36	0.40	0.43	0.47
Steep, Over 7%	0.35	0.39	0.41	0.45	0.48	0.52

2.2.3 Common Errors and Limitations

- In some cases runoff from a portion of the drainage area which is highly impervious may result in a greater peak discharge than would occur if the entire area were considered. In these cases, adjustments can be made to the drainage area by disregarding those areas where flow time is too slow to add to the peak discharge. Sometimes it is necessary to estimate several times of concentration to determine the design flow that is critical for an application.
- When designing a drainage system, the overland flow path is not necessarily perpendicular to the contours shown on available mapping. Often the land will be graded and swales will intercept the natural contour and conduct the water to the streets, which may reduce the time of concentration.
- The rational method only provides estimates of peak runoff. It does not provide information on the volume or timing of runoff. Modern drainage practices often include detention of urban storm runoff to reduce the peak rate of runoff downstream. The rational method is not appropriate for use in design of stormwater detention or storage facilities.

2.3 NRCS Unit Hydrograph Method

The NRCS method uses data similar to the rational method to determine peak discharge, such as drainage area, a runoff factor, time of concentration, and rainfall. However, the technique is more sophisticated in that it also considers the time distribution of the rainfall, the initial rainfall losses to interception and depression storage (initial abstraction), and an infiltration rate that decreases during the course of a storm. It can be used to estimate the peak runoff and runoff volumes for areas from 200 acres up to 10 square miles. The following discussion outlines the basic concepts and equations used in the NRCS method.

2.3.1 Concepts and Equations

The following discussion outlines the basic concepts and equations utilized in the NRCS method. Additional details not included in this manual can be found in the NRCS National Engineering Handbook Hydrology Chapters (Part 630).

2.3.1.1 Rainfall-Runoff

A relationship between accumulated rainfall and accumulated runoff was derived by the NRCS from experimental plots for numerous soils and vegetative cover conditions. The following NRCS runoff equation is used to estimate direct runoff from 24-hour storm rainfall:

$$Q = \frac{(P - I_a)^2}{(P - I_a) + S}$$

Where:

$$Q = Depth\ of\ Direct\ Runoff, inches$$
$$P = Depth\ of\ Accumulated\ Rainfall$$
$$or\ Potential\ Maximum\ Runoff, inches$$
$$I_a = Initial\ Abstraction, inches$$
$$S = Maximum\ Potential\ Retention, inches$$

I_a is highly variable but generally is correlated with soil and cover parameters. Through studies of many small agricultural watersheds, I_a was found to be approximated by the following empirical equation:

$$I_a = 0.2S$$

By substituting 0.2S for I_a, the NRCS runoff equation becomes:

$$Q = \frac{(P - 0.2S)^2}{(P + 0.8S)}$$

S is related to the soil and cover conditions of the watershed through the runoff factor (curve number, see Section 2.3.1.3) by the following equation:

$$S = \left(\frac{1000}{CN}\right) - 10$$

2.3.1.2 Rainfall

The NRCS method is based on a 24-hour storm event. Rainfall depths specific for this region to be used for the NRCS method should be selected from Table 2-7and should be used with a Type II rainfall distribution. All rainfall depth data provided was obtained from the National Oceanic and Atmospheric Administration (NOAA) Atlas 14 Point Precipitation Frequency Estimates.

Table 2-9. 24-Hour Accumulated Rainfall Total

Frequency	24-Hour Rainfall, inches
1 Year	2.65
2 Year	3.07
5 Year	3.83
10 Year	4.50
25 Year	5.52
50 Year	6.36
100 Year	7.26

2.3.1.3 Runoff Factor (Curve Number)

The principal physical watershed characteristics affecting the relationship between rainfall and runoff are land use, land treatment, soil types, and land slope. The NRCS method uses a combination of soil conditions and land uses (ground cover) to assign a runoff factor to an area. These runoff factors, called runoff curve numbers (CN), indicate the runoff potential of an area. The higher an area's CN, the higher that area's runoff potential will be. Soil properties influence the relationship between runoff and rainfall since soils have differing rates of infiltration. Based on infiltration rates, the NRCS has divided soils into four hydrologic soil groups (Groups A, B, C, and D), with Group A having the highest infiltration rate and Group D having the lowest infiltration rate. Hydrologic soil groups and other soil properties can be obtained online using the USDA/NRCS Web Soil Survey Tool.

Curve numbers should be selected from Table 2-10 or Table 2-11, depending on the land use. Where a drainage area consists of several land uses, a weighted curve number should be developed to represent the entire area. When land use is expected to change over time, the most conservative land use shall be selected.

Runoff curve numbers vary with antecedent moisture conditions (amount of soil moisture when rainfall occurs). Average antecedent soil moisture conditions (AMC II) are recommended for most hydrologic analysis. All curve numbers shown in this manual reflect an average antecedent soil moisture condition (AMC II).

Table 2-10. Curve Numbers for Developed Areas[1]

Cover Description	Average % Impervious[2]	CN for Hydrologic Soil Group			
		A	B	C	D
Fully Developed Urban Areas (Vegetation Established):					
Open Space (Lawns, Parks, Golf Courses, Cemeteries, etc.)[3]:					
Poor Condition (Grass Cover < 50%)		68	79	86	89
Fair Condition (Grass Cover 50% to 75%)		49	69	79	84
Good Condition (Grass Cover > 75%)		39	61	74	80
Urban Districts:					
Commercial and Business	85	89	92	94	95
Industrial	72	81	88	91	93
Residential Districts by Average Lot Size:					
1/8 Acre or Less (Town Houses)	65	77	85	90	92
1/4 Acre	38	61	75	83	87
1/3 Acre	30	57	72	81	86
1/2 Acre	25	54	70	80	85
1 Acre	20	51	68	79	84
2 Acres	12	46	65	77	82
Impervious Areas:					
Paved Parking Lots, Roofs, Driveways, etc. (Excluding Right-of-Way)		98	98	98	98
Streets and Roads:					
Paved; Curbs and Storm Sewers (Excluding Right-of-Way)		98	98	98	98
Paved; Open Ditches (Including Right-of-Way)		83	89	92	93
Gravel (Including Right-of-Way)		76	85	89	91
Dirt (Including Right-of-Way)		72	82	87	89
Developing Urban Areas:					
Newly Graded Areas (Pervious Areas Only, No Vegetation)		77	86	91	94

1 Average runoff condition, and $I_a = 0.2S$.

2 The average percent impervious shown was used to develop the composite CNs. Other assumptions are as follows: impervious areas are directly connected to the drainage system, impervious areas have a CN of 98, and pervious areas are considered equivalent to open space in good hydrologic condition.

3 CNs shown are equivalent to those of pasture. Composite CNs may be computed for other combinations of open space type.

Table 2-11. Curve Numbers for Undeveloped Areas[1]

Cover Description		Hydrologic Condition[3]	CN for Hydrologic Soil Group			
Cover Type	Treatment[2]		A	B	C	D
Fallow	Bare Soil		77	86	91	94
	Crop Residue Cover (CR)	Poor	76	85	90	93
		Good	74	83	88	90
Row Crops	Straight Row (SR)	Poor	72	81	88	91
		Good	67	78	85	89
	SR + CR	Poor	71	80	87	90
		Good	64	75	82	85
	Contoured (C)	Poor	70	79	84	88
		Good	65	75	82	86
	C + CR	Poor	69	78	83	87
		Good	64	74	81	85
	Contoured & Terraced (C&T)	Poor	66	74	80	82
		Good	62	71	78	81
	C&T + CR	Poor	65	73	79	81
		Good	61	70	77	80
Small Grain	SR	Poor	65	76	84	88
		Good	63	75	83	87
	SR + CR	Poor	64	75	83	86
		Good	60	72	80	84
	C	Poor	63	74	82	85
		Good	61	73	81	84
	C + CR	Poor	62	73	81	84
		Good	60	72	80	83
	C&T	Poor	61	72	79	82
		Good	59	70	78	81
	C&T + CR	Poor	60	71	78	81
		Good	58	69	77	80
Close-Seeded or Broadcast Legumes or Rotation Meadow	SR	Poor	66	77	85	89
		Good	58	72	81	85
	C	Poor	64	75	83	85
		Good	55	69	78	83
	C&T	Poor	63	73	80	83
		Good	51	67	76	80
Pasture, Grassland or Range – Continuous Forage for Grazing[4]		Poor	68	79	86	89
		Fair	49	69	79	84
		Good	39	61	74	80

Cover Description		Hydrologic Condition[3]	CN for Hydrologic Soil Group			
Cover Type	Treatment[2]		A	B	C	D
Meadow – Continuous Grass, Protected from Grazing and Generally Mowed for Hay		Good	30	58	71	78
Brush-Forbs-Grass Mixture with Brush the Major Element[5]		Poor	48	67	77	83
		Fair	35	56	70	77
		Good	30[6]	48	65	73
Woods-Grass Combination (Orchard or Tree Farm)[7]		Poor	57	73	82	86
		Fair	43	65	76	82
		Good	32	58	72	79
Woods[8]		Poor	45	66	77	83
		Fair	36	60	73	79
		Good	30	55	70	77
Farmstead – Buildings, Lanes, Driveways and Surround Lots			59	74	82	86
Roads (Including Right-of-Way)	Dirt		72	82	87	89
	Gravel		76	85	89	91

1 Average runoff condition, and I_a = 0.2S.

2 Crop residue cover applies only if residue is on at least 5 percent of the surface throughout the year.

3 Hydrologic condition is based on combinations of factors that affect infiltration and runoff, including (a) density and canopy of vegetative areas, (b) amount of year-round cover, (c) amount of grass or close-seeded legumes, (d) percent of residue cover on the land surface (good >20%), and (e) degree of surface toughness.

Poor: Factors impair infiltration and tend to increase runoff.
Good: Factors encourage average and better than average infiltration and tend to decrease runoff.

For conservation tillage poor hydrologic condition, 5 to 20 percent of the surface is covered with residue (less than 750 pounds per acre for row crops or 300 pounds per acre for small grain).

For conservation tillage good hydrologic condition, more than 20 percent of the surface is covered with residue (greater than 750 pounds per acre for row crops or 300 pounds per acre for small grain).

4 Poor: < 50% ground cover or heavily grazed with no mulch.

Fair: 50 to 75% ground cover and not heavily grazed.

Good: > 75% ground cover and lightly or only occasionally grazed.

5 Poor: < 50% ground cover.
Fair: 50 to 75% ground cover.
Good: > 75% ground cover.

6 If actual curve number is less than 30, use CN = 30 for runoff computation.

7 CNs shown were computed for areas with 50 percent woods and 50 percent grass (pasture) cover. Other combinations of conditions may be computed from the CNs for woods and pasture.

8 Poor: Forest litter, small trees, and brush are destroyed by heavy grazing or regular burning.
Fair: Woods are grazed, but not burned, and some forest litter covers the soil.
Good: Woods are protected from grazing, and litter and brush adequately cover the soil.

2.3.1.4 Time of Concentration

The time of concentration (Tc) is the time required for water to flow from the hydraulically most remote point of the drainage area to the design point. In some cases, for a basin with highly impervious areas several different Tc's must be calculated to determine the governing design flow. See Section 2.2.3 Common Errors and Limitations. For a storm drainage system, the Tc consists of the inlet time plus the time of flow in a pipe or open channel to the design point. The velocity method from the NRCS is recommended for computing Tc. See Section 2.2.2.1 for additional guidance on computing the Tc.

2.3.1.5 Lag Time

Lag time (L) can be considered as a weighted Tc and is related to the physical properties of a watershed, such as area, length, and slope. The NRCS derived the following empirical relationship between L and Tc.

$$L = 0.6Tc$$

Where:

$$L = Lag\ Time$$
$$Tc = Time\ of\ Concentration$$

In small urban areas (less than 2,000 acres), a curve number method can be used to estimate watershed lag time. In this method, the lag time for the runoff from an increment of excess rainfall can be considered as the time between the center of mass of the excess rainfall increment and the peak of its incremental outflow hydrograph. The equation developed by the NRCS to estimate lag time is:

$$L = {(l^{0.8}(S+1)^{0.7})}/{(1900Y^{0.5})}$$

Where:

$$L = Lag\ Time, hours$$
$$l = Length\ of\ Mainstream\ Flow\ Path\ from\ Farthest\ Drainage\ Divide\ to\ the\ Outlet$$
$$S = 1000/CN - 10$$
$$CN = NRCS\ Curve\ Number$$
$$Y = Average\ Slope\ of\ Watershed, Percent$$

2.3.1.6 NRCS Peak Discharge Calculation

The following NRCS peak discharge equation can be used for estimating the peak runoff rate from a single watershed with homogeneous land use:

$$Q_p = q_u A Q F_p$$

Where:

$$Q_p = Peak\ Discharge, cfs$$
$$q_u = Unit\ Peak\ Discharge, cfs/mi^2\ /in$$
A= $Drainage\ Area, mi^2$
$$Q = Depth\ of\ Direct\ Runoff, inches$$
$$F_p = Pond\ and\ Swamp\ Adjustment\ Factor$$

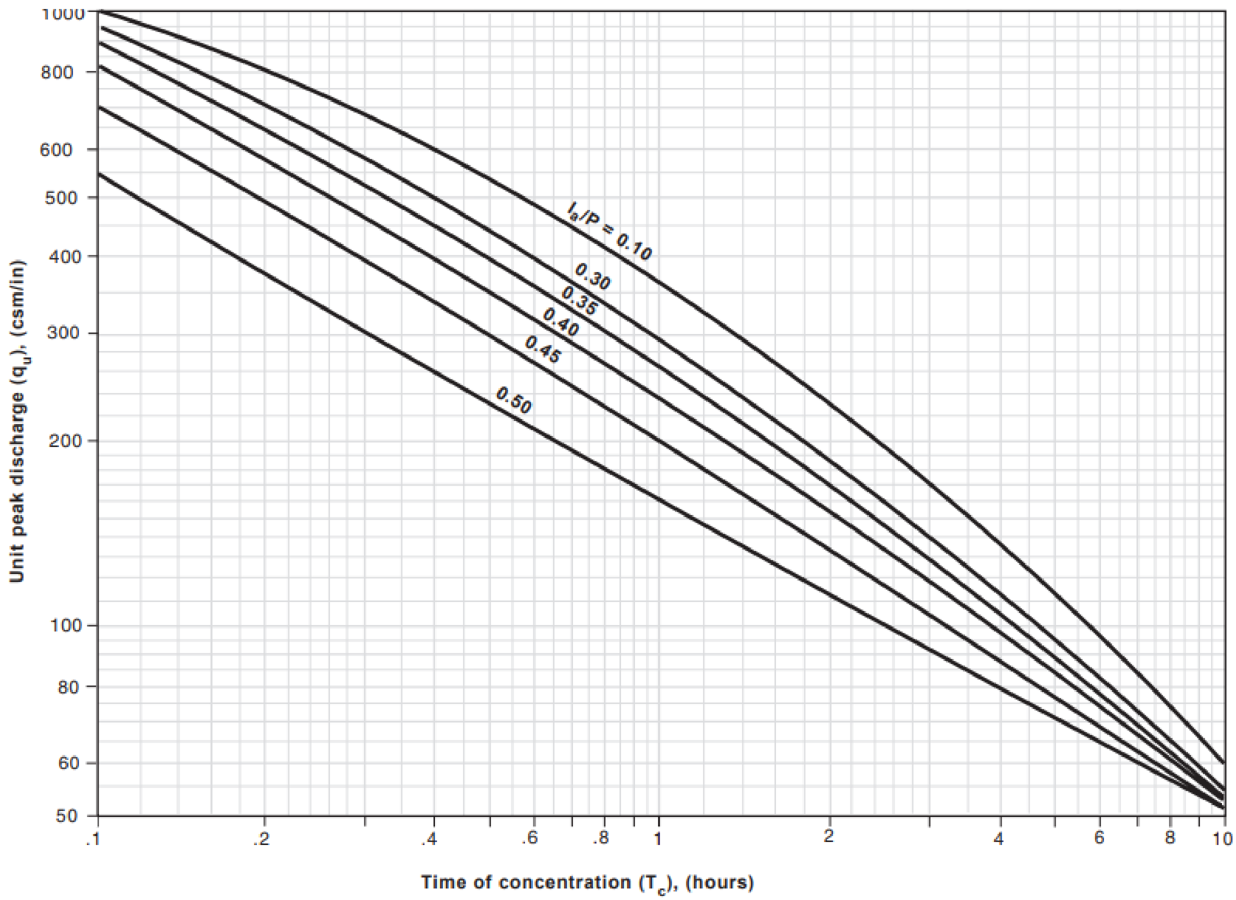
The input requirements are:

1. Time of concentration, Tc (hours)
2. Drainage area (mi^2)
3. 24-hr design rainfall
4. CN value
5. Pond and swamp adjustment factor (use 1.0, see below).

Computations for the peak discharge method proceed as follows:

1. The 24-hr rainfall depth, P, for the design storm is determined from Table 2-7.
2. The runoff curve number (CN) is estimated from Table 2-10 and Table 2-11, with weighted CNs calculated as needed.
3. Direct runoff, Q, is calculated by using the CN to solve for S and substituting into the direct runoff equation in Section 2.3.1.1.
4. CN and S are used to determine initial abstraction (I_a) from the equation given in Section 2.3.1.1.
5. Compute the ratio I_a/P for the return period of the design storm.
6. The drainage area's time of concentration (Tc) is computed using the procedures in Section 2.2.2.1.
7. The computed Tc and I_a/P is used to obtain the unit peak discharge, q_u, from Figure 2-2 below. If the ratio I_a/P lies outside the range shown, use the limiting values.
8. The pond and swamp adjustment factor, F_p, is assumed to be equal to 1.0 (no pond or swamp areas), in order to be conservative.
9. The peak discharge is computed using the equation at the beginning of this section.

Figure 2-2. Unit Peak Discharge, q_u



2.3.1.7 Hydrographs

The NRCS method can be used to estimate the entire hydrograph for a drainage area. From this hydrograph, discharge rates and volumes can be determined. The NRCS has developed a tabular hydrograph procedure that can be used to generate the hydrograph for small drainage areas. The tabular hydrograph procedure uses unit discharge hydrographs that have been generated for a series of times of concentrations. To use the tabular hydrograph procedure, designers should refer to the NRCS National Engineering Handbook Hydrology Chapters (Part 630).

2.4 References

- City of Brookings, South Dakota, 2006. *Storm Drainage Design and Technical Criteria Manual.*
- City of Lincoln Public Works and Utilities Department, 2000. *Drainage Criteria Manual.*
- City of Omaha Environmental Quality Control Division, 2014. *Omaha Regional Stormwater Design Manual.*
- Federal Highway Administration, 2009. *Hydraulic Engineering Circular No. 22, Third Edition, Urban Drainage Design Manual.*
- Nebraska Department of Transportation, 2006. *Drainage Design and Erosion Control Manual.*
- United States Department of Agriculture, Natural Resources Conservation Service, 1986. *Technical Release 55: Urban Hydrology for Small Watersheds*
- United States Department of Agriculture, Natural Resources Conservation Service, 1997. *National Engineering Handbook, Part 630 Hydrology*

3. PAVEMENT DRAINAGE AND STORM SEWER

3.1 Overview

In this chapter, guidelines are given for evaluating and designing storm drainage of the minor system. The minor drainage system is typically designed for more frequent storms with moderate flows and generally consists of storm drains and related appurtenances, such as inlets, curbs, and gutters.

Runoff from large areas draining toward a roadway should be intercepted prior to reaching the roadway whenever possible. This applies to drainage from residential neighborhoods, commercial or industrial property, long cut slopes, side streets, and other areas along the pavement. If extraneous drainage cannot be intercepted prior to reaching the roadway, it should be included in the pavement drainage design.

Additional design procedures for pavement drainage and storm sewer can be found in the most recent edition of the Hydraulic Engineering Circular No. 22: Urban Drainage Design Manual (HEC 22).

3.2 Pavement Drainage Criteria

3.2.1 Return Period

Since it generally is not economically feasible to design the minor system for the maximum runoff that a watershed is capable of producing, design storm frequency criteria must be established. The design storm frequency criteria for pavement drainage for the minor storm is 5 years for residential and 10 years for downtown, commercial, and industrial areas. Pavement drainage design storm frequency for the major storm is 100 years.

3.2.2 Spread and Cross Street Flow

Allowable maximum street encroachment by stormwater runoff is listed in Table 3-1 and Table 3-2. All freeways or expressways shall be designed per the NDOT Drainage Design and Erosion Control Manual.

Table 3-1. Allowable Maximum Street Encroachment

Street Classification	Minor Storm[1]	Major Storm[2]
Local	No curb overtopping.	Runoff shall be contained within the right-of-way or drainage easements. The maximum allowable depth at the gutter is 18 inches.
Collector	No curb overtopping, spread may not cover crown.	Runoff shall be contained within the right-of-way or drainage easements. The maximum allowable depth at the gutter is 18 inches.
Arterial	No curb overtopping, spread shall leave at least one lane free of water in each direction.	Runoff shall be contained within the right-of-way or drainage easements. The maximum allowable depth at the crown is 6 inches. The maximum allowable depth at the gutter is 18 inches.

[1] Minor Storm: 5 year for residential and 10 year for downtown/industrial/commercial.

[2] Major Storm: 100 year.

Table 3-2. Allowable Maximum Cross-Street Flow

Street Classification	Minor Storm[1]	Major Storm[2]
Local	6-inch depth at crown. Where cross-pans allowed, depth shall not exceed 6 inches.	Runoff shall be contained within the right-of-way or drainage easements. The maximum allowable depth at the gutter is 18 inches.
Collector	Where cross-pans allowed, depth shall not exceed 6 inches.	Runoff shall be contained within the right- of-way or drainage easements. The maximum allowable depth at the gutter is 18 inches.
Arterial	None	Runoff shall be contained within the right-of-way or drainage easements. The maximum allowable depth at the crown is 6 inches. The maximum allowable depth at the gutter is 18 inches.

[1] Minor Storm: 5 year for residential and 10 year for downtown/industrial/commercial.

[2] Major Storm: 100 year.

3.2.3 Longitudinal Grade

To provide for drainage, to avoid unacceptable stormwater spread into traffic lanes, and to avoid ponding in the gutter, curb and gutter grades shall not be less than 0.3 percent, except near sags in the roadway profile.

3.2.4 Cross Slope

Roadway cross slopes shall be determined by the City's standard roadway sections.

3.2.5 Curb and Gutter

Curb and gutter dimensions shall be determined by the City's standard details.

3.3 Gutter Flow Calculations

Gutter flow capacities should be calculated using the modified form of Manning's equation shown below and using Manning's n values from Table 3-3.

$$Q = (0.56/n)\ S_x^{5/3}\ S^{1/2}\ T^{8/3}$$

(Use when width of spread (T) is known.)

Or

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

(Use when depth (d) is known.)

Where:

$Q = Gutter\ Flow\ Rate, cfs$
$n = Manning's\ Roughness\ Coefficient$
$S_x = Pavement\ Cross\ Slope, ft/ft$
$S = Longitudinal\ Slope, ft/ft$
$T = Width\ of\ Flow\ or\ Spread, ft$
$z = Reciprocal\ of\ Pavment\ Cross\ Slope, 1/S_x$
$d = Depth\ of\ Flow, ft$

Table 3-3. Manning's n Values for Street and Pavement Gutters

Type of Gutter or Pavement		Manning's n
Concrete Gutter, Troweled Finish		0.012
Asphalt Pavement	Smooth Texture	0.013
	Rough Texture	0.016
Concrete Gutter with Asphalt Pavement	Smooth Texture	0.013
	Rough Texture	0.015
Concrete Pavement	Float Finish	0.014
	Broom Finish	0.016
For gutters with small slopes, where sediment may accumulate, increase above values of n by:		0.002

3.4 Stormwater Inlets

3.4.1 Overview

Stormwater inlets should be placed as necessary to limit the depth or spread of runoff in the roadway to allowable limits as previously described. Inlets should generally be placed at the following locations:

- At low points or sags in the gutter grade
- Upgrade of intersections, median breaks, and pedestrian crosswalks
- Upgrade of locations where cross slope reverses
- Upgrade of bridges
- Where gutter flow reaches allowable maximum spread widths

In sag locations on collector or arterial streets, flanking inlets should be placed upstream and to both sides of the inlet at the low point of the sag. Flanking inlets should be placed 0.2 vertical feet higher than the inlet at the low point or located according to HEC 22.

3.4.2 Grate Inlets

Grate inlets consist of an opening covered by one or more grates and may be used for parking lots, area drains, or similar scenarios. Grate inlets are generally not used on public streets.

3.4.2.1 Grate Inlets on a Continuous Grade

Generally, grate inlets placed on a continuous grade have lower efficiencies than curb inlets placed in a similar configuration; therefore, grate inlets are not recommended to be placed on a continuous grade along a public street. In situations where the installation of a grate inlet on a continuous grade is warranted, the interception efficiency and capacity can be calculated using the procedures found in HEC 22.

3.4.2.2 Grate Inlets in Sag Locations

A grate inlet in a sag location operates as a weir up to a certain depth, depending on the size of the grate, and as an orifice at greater depths. Grates of larger dimension will operate as weirs to greater depths than smaller grates. Some assumption must be made regarding the nature of clogging of a grate inlet in a sump condition to compute the capacity of a partially clogged grate. The clogging factor (C_f) is used to approximate the effects of clogging on a grate inlet.

The capacity of a grate inlet operating as a weir is:

$$Q_i = C_f C_w P d^{1.5}$$

Where:

$Q_i = Flow\ Capacity\ of\ an\ Inlet, cfs$

$C_f = Clogging\ Factor, 0.5\ is\ Recommended$

$C_w = Weir\ Coefficient\ Equal\ to\ 3.0$

$P = Perimeter\ of\ Grate\ Excluding\ the\ Side\ Against\ the\ Curb, ft$

$d = Average\ Depth\ of\ Water\ Above\ the\ Top\ of\ the\ Grate, ft$

The capacity of a grate inlet operating as an orifice is:

$$Q_i = C_f C_o A_{cl} (2gd)^{0.5}$$

Where:

$C_o = Orifice\ Coefficient\ Equal\ to\ 0.67$

$A_{cl} = Clear\ Opening\ Area\ of\ the\ Grate, sq\ ft$

$g = Gravitational\ Constant\ Equal\ to\ 32.2\ ft/s^2$

3.4.3 Curb Inlets

Curb inlets consist of a vertical opening in the curb covered by a top slab and are typically used to drain public streets.

3.4.3.1 Curb Inlets on a Continuous Grade

The length of the curb inlet required for total interception of gutter flow on a pavement section with a uniform cross slope is expressed by:

$$L_T = KQ^{0.42}S^{0.3}[1/(nS_x)]^{0.6}$$

Where:

$L_T = Curb\ Inlet\ Length\ Required\ to\ Intercept\ 100\%\ of\ the\ Gutter\ Flow, ft$

$K = 0.6$

$Q = Gutter\ Flow, cu\ ft/sec$

$S = Longitudinal\ Slope, ft/ft$

$n = Manning's\ Roughness\ Coefficient$

$S_x = Pavement\ Cross\ Slope, ft/ft$

The efficiency of curb inlets shorter than the length required for total interception is expressed by:

$$E = 1 - [1 - (L/L_T)]^{1.8}$$

Where:

$E = Capture\ Efficiency\ of\ a\ Curb\ Inlet$

$L = Curb\ Inlet\ Length, ft$

The length of inlet required for total interception by depressed curb inlets or curb openings in depressed gutter sections can be found by the use of an equivalent cross slope, S_e, in place of S_x. S_e is expressed by:

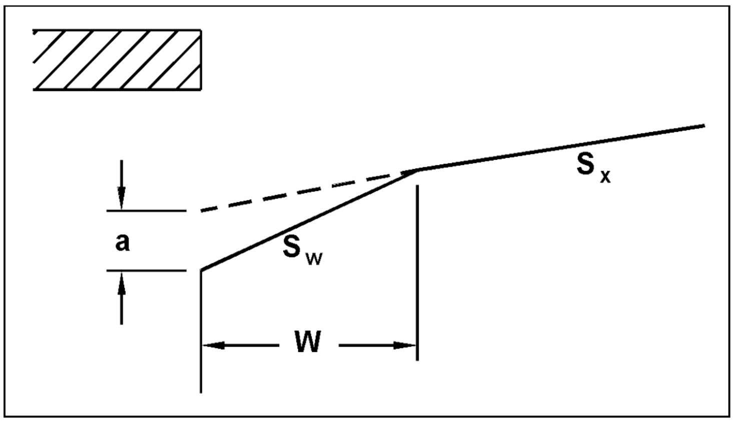
$$S_e = S_x + S'_w E_o$$

Where: $S_e = Equivalent\ Cross\ Slope, ft/ft$

$S'_w = Cross\ Slope\ of\ the\ Gutter\ Measured\ from\ the\ Cross\ Slope\ of\ the\ Pavement, ft/ft$

$E_o = Ratio\ of\ Flow\ in\ the\ Depressed\ Section\ to\ the\ Total\ Gutter\ Flow\ Determined\ by\ the\ Gutter\ Configuration\ Upstream\ of\ the\ Inlet$

Figure 3-1. Depressed Curb Inlet



The cross slope of the depressed gutter measured from the cross slope of the pavement is expressed by:

$$S'_w = a/W$$

Where: $a = Gutter\ Depression, ft$

$W = Width\ of\ the\ Depressed\ Gutter, ft$

The ratio of flow in the depressed section to the total gutter flow determined by the gutter configuration upstream of the inlet is expressed by:

$$E_o = Q_w/Q = 1 - (1 - W/T)^{2.67}$$

Where: $Q_w = Flow\ in\ Width\ of\ Depressed\ Gutter, W, cfs$

$Q = Total\ Gutter\ Flow, cfs$

$T = Spread\ of\ Total\ Gutter\ Flow, ft$

3.4.3.2 Curb Inlets in Sag Locations

The capacity of a curb inlet in a sag depends on water depth at the curb, the curb opening length, and the height of the curb opening, including any depression. The inlet operates as a weir to depths equal to the curb opening height and as an orifice at depths greater than 1.4 times the opening height. At depths between 1.0 and 1.4 times the opening height, flow is in a transition stage.

The equation for interception capacity of a non-depressed curb inlet operating as a weir is shown below. The depth limitation for operation as a weir is the depth at the curb must be less than or equal to the height of the curb opening ($d \leq h$).

$$Q_i = C_w L d^{1.5}$$

Where:

$Q_i = Interception\ Capacity\ of\ an\ Inlet, cfs$

$C_w = Weir\ Coefficient\ Equal\ to\ 3.0$

$L = Curb\ Inlet\ Length, ft$

$d = Depth\ at\ Curb\ Measured\ from\ the\ Normal\ Cross\ Slope, ft$ $(d = TS_x)$

At curb inlet lengths greater than 12 feet, the equation for non-depressed inlet (above) produces intercepted flows that exceed the values for the equation for depressed inlets (below). Since depressed inlets will perform at least as well as non-depressed inlets of the same length, the equation for non-depressed curb inlets (above) should be used for all curb inlets having lengths greater than 12 feet.

The equation for the interception capacity of a depressed curb inlet operating as a weir is shown below. The depth limitation for operation as a weir is the depth at the curb must be less than or equal to the height of the curb opening plus the depth of the depression ($d \leq h + a$).

$$Q_i = C_w (L + 1.8W) d^{1.5}$$

Where:

$C_w = Weir\ Coefficient\ Equal\ to\ 2.3$

$W = Width\ of\ the\ Depressed\ Gutter, ft$

Curb inlets operate as orifices at depths greater than approximately 1.4 times the opening height. The equation for the interception capacity of a curb inlet acting as an orifice is shown below. This equation is applicable to depressed and non-depressed curb inlets. The depth at the inlet includes any gutter depression.

$$Q_i = C_o h L (2 g d_o)^{0.5}$$

Where:

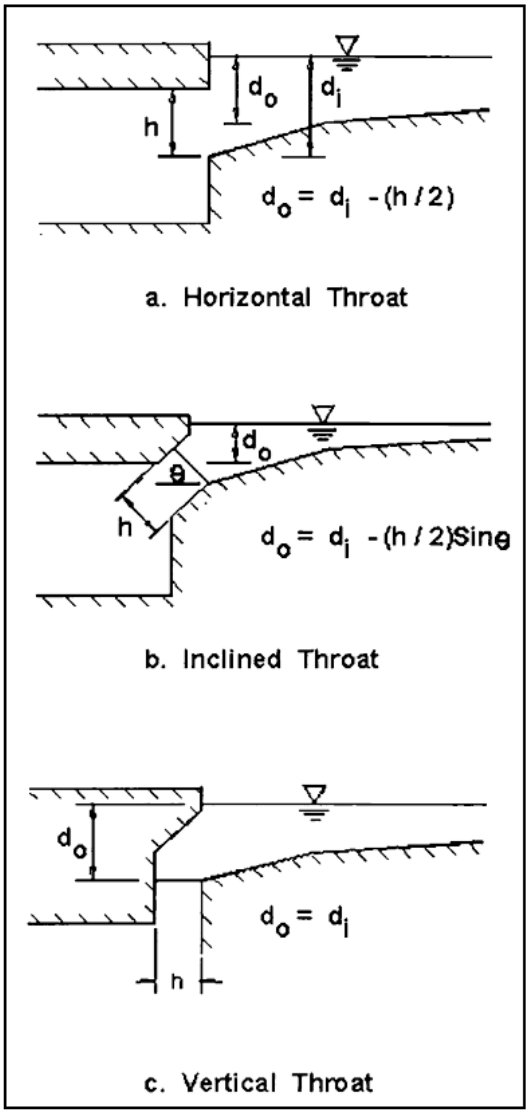
$C_o = Orifice\ Coefficient\ Equal\ to\ 0.67$

$h = Height\ of\ Curb\ Opening, ft$

$g = Gravitational\ Constant\ Equal\ to\ 32.2\ ft/s^2$

$d_o = Effective\ Head\ on\ the\ Center\ of\ the\ Orifice\ Throat, ft$

Figure 3-2. Curb Inlet Opening Configurations



3.5 Storm Sewer

3.5.1 Overview

The installation of storm sewer systems is required when the other parts of the minor system (i.e., curb, gutter, and roadside ditches) no longer have capacity for additional runoff, so that spread widths and flow depths exceed requirements previously presented. It should be recognized that the rate of discharge to be carried by any section of storm sewer is not necessarily the sum of the inlet design discharge rates of all inlets above that section of pipe, but as a general rule is somewhat less than this total. The time of concentration is most influential, and as the time of concentration grows larger, the proper rainfall intensity to be used in the design grows smaller.

3.5.2 Design Criteria

Hydraulic design of storm sewers shall be in accordance with the following:

3.5.2.1 Material and Capacity

- All storm sewer pipe shall have smooth interior walls.
- All storm sewer pipe shall be reinforced concrete pipe (RCP), high density polyethylene pipe – smooth interior (HDPE-SI), or polyvinyl chloride pipe (PVC). Reinforced concrete pipe shall have a pipe class determined according to the actual depth of cover over the pipe. Pipe joints and construction shall conform with the requirements of the City standard specifications.
- Storm sewers shall be designed using a Manning's n value of 0.012. See Chapter Five for Manning's n values of pipe materials other than RCP to evaluate the hydraulic capacity of existing systems.
- The minimum pipe size for storm sewer is 15 inches.
- Storm sewers should be designed to flow full at the design runoff for the minor storm. To prevent silt accumulation, a full flow velocity of 3 feet per second should be maintained in the storm sewer. The full flow velocity should not exceed 20 feet per second.
- The hydraulic grade line shall be 0.75 feet below the intake lip of any affected inlet, any manhole cover, or the flow line of the highest pipe of any entering non-pressurized system.
- The energy grade line shall not rise above the intake lip of any affected inlet, any manhole cover, or the flow line of any such entering non-pressurized system.
- Storm sewer pipes will remain the same size or increase in size going downstream within a system.

3.5.2.2 Alignment and Depth of Cover

- Storm sewers should be constructed on a straight (tangent) alignment between manholes and inlets. Storm sewers should not be constructed on curves.
- Pipe crowns shall be matched at manholes and inlets unless a drop manhole is being used to control the velocity.
- The maximum spacing of access points to the storm sewer shall not exceed 500 feet.
- The minimum physical pipe slope shall be 0.5 percent. Flatter slopes, especially for large-diameter storm sewer, may be used in design if scour velocity is maintained and if approved by the City.
- The desired depth of cover above a storm sewer pipe shall be 2 to 3 feet, with 1.5 feet being the absolute minimum. Cover greater than 3 feet should generally be avoided due to the possibility of the storm sewer blocking access of sanitary sewer service lines.
- Storm sewers should be laid a minimum of 10 feet horizontally from any existing or proposed water main (measured edge to edge). In cases where it is not practical to maintain a 10-foot separation, the Nebraska Department of Health and Human Services (NDHHS) may allow installation of the sewer closer to the water main, provided that the sewer is laid in a separate trench or on an undisturbed earth shelf located on one side of the water main or at such an elevation that the bottom of the sewer is at least 18 inches above the top of the water main.

- When crossing a water main, the edge of the storm sewer shall be a minimum vertical distance of 18 inches from the outside edge of the water main. This shall be the case whether the sewer is above or below the water main. At crossings, one full length of water pipe shall be located so that both joints will be at least 10 feet from the sewer, or 20 feet of the water main shall be enclosed by casing centered on the sewer.
- The NDHHS must specifically approve any variance from the requirements of these instructions when it is impossible to obtain the specified separation distances.

3.5.3 Capacity Calculations

The most widely used formula for determining the hydraulic capacity of storm sewer pipes is Manning's equation expressed by:

$$V = \left(1.486R^{2/3}S^{1/2}\right)/n$$

Where:

$$V = Average\ Velocity\ of\ Flow, ft/s$$

$$R = Hydraulic\ Radius, ft$$

$$= The\ Area\ of\ Flow\ Divided\ By\ the\ Wetted\ Perimeter\ (A/WP)$$

$$S = The\ Slope\ of\ the\ Hydraulic\ Grade\ Line, ft/ft$$

$$n = Manning's\ Roughness\ Coefficient$$

In terms of discharge, Manning's equation becomes:

$$Q = \left(1.486AR^{2/3}S^{1/2}\right)/n$$

$$Q = Rate\ of\ Flow, cfs$$

$$A = Cross\ Sectional\ Area\ of\ Flow, sq\ ft$$

For pipes flowing full, the above equations become:

$$V = \left(0.590D^{2/3}S^{1/2}\right)/n$$

$$Q = \left(0.463D^{8/3}S^{1/2}\right)/n$$

Where:

$$D = Diameter\ of\ Pipe, ft$$

3.5.4 Energy Grade Line and Hydraulic Grade Line

The energy grade line (EGL) is an imaginary line that represents the total energy along a channel or conduit carrying water. Total energy includes elevation (potential) head, velocity head, and pressure head. The calculation of the EGL for the full length of the system is critical to the evaluation of a storm sewer. To develop the EGL, it is necessary to calculate all of the losses through the system. The energy equation states that the energy head at any cross section must equal that in any other downstream section plus the intervening losses. The intervening losses are typically classified as either friction losses or form losses. Knowledge of the location of the EGL is critical to understanding and calculating the location of the hydraulic grade line (HGL).

The HGL is a line coinciding with the level of flowing water at any point along an open channel. In closed conduits flowing under pressure, the HGL is the level to which water would rise in a vertical tube at any point along the pipe. The HGL is determined by subtracting the velocity head ($V^2/2g$) from the EGL. The HGL is used to aid the designer in determining the acceptability of a proposed storm drainage system by establishing the elevation to which water will rise when the system is operating under design conditions.

The methodology in HEC 22 should be used for the calculation of the energy losses, the energy grade line, and the hydraulic grade line for a storm sewer system.

3.5.5 Manholes

Manholes provide access to storm drains for inspection and cleanout and are used for changing direction, grade, or convergence. Care should be taken to ensure the diameter of the manhole is adequate to accommodate all entering and exiting pipes. The designer should use supplier's recommendations and lay out the geometrics of the pipes and manhole to verify the diameter is adequate. The crowns of all storm sewer pipes entering and leaving a manhole shall be at the same elevation. Manholes should generally be placed at the following locations:

- Convergence of two or more storm sewers
- Intermediate points along tangent sections
- Change in pipe size
- Change in pipe alignment
- Change in pipe grade

3.6 References

- City of Brookings, South Dakota, 2006. *Storm Drainage Design and Technical Criteria Manual.*
- City of Lincoln Public Works and Utilities Department, 2000. *Drainage Criteria Manual.*
- City of Omaha Environmental Quality Control Division, 2014. *Omaha Regional Stormwater Design Manual.*
- Federal Highway Administration, 2009. *Hydraulic Engineering Circular No. 22, Third Edition, Urban Drainage Design Manual.*
- Nebraska Department of Transportation, 2006. *Drainage Design and Erosion Control Manual.*

4. OPEN CHANNELS

4.1 Overview

Open channels are the cornerstone of most major drainage systems, providing conveyance of drainage and floodwaters through natural and manmade drainageways. This chapter discusses the fundamentals of open channel hydraulics and includes procedures for the design of open channels. The designer should consult the most recent editions of Hydraulic Design Series No. 4: Introduction to Highway Hydraulics (HDS 4) and Hydraulic Engineering Circular No. 15: Design of Roadside Channels with Flexible Linings for detailed explanations of specialized procedures and methods pertaining to open channel hydraulics.

Use of natural channels is encouraged whenever possible, particularly for the major drainage system, as there can be advantages in terms of cost, capacity, and multiple use (i.e., recreation, wildlife habitat, etc.). Where natural channels are not well defined, drainage paths can usually be determined by topography and inspection, and these paths can be used as the basis for location and construction of channels. For any open channel conveyance, channel stability must be evaluated to determine what measures may be needed to prevent bottom scour and bank cutting or incising. Channels shall be designed for long-term stability but be left in as near natural condition as possible. Even where streams retain a relatively natural state, streambanks may need to be stabilized while vegetation recovers. To preserve riparian characteristics of channels, channel improvement or stabilization projects should minimize the use of visible concrete, riprap, or other hard stabilization materials.

Hydraulic analysis software such as the US Army Corps of Engineers HEC-RAS or Federal Highway Administration's Hydraulic Toolbox may be useful for preliminary and final channel analysis and design. Channel alignment revisions will require a Corps of Engineers 404 permit if the work is on a jurisdictional channel.

4.2 Open Channel Flow

Several types of flow are possible in open channels, which can be classified as:

- Uniform or Non-uniform
- Steady or Unsteady
- Subcritical, Critical, or Supercritical

Uniform flow is defined as a flow with a constant depth, cross-section, and velocity as it travels the length of channel. ***Non-uniform flow*** is one where the flow depth, cross-section, and/or velocity changes as it travels a length of channel.

Steady flow is defined as a flow with a constant discharge over time. ***Unsteady flow*** is one where the amount of discharge changes over time.

Subcritical flow is defined as a flow with a Froude number less than one ($Fr < 1.0$) and the depth of the channel flow is greater than the critical depth for the channel. Water flowing in a subcritical state has a relatively low velocity and is often described as tranquil. Subcritical flows will allow downstream losses to be transferred upstream.

Supercritical flow is defined as a flow with a Froude number greater than one ($Fr > 1.0$) and the depth of the channel flow is less than the critical depth for the channel. Water flowing in a supercritical state has a high velocity and is often described as rapid or shooting. Supercritical flows do not transfer downstream losses upstream.

Critical flow is defined as a flow with a Froude number equal to one (Fr = 1).

Non-uniform, unsteady, subcritical flow is the most common type of flow in open channels. However, due to the complexity and difficulty involved in the analysis of this type of flow, most hydraulic computations are made with certain simplifying assumptions that allow the application of steady, uniform (or gradually varied) flow principles.

The use of **steady flow methods** assumes that the discharge at a point does not change with time, and the use of **uniform flow methods** assumes that there is no change in velocity, in magnitude, or in direction with distance along a streamline. **Steady, uniform flow** is thus characterized by constant velocity and flow rate from section to section along the channel.

Steady, uniform flow is an idealized concept of open channel flow, which seldom occurs in natural channels and is difficult to obtain even in model channels. However, for most practical applications, the flow is assumed to be steady, and changes in width, depth, or direction (resulting in non-uniform flow) are sufficiently small that flow can be considered uniform. For these reasons, use of uniform flow theory is usually within acceptable degrees of accuracy.

4.2.1 Critical Depth

Critical depth is the depth at which a given quantity of water flows with the minimum content of energy. In a given channel, critical depth occurs when the specific energy (depth + velocity head) is at a minimum. Critical depth is important as a hydraulic "control point," which is a location along the channel or culvert where depth of flow can be computed directly.

Critical depth is particularly helpful in the hydraulic analysis of culverts. Since flow must pass through critical depth when changing from subcritical flow to supercritical flow, critical depth typically occurs at the following locations:

- Abrupt changes in channel or culvert slope when a flat slope is sharply increased to a steep slope (as in broken-back culverts)
- A channel constriction such as a culvert entrance
- The unsubmerged outlet of a culvert on subcritical slope, discharging into a wide channel or free outfall (no tailwater present at the outlet)
- The crest of an overflow dam or weir

The following relationship is used to calculate critical depth:

$$A^3/T = Q^2/g$$

where:

$A = Cross-sectional\ Area\ of\ Channel, ft^2$
$T = Topwidth\ of\ Water\ Surface, ft$
$Q = Discharge, cfs$
$g = Acceleration\ of\ Gravity = 32.2\ ft/sec^2$

As can be seen from this equation, critical depth is dependent on channel geometry (shape) and discharge **only**. It is independent of channel slope and roughness. This means that for a given flow rate and channel cross-section, critical depth remains constant throughout the channel or culvert length, even though the channel slope may change.

4.2.2 Froude Number

The Froude number is a dimensionless number that represents the ratio of inertial to gravitational forces. It is defined by the following equation:

$$Fr = {V}/{(gD)^{0.5}}$$

where:

$Fr = Froude\ Number$
$V = Velocity\ in\ Channel, {ft}/{sec}$
$g = Acceleration\ of\ Gravity = 32.2\ {ft}/{sec^2}$
$D = Hydraulic\ Depth, ft = {Flow\ Area}/{Top\ Width}$

- **Critical flow** exists when inertial forces and gravity are equal, (Fr = 1.0).
- **Supercritical flow** (Shallow, Rapid flow) exists when the inertial forces are greater than gravity forces (High Velocity), (Fr > 1.0).
- **Subcritical flow** (Deep, Tranquil flow) exists when inertial forces are less than gravity forces (Low Velocity), (Fr < 1.0).

4.2.3 Manning's Equation

An open channel must be designed to convey the peak runoff rate for the selected design storm frequency. The hydraulic capacity of an open channel can be determined from Manning's equation for evaluating uniform flow in open channels. See Section 4.3.7 for Manning's equation and further discussion on open channel flow criteria.

4.3 Open Channel Design Criteria

4.3.1 General Criteria

The following criteria should be used for open channel design:

- Trapezoidal cross sections are preferred; triangular shapes should be avoided.
- Channel side slopes shall be stable throughout the entire length and side slope shall depend on the channel material. A maximum of 4H:1V is recommended for vegetation and 2H:1V for riprap, unless otherwise justified by calculations.
- If relocation of a stream channel is unavoidable, the cross-sectional shape, meander, pattern, roughness, sediment transport, and slope should generally conform to the existing conditions, taking increased flows from urbanization into consideration. Energy dissipation or grade control may be necessary.
- Streambank stabilization should be provided, when appropriate and should include upstream and downstream banks, as well as the local project site.
- A low flow or trickle channel may be needed for grass-lined channels.

4.3.2 Channel Transitions

The following criteria should be considered at channel transitions:

- Transitions from one channel section to another should be smooth and gradual to avoid turbulence and eddies.
- Energy losses in transitions should be accounted for as part of the water surface profile calculations.
- Scour downstream from rigid-to-natural and steep-to-mild slope transition sections should be accounted for through velocity-slowing and energy-dissipating devices.

4.3.3 Return Period Design Criteria

Open channels, including floodplains, shall be sized to handle the 100-year storm. The 100-year storm event shall not encroach on buildable lots and shall be contained in out-lots or easements when not confined to the channel itself. When comprising the minor drainage system, open channels shall be sized to handle the 5-year storm in residential areas and the 10-year storm in downtown, commercial, and industrial areas. If a low flow channel is incorporated into the channel cross section, it shall be designed to convey 1 percent of the 100-year storm.

4.3.3.1 Approximate Flood Limits Determination

The approximate flood limits of the 100-year storm shall be determined for all open channels and all areas inundated shall be protected from development through out-lots or easements as directed by the City. Using the Manning's Equation may be an acceptable procedure to determine flood limits for small and intermediate open channels. The City may require a hydraulic model to determine flood limits for large and/or complex channels where steady, uniform flow assumptions may provide inaccurate results.

4.3.4 Velocity Limitations

Sediment transport requirements must be considered for conditions of flow below the design frequency. Minimum channel flow velocity for the 2-year storm shall be 2 feet per second. A low flow channel component within a larger channel can reduce maintenance by increasing the velocity of small storms to improve sediment transport in the channel.

4.3.5 Freeboard

A minimum freeboard of 1 foot should be provided between the water surface and top of bank or the elevation of the lowest opening of adjacent structures. Freeboard should be determined based on the 100-year storm water surface elevation under mature channel conditions.

4.3.6 Grade Control Structures

Grade control structures are used to prevent streambed degradation. This is accomplished in two ways. First, the structures provide a firm structural flowline elevation that prevents bed erosion and subsequent slope increases. Second, some structures provide controlled dissipation of energy between upstream and downstream sides of the structure. Structure choice depends on existing or anticipated erosion, cost, and environmental objectives. Design guidance for grade control structures can be found in the most recent editions of Hydraulic Engineering Circular No. 14: Hydraulic Design of Energy Dissipators for Culverts and Channels (HEC 14) and Hydraulic Engineering Circular No. 23: Bridge Scour and Stream Instability Countermeasures.

4.3.7 Manning's Equation

An open channel must be designed to convey the peak runoff rate for the selected design storm frequency. The hydraulic capacity of an open channel can be determined from Manning's equation for evaluating uniform flow in open channels.

$$Q = VA$$

Where:

$$Q = Discharge, cfs$$
$$A = Cross - sectional\ Area\ of\ Channel, ft^2$$
$$V = Velocity\ in\ Channel, {}^{ft}/_{sec}$$

$$\mathrm{V} = \frac{1.486}{\mathrm{n}} \mathrm{R}^{2/3} \mathrm{S}^{1/2}$$

Where:

$$R = Hydraulic\ Radius, ft = {}^{A}/_{WP}$$
$$WP = Wetted\ Perimeter, ft$$
$$S = Slope\ of\ Hydraulic\ Grade\ Line, {}^{ft}/_{ft}$$
$$(Can\ be\ Approximated\ by\ Channel\ Slope)$$
$$n = Manning's\ Roughness\ Coefficient$$

If a channel cross section is irregular in shape, such as a channel with a relatively narrow, deep main channel and wide, shallow overbank channels, the cross section should be subdivided, and the discharge computed separately for the main channel and the overbank channels. The same procedure is used when parts of the cross section have different roughness coefficients. In computing the hydraulic radius of the subsections, the water depth common to adjacent subsections is not counted as wetted perimeter.

Table 4-1. Open Channel Manning's Roughness Coefficients

Lined, Straight Alignment		Manning's n Range
Concrete with Surface as Indicated	Formed, No Finish	0.013 – 0.017
	Trowel Finish	0.012 – 0.014
	Float Finish	0.013 – 0.015
	Float Finish, Some Gravel on Bottom	0.015 – 0.017
	Gunite, Good Section	0.016 – 0.019
	Gunite, Wavy Section	0.018 – 0.022
Concrete, Bottom Float Finished, Sides as Indicated	Dressed Stone in Mortar	0.015 – 0.017
	Random Stone in Mortar	0.017 – 0.020
	Cement Rubble Masonry	0.020 – 0.025
	Cement Rubble Masonry, Plastered	0.016 – 0.020
	Dry Rubble (Riprap)	0.020 – 0.030
Gravel Bottom, Sides as Indicated	Formed Concrete	0.017 – 0.020
	Random Stone in Mortar	0.020 – 0.023
	Dry Rubble (Riprap)	0.023 – 0.033
Asphalt	Smooth	0.013
	Rough	0.016
Concrete Lined Excavated Rock	Good Section	0.017 – 0.020
	Irregular Section	0.022 – 0.027
Excavated, Straight Alignment, Natural Lining		**Manning's n Range**
Earth, Uniform Section	Clean, Recently Completed	0.016 – 0.018
	Clean, After Weathering	0.018 – 0.020
	With Short Grass, Few Weeds	0.022 – 0.027
	In Gravelly Soil, Uniform Section, Clean	0.022 – 0.025
Earth, Fairly Uniform Section	No Vegetation	0.022 – 0.025
	Grass, Some Weeds	0.025 – 0.030
	Dense Weeds or Aquatic Plants in Deep Channels	0.030 – 0.035
	Sides Clean, Gravel Bottom	0.025 – 0.030
	Sides Clean, Cobble Bottom	0.030 – 0.040
Dragline Excavated or Dredged	No Vegetation	0.028 – 0.033
	Light Brush on Banks	0.035 – 0.050
Rock	Based on Design Section	0.035
	Based on Actual Mean Section, Smooth and Uniform	0.035 – 0.040
	Based on Actual Mean Section, Jagged and Irregular	0.040 – 0.045
Channels not Maintained, Weeds and Brush Uncut	Dense Weeds, High as Flow Depth	0.080 – 0.120
	Clean Bottom, Brush on Sides	0.050 – 0.080
	Clean Bottom, Brush on Sides, Highest Stage of Flow	0.070 – 0.110
	Dense Brush, High Stage	0.100 – 0.140

Channels & Swales with Maintained Vegetation (2-6 ft/s)			Manning's n Range
Depth of Flow up to 0.7 Foot	Bermudagrass, Kentucky Bluegrass, Buffalograss	Mowed to 2 Inches	0.045 – 0.070
		Length 4-6 Inches	0.050 – 0.090
	Good Stand, Any Grass	Length 12 Inches	0.090 – 0.180
		Length 24 Inches	0.150 – 0.300
	Fair Stand, Any Grass	Length 12 Inches	0.080 – 0.140
		Length 24 Inches	0.130 – 0.250
Depth of Flow 0.7 – 1.5 Feet	Bermudagrass, Kentucky Bluegrass, Buffalograss	Mowed to 2 Inches	0.030 – 0.050
		Length 4-6 Inches	0.040 – 0.060
	Good Stand, Any Grass	Length 12 Inches	0.070 – 0.120
		Length 24 Inches	0.100 – 0.200
	Fair Stand, Any Grass	Length 12 Inches	0.060 – 0.100
		Length 24 Inches	0.090 – 0.170
Natural Stream Channels			**Manning's n Range**
Minor Streams, Surface Width at Flood Stage Less than 100 Feet	Fairly Regular Section	Some Grass & Weeds, Little or No Brush	0.030 – 0.035
		Dense Growth of Weeds, Depth of Flow Materially Greater than Weed Height	0.035 – 0.050
		Some Weeds, Light Brush on Banks	0.035 – 0.050
		Some Weeds, Heavy Brush on Banks	0.050 – 0.070
		Some Weeds, Dense Willows on Banks	0.060 – 0.080
		For Trees within Channel with Branches Submerged at High Stage, Increase all Above Values by:	0.010 – 0.020
	Irregular Sections w/ Pools & Channel Meander, Increase all Above Values by:		0.010 – 0.020

<table>
<tr><th colspan="3">Natural Stream Channels</th><th>Manning's n Range</th></tr>
<tr><td rowspan="15">Floodplains Adjacent to Natural Streams</td><td rowspan="2">Pasture, No Brush</td><td>Short Grass</td><td>0.030 – 0.035</td></tr>
<tr><td>High Grass</td><td>0.035 – 0.050</td></tr>
<tr><td rowspan="3">Cultivated Areas</td><td>No Crop</td><td>0.030 – 0.040</td></tr>
<tr><td>Mature Row Crops</td><td>0.035 – 0.045</td></tr>
<tr><td>Mature Field Crops</td><td>0.040 – 0.050</td></tr>
<tr><td colspan="2">Heavy Weeds, Scattered Brush</td><td>0.050 – 0.070</td></tr>
<tr><td rowspan="2">Light Brush & Trees</td><td>Winter</td><td>0.050 – 0.060</td></tr>
<tr><td>Summer</td><td>0.060 – 0.080</td></tr>
<tr><td rowspan="2">Medium to Dense Brush</td><td>Winter</td><td>0.070 – 0.110</td></tr>
<tr><td>Summer</td><td>0.100 – 0.160</td></tr>
<tr><td colspan="2">Dense Willows, Summer, Not Bent by Current</td><td>0.150 – 0.200</td></tr>
<tr><td rowspan="2">Cleared Land w/ Tree Stumps</td><td>No Sprouts</td><td>0.040 – 0.050</td></tr>
<tr><td>Heavy Growth of Sprouts</td><td>0.060 – 0.080</td></tr>
<tr><td rowspan="2">Heavy Timber, Little Brush</td><td>Depth Below Branches</td><td>0.100 – 0.120</td></tr>
<tr><td>Depth Reaches Branches</td><td>0.120 – 0.160</td></tr>
<tr><td colspan="3">Major Streams, Surface Width at Flood Stage More than 100 Feet, No Boulders or Brush (1)</td><td>0.028 – 0.033</td></tr>
</table>

(1) Roughness coefficient is usually less than for minor streams of similar description on account of less effective resistance offered by irregular banks or vegetation on banks. Values of n may be somewhat reduced.

4.3.8 Flow in Bends

Flow around a bend in an open channel induces centrifugal forces because of the change in flow direction. This results in a super elevation of the water surface at the outside of bends and can cause the flow to splash over the side of the channel if adequate freeboard is not provided. This super elevation can be estimated by the following equation.

$$\Delta d = {V^2 T}/{g R_c}$$

Where:

$$\Delta d = Difference\ in\ Water\ Surface\ Elevation\ Between\ Inner\ \&\ Outer\ Banks$$
$$V = Average\ Velocity, {ft}/{sec}$$
$$T = Surface\ Width\ of\ Channel, ft$$
$$g = Acceleration\ of\ Gravity = 32.2\ {ft}/{sec^2}$$
$$R_c = Radius\ of\ Centerline\ of\ Channel, ft$$

The elevation of the water surface at the outer channel bank will be Δd/2 higher than the centerline water surface elevation (the average water surface elevation immediately before the bend) and the elevation of the water surface at the inner channel bank will be Δd/2 lower than the centerline water surface elevation. Flow around a channel bend also imposes higher shear stress on the channel bottom and banks and may impact channel stability as described in the following sections.

4.3.9 Shear Stress

The hydrodynamic force created by water flowing in a channel causes a shear stress on the channel bottom. The bed material, in turn, resists this shear stress by developing a tractive force. Tractive force theory states that the flow-induced shear stress should not produce a force greater than the tractive resisting force of the bed material. This tractive resisting force of the bed material creates the permissible or critical shear stress of the bed material.

4.3.9.1 Shear Stress in Straight Channels

The maximum shear stress for a straight channel occurs on the channel bed and is less than or equal to the shear stress at maximum depth. The maximum shear stress is computed as:

$$\tau_d = \gamma d S_o$$

Where:

$$\tau_d = Maximum\ Shear\ Stress, {lb}/{ft^2}$$
$$\gamma = Unit\ Weight\ of\ Water, 62.4\ {lb}/{ft^3}$$
$$d = Maximum\ depth\ of\ Flow, ft$$
$$S_o = Average\ Bed\ Slope\ or\ Engery\ Slope, {ft}/{ft}$$

4.3.9.2 Shear Stress of Channel Sides

Shear stress is generally reduced on the channel sides compared with the channel bottom. The maximum shear on the side of a channel is given by the following equation for trapezoidal channels:

$$\tau_s = K_1 \tau_d$$

Where: $\tau_s = Side\ Shear\ Stress, {}^{lb}/_{ft^2}$

$K_1 = Ratio\ of\ Channel\ Side\ to\ Bottom\ Shear\ Stress$

Table 4-2. Ratios of Channel Side to Bottom Shear Stress

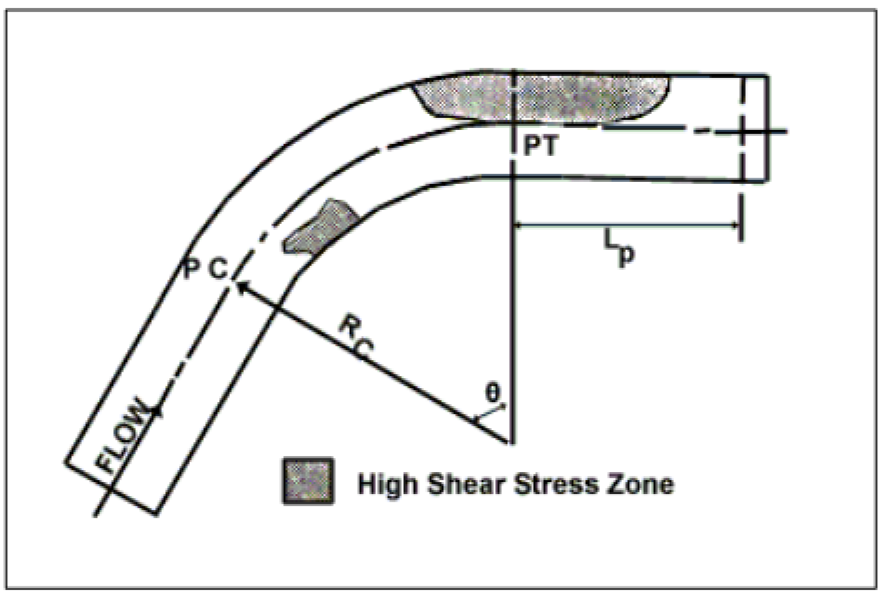
Value of K_1	Channel Side Slope
0.77	Z ≤ 1.5
0.066Z + 0.67	1.5 < Z < 5
1.0	5 ≤ Z

The Z value represents the horizontal dimension Z:1 (H:V). Use of side slopes steeper than 3:1 (H:V) is not encouraged for flexible linings other than riprap or gabions because of the potential for erosion of the side slopes.

4.3.9.3 Shear Stress in Bends

Flow around a bend creates secondary currents, which impose higher shear stresses on the channel sides and bottom compared to a straight reach as shown on Figure 4-1. At the beginning of the bend, the maximum shear stress is near the inside and moves toward the outside as the flow leaves the bend. The increased shear stress caused by a bend persists downstream of the bend.

Figure 4-1. High Shear Stress Zone in Bends



The maximum shear stress in a bend is computed as:

$$\tau_b = K_b \tau_d$$

Where: $\tau_b = Shear\ Stress\ in\ a\ Bend, {}^{lb}/_{ft^2}$

$K_b = Ratio\ of\ Channel\ Bend\ to\ Bottom\ Shear\ Stress$

The maximum shear stress in a bend is a function of the ratio of channel curvature to the top (water surface) width, R_C/T. As R_C/T decreases, that is as the bend becomes sharper, the maximum shear stress in the bend tends to increase. K_b can be determined from Table 4-3.

Table 4-3. Ratios of Channel Bend to Bottom Shear Stress

Value of K_b	${}^{R_C}/_T$
2.00	${}^{R_C}/_T \le 2$
$2.38 - 0.206\left({}^{R_C}/_T\right) + 0.0073\left({}^{R_C}/_T\right)^2$	$2 < {}^{R_C}/_T < 10$
1.05	$10 \le {}^{R_C}/_T$

The added stress induced by bends does not fully attenuate until some distance downstream of the bend. If added lining protection is needed to resist the bend stresses, this protection should continue downstream a length given by:

$$L_p = \alpha\left(\frac{R^{7/6}}{n}\right)$$

Where: $L_p = Length\ of\ Protection, ft$

$R = Hydraulic\ Radius, ft = {}^{A}/_{WP}$

$n = Manning's\ Roughness\ for\ Lining\ Material\ in\ Bed$

$\alpha = Unit\ Conversion\ Constant = 0.60$

4.3.9.4 Effective Shear Stress in Grass Lined Channels

Grass linings move shear stress away from the soil surface. The remaining shear at the soil surface is termed the effective shear stress. When the effective shear stress is less than the allowable shear for the soil surface, then erosion of the soil surface will be controlled. Grass linings provide shear reduction in two ways. First, the grass stems dissipate shear force within the canopy before it reaches the soil surface. Second, the grass plant (both the root and stem) stabilizes the soil surface against turbulent fluctuations. This process model for the effective shear at the soil surface is given by the following equation.

$$\tau_e = \tau_d K_e$$

Where: $\tau_e = Effective\ Shear\ Stress\ on\ the\ Soil\ Surface, {}^{lb}/_{ft^2}$

$K_e = Ratio\ of\ Effective\ to\ Bottom\ Shear\ Stress$

Table 4-4 provides typical examples of K_e for common grass linings. See the most recent edition of Hydraulic Engineering Circular No. 15: Design of Roadside Channels with Flexible Linings (HEC 15) for effective shear stress development for grasses not provided in Table 4-4.

Table 4-4. Typical Ratios of Effective to Bottom Shear Stress

Grass Type	Grass Length	Flow Depth	K_e
Bermudagrass, Kentucky Bluegrass, Buffalograss	Mowed to 2 Inches	4 Inches	0.013
		8 Inches	0.016
		12 Inches	0.021
		18 Inches	0.028
	Length 4-6 Inches	4 Inches	0.010
		8 Inches	0.012
		12 Inches	0.015
		18 Inches	0.016
Fair Stand, Any Grass (Includes Native Grasses)	Length 12 Inches	4 Inches	0.021
		8 Inches	0.026
		12 Inches	0.033
		18 Inches	0.038
	Length 24 Inches	4 Inches	0.008
		8 Inches	0.010
		12 Inches	0.014
		18 Inches	0.017
Good Stand, Any Grass	Length 12 Inches	4 Inches	0.008
		8 Inches	0.010
		12 Inches	0.012
		18 Inches	0.013
	Length 24 Inches	4 Inches	0.003
		8 Inches	0.004
		12 Inches	0.005
		18 Inches	0.006
Good Stand, Wetland Mixture (Cattails)	Uncut	4 Inches	0.001
		8 Inches	0.001
		12 Inches	0.001
		18 Inches	0.001

4.3.9.5 Permissible Shear Stress

Flexible linings (grass, riprap, etc.) act to reduce the shear stress on the underlying soil surface. For example, a long-term lining of vegetation in good condition can reduce the shear stress on the soil surface by over 90 percent. Transitional linings (erosion control blankets, transition mats, etc.) act in a similar manner as vegetative linings to reduce shear stress. Performance of these products depends on their properties: thickness, cover density, and stiffness.

The erodibility of the underlying soil, therefore, is a key factor in the performance of flexible linings. The erodibility of soils is a function of particle size, cohesive strength, and soil density. The erodibility of non-cohesive soils (defined as soils with a plasticity index of less than 10) is due mainly to particle size, while fine-grained cohesive soils are controlled mainly by cohesive strength and soil density. For most construction, the density of the embankment is controlled by compaction rather than the natural density of the undisturbed ground. However, when the ditch is lined with topsoil, the placed density of the topsoil should be used instead of the density of the compacted embankment soil.

For stone linings, the permissible shear stress, τ_p, indicates the force required to initiate movement of the stone particles. Prior to movement of stones, the underlying soil is relatively protected. Therefore, permissible shear stress is not significantly affected by the erodibility of the underlying soil. However, if the lining moves, the underlying soil will be exposed to the erosive force of the flow.

Table 4-5 provides typical examples of permissible shear stress for bare soil and selected linings. See HEC 15 for permissible shear stress development for linings not provided in Table 4-5.

Table 4-5. Typical Permissible Shear Stresses for Bare Soil and Stone Linings

Lining Category	Lining Type	Permissible Shear Stress, $^{lb}/_{ft^2}$
Bare Soil, Cohesive (PI = 10)	Clayey Sands	0.037-0.095
	Inorganic Silts	0.027-0.110
	Silty Sands	0.024-0.072
Bare Soil, Cohesive (PI ≥ 20)	Clayey Sands	0.094
	Inorganic Silts	0.083
	Silty Sands	0.072
	Inorganic Clays	0.140
Bare Soil, Non-cohesive (PI < 10)	Finer than Coarse Sand, D_{75} < 0.05 inch	0.02
	Fine Gravel, D_{75} = 0.3 inch	0.12
	Gravel, D_{75} = 0.6 inch	0.24
Gravel Mulch	Course Gravel, D_{50} = 1.0 inch	0.4
	Very Course Gravel, D_{50} = 2.0 inch	0.8
Rock Riprap	NDOT, Type A, D_{50} = 0.77 feet	3.1
	NDOT, Type B, D_{50} = 1.02 feet	4.1
	NDOT, Type C, D_{50} = 1.28 feet	5.1
Concrete Riprap	NDOT, D_{50} = 1.10 feet	4.4

4.4 Construction and Maintenance Considerations

Open channels can lose hydraulic capacity without adequate maintenance. Brush, sediment, or debris can reduce design capacity and can harm or kill vegetative linings, thus creating the potential for erosion damage during large storm events. Maintenance may include repairing erosion damage, mowing grass, cutting brush, removing sediment or debris, applying fertilizer appropriately, irrigating during dry periods, and reseeding or resodding to restore the viability of damaged areas. Ample sizing of channels should be used to account for future vegetation growth.

Implementation of a successful maintenance program is directly related to the accessibility of the channel system and the easements necessary for maintenance activities. The easement cross-section must accommodate the depth and width of flow for the 100-year storm. The width must also be designed to allow access of maintenance equipment.

4.5 References

- City of Lincoln Public Works and Utilities Department, 2004. *Drainage Criteria Manual.*
- City of Omaha Environmental Quality Control Division, 2014. *Omaha Regional Stormwater Design Manual.*
- Federal Highway Administration, 2008. *Hydraulic Design Series No. 4, Third Edition, Introduction to Highway Hydraulics.*
- Federal Highway Administration, 2006. *Hydraulic Engineering Circular No. 14, Third Edition, Hydraulic Design of Energy Dissipators for Culverts and Channels.*
- Federal Highway Administration, 2005. *Hydraulic Engineering Circular No. 15, Third Edition, Design of Roadside Channels with Flexible Linings.*
- Federal Highway Administration, 2009. *Hydraulic Engineering Circular No. 23, Third Edition, Bridge Scour and Stream Instability Countermeasures.*
- Nebraska Department of Transportation, 2006. *Drainage and Erosion Control Manual.*

5. DESIGN OF CULVERTS

5.1 Overview

Culverts are enclosed conduits used to convey water through embankments such as highways, streets, and driveways. In addition to their hydraulic function, culverts must also support earth loads, traffic, and construction equipment. Therefore, culvert design involves both hydraulic and structural design. They must be designed to protect the traveling public and adjacent property from flood hazards in a reasonable and prudent manner.

Primary considerations for the final selection of any drainage structure are that its design be based on appropriate hydraulic principles, economy, and that it has allowable design storm headwater depth and outlet velocity. The allowable headwater elevation is that elevation above which unacceptable impacts may be caused to adjacent property and/or the roadway. It is this allowable headwater depth that is the primary basis for sizing a culvert. In addition to sound hydraulic design, sound structural design, site design and construction practices are necessary for a culvert to function properly.

Any structure that measures less than 20 feet from the inside face of the exterior wall to the inside face of the exterior wall (including interior walls) along the centerline of the roadway is classified as a culvert. Any structure that measures 20 feet or greater for the same dimensions is classified as a bridge or major structure.

5.2 Engineering Design Criteria

The engineering design criteria described in this chapter are based on the most recent edition of Hydraulic Design Series 5: Hydraulic Design of Highway Culverts (HDS 5). See HDS 5 for additional design procedures not found in this manual.

Hydraulic analysis of culverts includes the computation of:

- Drainage area
- Design flow
- Allowable headwater
- Headwater at design flow
- Outlet velocity

Culvert design also involves the consideration of the following factors:

- Inlet and outlet control
- Culvert shape and cross section
- Culvert length and extensions
- End treatments
- Multiple installations
- Inlet improvement
- Outlet velocity
- Culvert size
- Slope and alignment
- Camber
- Bedding and fill requirements

5.2.1 Return Period

Since it is generally not economically feasible to design culverts for the maximum runoff that a watershed is capable of producing, design storm frequency criteria must be established. The design storm frequency criteria for culverts is 50 years for the major system and 10 years for the minor system. The minor system consists of culverts and open channels that run parallel to the roadway and are used to drain the roadway in lieu of a storm sewer system.

5.2.2 Headwater Elevation

Any culvert that constricts the natural stream flow will cause a rise in the upstream water depth to some extent. The depth of water in the stream measured from the culvert inlet invert (flowline) is termed headwater.

The maximum allowable headwater elevation for culverts will be the lowest of the following:

- One foot below the top of all roadway curbs or edges of roadway pavement.
- One foot above the top of the culvert.
- Elevations that could damage adjacent property.
- Elevations established to delineate floodplain zoning at the culvert.
- Ditch elevation of the terrain that would permit flow to divert around the culvert.

The headwater shall also be checked for the 100-year design storm to ensure compliance with street cross flow criteria established for the major storm in Chapter 3 of this manual, to ensure compliance with floodplain management regulations, and to avoid increasing the water surface elevation on an adjacent property.

5.2.3 Tailwater Elevation

Tailwater is the flow depth in the downstream channel measured from the invert at the culvert outlet. It can be an important factor in culvert hydraulic design because a submerged outlet may cause the culvert to flow full rather than partially full.

A field inspection of the downstream channel should be made to determine whether there are obstructions that will influence the flow depth. Tailwater depth may be controlled by the stage in another stream, headwater from structures downstream of the culvert, reservoir water surface elevations, or other downstream features.

5.2.4 Inlet and Outlet Control

Based on laboratory tests and field observations there are two major types of culvert flow:

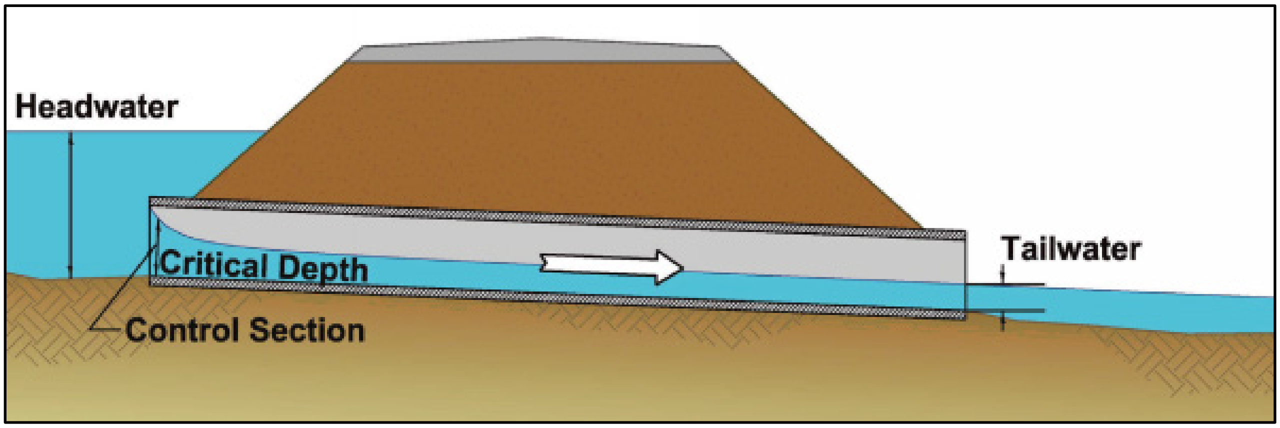
- Flow with inlet control
- Flow with outlet control

For each type of control, different factors and formulas are used to compute the hydraulic capacity of a culvert. Hydraulic analysis of a culvert design includes determining the headwater elevation at the design discharge. This is done by comparing the inlet control headwater elevation against the outlet control headwater elevation and selecting the higher value. For additional information, see HDS 5.

5.2.4.1 Inlet Control

In inlet control, the discharge capacity of a culvert is controlled by the conditions at the culvert entrance. Inlet control generally occurs when the culvert opening is not capable of accepting as much flow as the culvert barrel is able to convey. Flow passes through critical depth shortly after entering the culvert, becoming high-velocity, shallow (supercritical) flow in the culvert. Under inlet control, the cross-sectional area of the culvert opening, the inlet shape, entrance configuration (projecting, headwalls, wingwalls) and depth of the headwater at the entrance are of primary importance. Hydraulic characteristics downstream of the inlet control section do not affect the culvert capacity. The efficiency of the culvert inlet can be enhanced by beveling or tapering the opening (see Section 5.2.11, Culvert Inlet Configurations and HDS 5).

Figure 5-1. Example Inlet Control Flow Condition



5.2.4.2 Outlet Control

In outlet control, the discharge capacity of a culvert is controlled by the barrel exit or downstream conditions. Outlet control generally occurs when the culvert barrel is not capable of conveying as much flow as the inlet opening will accept. Water flows through the culvert as low-velocity, deep (subcritical) flow, or pressure flow. The culvert may flow completely or partially full. Under outlet control, in addition to the parameters affecting inlet control, the barrel slope, length, and roughness are important. Also of importance is the tailwater elevation of the outlet.

Figure 5-2. Typical Outlet Control Flow Conditions

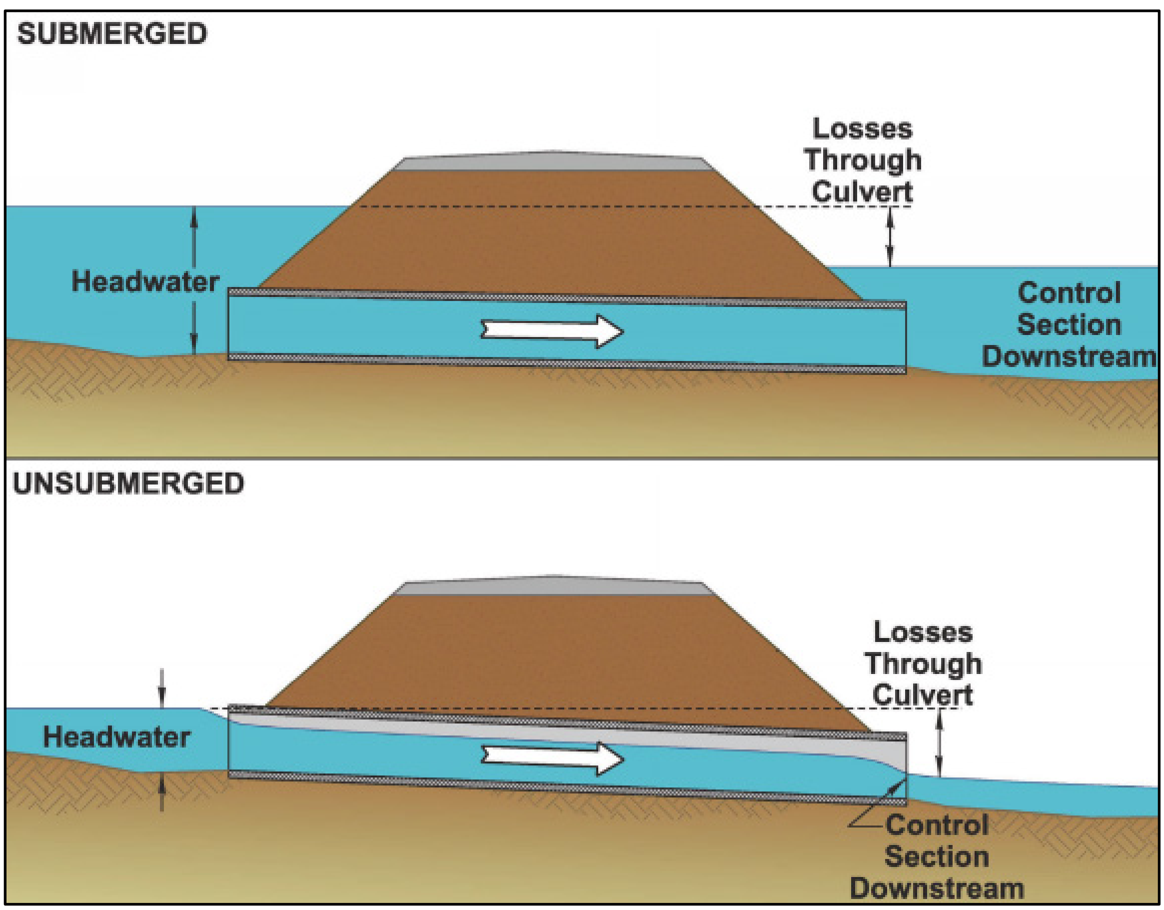


Table 5-1 summarizes factors affecting inlet and outlet control conditions at a culvert.

Table 5-1. Factors Affecting Inlet and Outlet Control

Inlet Control	Outlet Control
Headwater Depth	Headwater Depth Tailwater Depth
Inlet Edge Cross Sectional Area Shape	Inlet Edge Cross Sectional Area Shape
n/a	Slope Length Roughness

5.2.5 Culvert Shape, Cross Section, and Material

Culvert type selection includes the shape and cross section, choice of materials, and number of culvert barrels or spans. The following shapes and cross sections are acceptable for culverts:

- Circular: Most common; standard lengths and strength classes are available.
- Pipe Arch and Elliptical: Typically used where cover is limited.
- Box or Rectangle: Typically used for larger culverts where pipes are not adequate. A longer construction time is required for cast-in-place construction; precast construction may be considered.

Table 5-2 shows equivalent pipe cross sections.

Table 5-2. Equivalent Pipe Cross Sections

Circular Pipe		Concrete Pipe Horizontal – Elliptical			Concrete Pipe Arch			Corrugated Metal Pipe Arch ($2\frac{2}{3}$ in x $\frac{1}{2}$ in)		
Diameter (in)	Area (ft^2)	Span (in)	Rise (in)	Area (ft^2)	Span (in)	Rise (in)	Area (ft^2)	Span (in)	Rise (in)	Area (ft^2)
15	1.23	—	—	—	—	—	—	—	—	—
18	1.77	23	14	1.84	22	$13\frac{1}{2}$	1.6	—	—	—
21	2.41	—	—	—	—	—	—	25	16	2.16
24	3.14	30	19	3.28	$28\frac{1}{2}$	18	2.8	29	18	2.83
27	3.98	34	22	4.14	—	—	—	—	—	—
30	4.91	38	24	5.12	$36\frac{1}{4}$	$22\frac{1}{2}$	4.4	36	22	4.42
33	5.94	42	27	6.31	—	—	—	—	—	—
36	7.07	45	29	7.37	$43\frac{3}{4}$	$26\frac{5}{8}$	6.4	43	27	6.36
42	9.62	53	34	10.21	$51\frac{1}{8}$	$31\frac{5}{16}$	8.8	50	31	8.65
48	12.57	60	38	12.92	$58\frac{1}{2}$	36	11.4	58	36	11.30
54	15.90	68	43	16.6	65	40	14.3	65	40	14.34
60	19.64	76	48	20.5	73	45	17.7	72	44	17.7
66	23.76	83	53	24.8	88	54	25.6	—	—	—
72	28.27	91	58	29.5	—	—	—	—	—	—

Allowable materials for culverts, most commonly reinforced concrete, smooth or corrugated metal, and smooth or corrugated PVC or HDPE, can be found in the City's Standard Specifications.

5.2.6 Velocity

A minimum velocity of 2 feet per second should be maintained in the culvert to preclude settlement of silts and other solids. Velocities greater than 10 feet per second should be avoided when possible. See Chapter 6 of this manual for energy dissipation measures for outlet velocities greater than 10 feet per second.

5.2.7 Culvert Sizes

Culvert sizes will be determined in accordance with the charts and methods contained in HDS 5 or from computer programs based on HDS 5, such as FHWA's HY-8 culvert analysis program. Minimum culvert sizes shall be as follows:

- 18-inch pipes for roadways
- 15-inch pipes for driveways
- 4-feet by 4-feet for box culverts

5.2.8 Manning's n Values

The recommended Manning's n value for design purposes when using corrugated pipe is 0.024. The recommended Manning's n value for smooth interior pipes is 0.012. When it is necessary to determine the true magnitude of the pipe outlet flow velocity, designers should use the actual Manning's n value recommended by the manufacturer to perform computations. When both corrugated and smooth pipe are selected as options, the designer shall use a Manning's n value of 0.024. A Manning's n value of 0.012 shall be used when only smooth interior pipe is specified.

5.2.9 Length, Slope, and Alignment

Since the capacity of culverts in outlet control will be affected by the length of the culvert, their length should be kept to a minimum and existing facilities shall not be extended without determining the decrease in capacity that may occur. In addition, the culvert length and slope should be chosen to generally match existing topography.

To the degree practicable, the culvert invert should be aligned with the channel bottom and the skew angle of the stream. The culvert entrance should fit with the geometry of the roadway embankment. Culvert skews shall not exceed 45 degrees as measured from a line perpendicular to the roadway centerline without approval of the City.

5.2.10 Multiple Barrels and Spans

In the case of box culverts, it is usually more economical to use a multiple span structure than a wide single span, due to a reduction in the thickness of the top slab. In some locations, multiple spans tend to catch debris and clog the waterway. They are also susceptible to ice jams and the deposition of silt in one or more spans. Alignment of the culvert face normal to the approach flow and installation of debris control structures can help to alleviate these problems.

In the case of pipe culverts, multiple pipe installations often exhibit settlement after construction. Use of multiple pipes should be avoided whenever possible. However, if multiple pipes are used, sufficient space between pipes must be provided to allow proper backfill and compaction to eliminate the settlement problem. Multiple pipe installations should desirably have 5 feet or greater clearance from outside of pipe to outside of pipe. Backfill material for the minimum clear spacing of one foot shall be flowable fill. Proper indigenous soils may be used for backfill material where spacing is greater than 5 feet.

Headwalls are preferred to flared end sections for multiple pipe installations where the headwall does not present an obstacle, (e.g., is outside the clear zone). Flared end sections are also available that permit one foot minimum clear spacing between pipes.

5.2.11 End Treatments

Flared end sections are preferred over a headwall for single pipe culverts from a safety standpoint and shall be used whenever feasible. The material of the flared end section generally shall match the pipe material unless plastic pipe is used, which requires a metal flared end section. Flared end sections may prove to be unsatisfactory for skewed culverts with low fills and the use of a headwall may be necessary. Installation of flared end sections on multiple pipe installations is preferred over cast-in-place concrete headwalls within the clear zone.

Headwalls may be used for:

- Multiple pipe installations.
- Culverts with skews of 30° or more.
- Culverts with slopes too steep for flared end sections.
- Broken-back culverts where the possibility of slippage exists (e.g., drop pipes in backslopes).

Headwalls with a deeper footing are needed for culverts placed on steep grades or in areas of potential head cutting.

5.2.12 Culvert Inlet Configurations

The culvert inlet configuration is the cross-sectional area and shape of the culvert face and the type of inlet edge. When a culvert operates in inlet control, headwater depth and the inlet configuration determine the culvert capacity and the culvert barrel usually flows only partially full. Inlet geometry refinements or inlet improvements can be used to reduce the contraction losses at the inlet and to increase the capacity of the culvert without increasing the headwater depth.

Culverts operating in outlet control usually flow full at the design flow rate. Therefore, inlet improvements on these culverts only reduce the entrance loss coefficient, which results in only a small decrease in the required headwater elevation.

Common conventional culvert inlets include projecting inlets, groove-end projecting inlets, square-edge inlets in a headwall with wingwalls, mitered inlets with slope paving and flared end inlets. Recommended entrance loss coefficients for inlets can be found in Table 5-2.

Table 5-3. Entrance Loss Coefficients, Outlet Control

Type of Structure and Design of Entrance		Coefficient, K_e
Pipe, Concrete	Projecting from Fill, Socket End (Groove-end)	0.2
	Project from Fill, Square Cut End	0.5
	Headwall or Headwall and Wingwalls	
	Socket End (Groove-End)	0.2
	Square-edge	0.5
	Rounded (Radius = D/12)	0.2
	Mitered to Conform to Fill Slope	0.7
	*Flared End Section Conforming to Fill Slope	0.5
	Beveled Edges, 33.7° or 45° Bevels	0.2
	Side- or Slope-tapered Inlets	0.2
Pipe or Pipe-Arch, Corrugated Metal	Projecting from Fill	0.9
	Headwall or Headwall and Wingwalls, Square-edge	0.5
	Mitered to Conform to Fill Slope, Paved or Unpaved	0.7
	*Flared End Section Conforming to Fill Slope	0.5
	Beveled Edges, 33.7° or 45° Bevels	0.2
	Side- or Slope-Tapered Inlet	0.2
Box, Reinforced Concrete	Headwall Parallel to Embankment (No Wingwalls)	
	Square-edge on 3 Edges	0.5
	Rounded on 3 Edges to Radius of D/12 or B/12 or Beveled Edge on 3 Sides	0.2
	Wingwalls at 30° to 75° to Barrel	
	Square-edge at Crown	0.4
	Crown Edge Rounded to Radius of D/12 or Beveled	0.2
	Wingwalls at 10° to 25° to Barrel, Squared-edge at Crown	0.5
	Wingwalls Parallel (Extension of Sides)	
	Square-edge at Crown	0.7
	Side- or Slope-tapered Inlet	0.2

*Note: Flared end sections conforming to fill slope, made of either metal or concrete, are the section commonly available from manufacturers. From limited hydraulic tests, they are equivalent in operation to a headwall in both inlet and outlet control. Some flared end sections incorporating a closed taper in their design have a superior hydraulic performance. These latter sections can be designed using the information given for the beveled inlet.

5.2.12.1 Improved Inlets

Even though the construction of an improved inlet will increase the labor and material costs for the inlet portion of a new culvert, a substantial savings may be attained by a reduction in the size of the barrel that represents the major portion of the structure. Improved inlets may also be installed on existing culverts with inadequate flow capacity, thus avoiding the replacement of the entire structure or the addition of a new parallel structure. The greatest savings usually result from the use of improved inlets on culverts with long barrels. Short barrels, however, should also be checked, especially when an improved inlet might increase the capacity sufficiently to avoid replacement of an existing structure.

Improved inlets include bevel-edged, side-tapered, and slope-tapered inlets. Additional information and design procedures for improved inlets can be found in HDS 5.

5.2.13 Broken-back Culverts

Abrupt changes in slope or direction are not typically desirable from a maintenance and construction standpoint. However, at locations where the inlet is substantially higher than the outlet, culverts referred to as "broken-back" (with either one or two breaks in the vertical alignment), are commonly constructed to effectively control the drop in flow line and the outlet velocity.

Figure 5-3. Single Broken-back Culvert

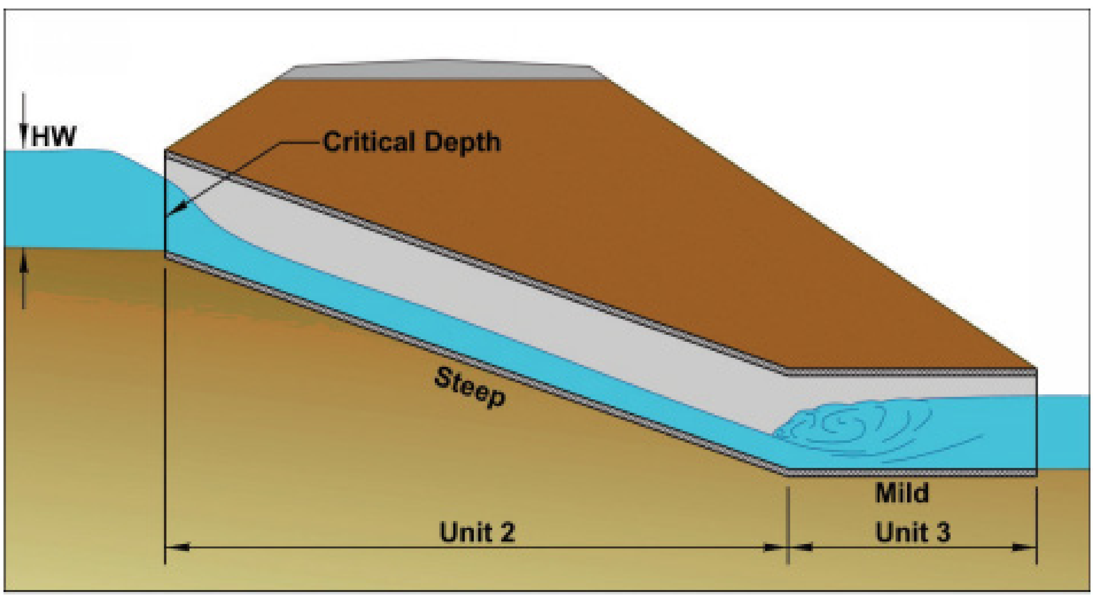
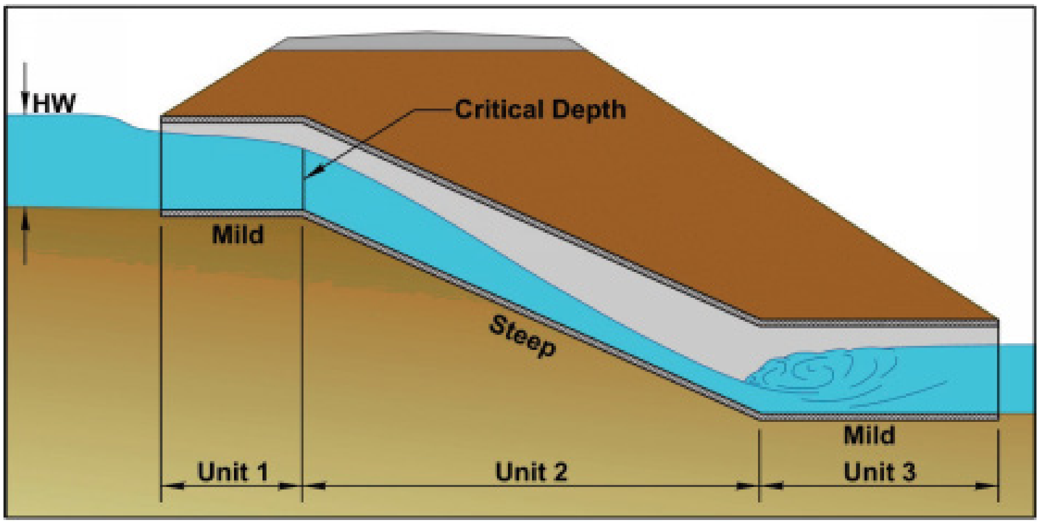


Figure 5-4. Double Broken-back Culvert



The total hydraulic performance of these culverts is difficult to analyze without the aid of a computer program written for such a purpose. The hydraulics of circular and rectangular broken-back culverts can be analyzed using the FHWA HY-8 software or the Broken-back Culvert Analysis Program (BCAP) software from the Nebraska Department of Transportation.

Many broken-back culverts are constructed to control head cut erosion, when there is great differential between the inlet and outlet elevations. In broken-back culverts, velocity of flow is greatest at the lower break due to acceleration in the steeply sloped segment; however, subcritical flow is desirable at the culvert outlet to reduce the erosive potential of the flow as it exits the culvert. A hydraulic jump will occur within a broken-back culvert when there is sufficient roughness within the culvert barrel, sufficient tailwater at the outlet, or both. It is often advantageous to specify corrugated interior pipes for these culverts to help reduce velocity between the lower break point and the culvert outlet. In many cases, HY-8 or BCAP can be used to optimize the length of the outlet section and provide for velocity reduction between the lower break point and the culvert outlet.

5.2.14 Debris Control

The need for debris control should be considered for each culvert, but in general, debris control shall not be used on entrances for culverts unless approved by the City and should never be installed at the outlet of a culvert. Upstream property management is generally preferred over a debris control structure. See HDS 5 for design of debris control structures.

5.2.15 Anchorage

Anchorage at the culvert entrance or at the outlet of the culvert may be necessary for the following:

- Protect the inlet and especially the outlet from undermining by scour.
- Protect against buoyant forces or uplift.
- Protect against separation of concrete pipe joints.

End anchorage can be in the form of headwalls, slope paving, or piling. These techniques protect the slope from scour and preclude undermining of the culvert end. The culvert barrel, however, must be anchored to the end treatment to be effective.

Buoyant forces are produced when the pressure outside the culvert is greater than the pressure in the barrel. This condition can occur in a culvert in inlet control with a submerged upstream end and in culverts placed in areas of high groundwater.

Culvert ends projected through levees are also susceptible to failure from buoyant forces if flap gates are used on the end. Generally, flexible barrel materials are most vulnerable to this type of failure because of their light weight and lack of resistance to longitudinal bending. Installation of headwalls and wingwalls will increase the dead load on the end of the culvert and protect it from uplift.

Rigid concrete pipe susceptible to separation of the pipe joints can be protected by installation of pipe couplers.

5.2.16 Fill Heights and Loading Requirements

Fill height over a culvert determines the amount of dead or live loads imposed on the culvert structure. Minimum fill height is defined as the vertical fill distance measured from the top of the conduit to the bottom of the pavement or the shoulder surface at its lowest point. Maximum fill height is defined as the vertical distance measured from the top of the conduit to the top of the pavement at its highest. Minimum fill height for all culverts is one foot.

All culverts shall be designed, as a minimum, for HS20 live load with the appropriate impact factor and dead load. Dead load shall be based on the depth of earth cover plus pavement above the top of the culvert.

5.2.17 Storage Routing

A significant storage capacity behind a roadway embankment may attenuate a flood hydrograph. Because of the reduction of the peak discharge associated with such attenuation, the required capacity of the culvert, and its size, may be reduced. If significant storage is anticipated behind a culvert, the design may be checked by routing the design hydrographs through the culvert to determine the discharge and stage behind the culvert. If credit for storage attenuation is taken during culvert design, the facility should be designed as a storage facility according to Chapter 7 of this Manual and measures should be taken to ensure the area inundated by floodwater is not encroached upon in the future. Additional routing procedures are also outlined in HDS 5. No roadway embankment shall be designed as a storage facility without prior approval of the City.

5.3 References

- City of Lincoln Public Works and Utilities Department, 2000. *Drainage Criteria Manual.*
- City of Omaha Environmental Quality Control Division, 2014. *Omaha Regional Stormwater Design Manual.*
- Federal Highway Administration, 2012. *Hydraulic Design Series Number 5, Third Edition, Hydraulic Design of Highway Culverts.*
- Nebraska Department of Transportation, 2006. *Drainage Design and Erosion Control Manual.*

6. ENERGY DISSIPATION

6.1 Overview

The failure or damage of many culverts, storm sewer outfalls, and detention basin outlet structures can be traced to unchecked erosion and scour. When the outlet velocity from a culvert or storm sewer outfall cannot be reduced to acceptable levels by other means, the flow energy should be dissipated before the discharge is returned to the downstream channel. Prior to designing an energy dissipator, the designer should try to reduce outlet velocity of the culvert by:

- Choosing gentler slopes, if possible.
- Installing a "soil saver" or depressed inlet end section at the inlet and lowering the slope of the culvert.
- Designing a broken back culvert with a flat outlet section (See Chapter 5: Design of Culverts for more information on culvert design).
- Installing a drop manhole at the last manhole upstream of the storm sewer outfall.

6.2 Design Criteria

An energy dissipator should be constructed when the outlet velocity of a culvert exceeds the values shown in Table 6-1. The flood frequency used in the design of the energy dissipator shall be the same flood frequency used for the culvert or storm sewer design.

Table 6-1. Requirements for Energy Dissipation

Design Flow Outlet Velocity	Energy Dissipation Requirement
Less than 8 ft/sec	Not Required
8 to 10 ft/sec	Evaluate on a Case-by-Case Basis
Greater than 10 ft/sec	Required

6.2.1 Dissipator Type Selection

The dissipator type selected for a site must be appropriate to the location. In this chapter, the terms "internal" and "external" are used to indicate the location of the dissipator in relationship to the culvert. An internal dissipator is located within the culvert barrel, and an external dissipator is located outside the culvert. For internal energy dissipation, the hydraulic jump occurs within the culvert barrel; for external energy dissipation, the hydraulic jump occurs outside the barrel.

For many designs, the following external energy dissipators provide sufficient protection at a reasonable cost and can be used when the following outlet conditions exist. Design procedures for these and other energy dissipators can be found in the most recent edition of Hydraulic Engineering Circular No. 14: Hydraulic Design of Energy Dissipators for Culverts and Channels (HEC 14).

- Riprap Apron
    - A riprap apron consists of riprap placed at the outlet of a drainage structure and reduces velocity by increasing the roughness of the outlet channel. Riprap aprons may be applicable if the outlet Froude number is 2.5 or lower. Refer to Chapter 4 Open Channels for a discussion of the Froude number. In general, riprap aprons prove economical for transitions from stormwater conveyance facilities to overland sheet flow at terminal outlets but may also be used for transitions from conveyance outlets to stable channel sections. Riprap aprons are typically used for storm sewer or culverts up to 60 inches in diameter. Stability of the surface at the termination of the apron needs to be considered.

- Riprap Basin (or Pre-formed Scour Hole)
    - A riprap basin or preformed scour hole is an excavated hole or depression that is lined with riprap of a stable size and designed to prevent scouring at a culvert outlet. The depression provides both a vertical and lateral expansion of the flow and a temporary stilling pool at the culvert outlet. The depth of the depression for the preformed scour hole is based on the flow velocity and depth at the culvert outlet, and the size of the riprap used to line the depression. A riprap basin may be applicable if the outlet Froude number is 3.0 or lower. Refer to Chapter 4 Open Channels for a discussion of the Froude number. Riprap basins are generally used for transitions from pipe outlets to stable channels. Since they function by creating a hydraulic jump to dissipate energy, their design is impacted by tailwater conditions.
- USBR Type VI Impact Basin
    - The U.S. Bureau of Reclamation (USBR) Type VI impact basin is contained in a relatively small box-like structure that dissipates energy through impact and turbulence and requires no tailwater for successful performance. Although the emphasis in this manual is on its use at culvert outlets, the structure may also be used in open channels. Type VI Impact Basins may be used for outlet flow rates as high as 400 cubic feet per second and velocities as high as 50 feet per second. Impact basins may be used at both terminal outlet and channel outlet transitions.

6.2.2 Design Limitations

6.2.2.1 Ice Buildup

If ice buildup within a culvert pipe or a box culvert is a factor, it shall be mitigated by sizing the structure to not obstruct the winter low flow and by using external dissipators.

6.2.2.2 Debris Control

Design and installation of debris control, consistent with the guidance of the most recent edition of Hydraulic Engineering Circular No. 9: Debris Control Structures (HEC 9), shall be considered where clean-out access is limited and if the dissipator type selected cannot pass debris.

6.2.2.3 Tailwater Relationship

The hydraulic conditions downstream shall be evaluated to determine a tailwater depth and the maximum velocity for a range of discharges according to Chapter 4: Open Channels. Tailwater depths at a lake, a pond or a large water body shall be evaluated using the high-water elevations that have the same frequency as the design storms for the conveyance outlet.

6.2.3 Design Options

6.2.3.1 Material Selection

The material selected for the dissipator shall be based on a comparison of the total cost over the design life of alternate materials and shall not be made using first cost as the only criteria. This comparison shall consider replacement cost and the difficulty of construction as well as traffic delay.

6.2.3.2 Pipe Outlet Type

In choosing a dissipator, the selected pipe end treatment has the following implications:

- Pipe ends that are projecting or mitered to the fill slope offer no outlet protection.
- Headwalls provide embankment stability and erosion protection. They provide protection from buoyancy and reduce damage to the culvert.
- Commercial end sections add little cost and may require less maintenance, retard embankment erosion, and incur less damage from maintenance.
- Concrete aprons do not reduce outlet velocity; if used, they should not protrude above the normal streambed elevation.
- Wingwalls are used where the side slopes of the channel are unstable, where an outlet is skewed to the normal channel flow, to redirect outlet velocity or to retain fill.

6.2.3.3 Safety Considerations.

Traffic shall be protected from external energy dissipators by locating them outside the appropriate "clear zone" distance per the AASHTO Roadside Design Guide or shielding them with a traffic barrier. Protection of the general public (children, bicyclists, skaters, etc.) should also be carefully considered whenever energy dissipators are located in or near parks or other public places.

6.2.3.4 Weep Holes

If weep holes are used to relieve uplift pressure, they shall be designed in a manner similar to underdrain systems.

6.2.4 Related Designs

6.2.4.1 Culverts and Storm Sewer

Culverts and storm sewer shall be designed independently of the dissipator design. The design shall be completed before the outlet protection is designed and shall include computation of outlet velocity.

6.2.4.2 Downstream Channel

Necessary downstream channel protection shall be designed concurrently with dissipator design. A channel that will receive flow from a stormwater outfall or energy dissipator that is to be installed should be analyzed and, if necessary to be stable, designed and stabilized for the distance that it may be affected by the installation of the outfall.

6.3 Design Procedures

Design procedures for energy dissipators described in this chapter, as well as additional energy dissipators, can be found in the most recent edition of HEC 14: Hydraulic Design of Energy Dissipators for Culverts and Channels.

The computer software HY-8 from the Federal Highway Administration contains an energy dissipator module that can be used to analyze most types of energy dissipators described in HEC 14.

6.4 References

- City of Lincoln Public Works and Utilities Department, 2004. *Drainage Criteria Manual.*
- City of Omaha Environmental Quality Control Division, 2014. *Omaha Regional Stormwater Design Manual.*
- Federal Highway Administration, 2005. *Hydraulic Engineering Circular No. 9, Third Edition, Debris Control Structures Evaluation and Countermeasures.*
- Federal Highway Administration, 2006. *Hydraulic Engineering Circular No. 14, Third Edition, Hydraulic Design of Energy Dissipators for Culverts and Channels.*
- Nebraska Department of Transportation, 2006. *Drainage and Erosion Control Manual.*

7. STORAGE FACILITIES

7.1 Overview

As communities grow and change through new construction, development or redevelopment, modifications in land use can affect the amounts of permeable and impermeable surfacing in a drainage basin. Increases in impermeable surface areas from roofs or pavement in streets and parking lots, for example, can affect the rate of stormwater runoff. New construction or reconstruction in a basin often increases the amount of impermeable surfacing in the basin and also peak flow downstream. These increased flows may overwhelm an existing downstream storm sewer system or cause downstream flooding.

In addition to reducing or maintaining downstream peak flows, storage of stormwater runoff provides a water quality benefit as well. Slowing and temporarily storing runoff can allow sediment and other pollutants to settle out before being discharged to a stream or other water feature.

Storage facilities can range in size from small facilities contained in parking lots or other on-site facilities to large regional facilities, lakes, and reservoirs. Unless the master planning process or regional analysis has shown that the detention requirements can be transferred to a regional facility approved by the City, on-site storage facilities to maintain or reduce existing peak flows are required. Any approved transfer or combining of detention requirements must occur within the same watershed as defined by the City's master plan. Even if detention requirements can be transferred to a regional facility, on-site facilities may still be necessary to maintain receiving stream channel stability, maintenance, and water quality.

The location of storage facilities must be carefully considered. The designer must keep in mind how the facility controls runoff within a defined basin as well as its effect on other drainage features and infrastructure within the larger urban environment. Consideration may also be given to larger stormwater storage basins being multi-use facilities. Some basins may function as sports fields when dry or ponds for parks and urban areas if they are designed to maintain a permanent pool of water.

In addition to guidance outlined in the following sections, methods and procedures for design of stormwater detention facilities can be found in Hydraulic Engineering Circular No. 22, Urban Drainage Design Manual.

7.2 Detention and Retention

Stormwater storage facilities may be referred to as detention facilities or retention facilities. Detention basins are stormwater runoff storage facilities that usually have a dry bottom except during and for a temporary period after a storm event. A detention basin may be a swale, ditch, dry pond, hard-surfaced basin, or underground facility.

Retention basins are stormwater runoff storage facilities that have a permanent pool of water and have capacity to store additional runoff when required. Retention basins are often ponds or small lakes.

Some stormwater storage basins function as water quality sedimentation basins to separate pollutants, suspended solids, and debris from stormwater. Sedimentation basins can be incorporated into the design of detention or retention basins. Chapter 8 of this manual provides guidance on sedimentation basins.

Since design principles are primarily the same for detention and retention basins, the term "storage facilities" in this manual will refer to both. The specific terms "detention" or "retention" will be used in the case where one or the other is specifically indicated.

7.2.1 Computer Programs

Routing calculations for design of storage facilities can be time-consuming and repetitive. To assist with these calculations, reservoir routing computer programs such as Hydraflow Hydrographs or the U.S. Army Corps of Engineers HEC-HMS are available. Storage facilities shall be designed and analyzed using the NRCS Curve Number method for inflow hydrograph development and Storage Indication or modified Puls method for reservoir routing calculations.

7.2.2 Plan Review

If required, the owner shall submit storage facility construction plans to the Nebraska Department of Natural Resources (NeDNR) for approval. See Section 7.5 for dam classification and requirements.

Plan submittal to the City for review and approval shall include:

- Supporting calculations for hydrologic and hydraulic analysis and design. At a minimum, supporting calculations shall include design storm inflow and outflow hydrographs, stage-storage-discharge curves, and cumulative inflow and outflow elevation curves for the design storms.
- Appropriate soil investigation (i.e., suitability for water storage, settlement potential, slope stability, and influence of groundwater) for the structure hazard classification.
- Construction plans for storage, including the outlet structure.

At the end of construction, a licensed surveyor or engineer shall submit a separate written statement to the City documenting that the grading and construction of storage facilities has been completed in conformance with the approved construction plans.

7.2.3 Ownership and Maintenance of Storage Facilities

Storage facilities in a development, along with all inlet and outlet structures and/or channels, are to be owned and maintained by the developer or a property-owners' association unless the City has approved an alternative ownership/maintenance arrangement. Because the downstream storm sewer drainage system will be designed assuming detention storage upstream, a storage facility in the storm sewer drainage system shall remain permanently functional as a storage facility site unless or until the City relieves the owner of such responsibility in writing. Documentation of the storage facility and owner maintenance responsibility will be made in permanent records such as a plat, agreement, or other record acceptable to the City.

7.3 Design Criteria

7.3.1 General Criteria

As described in Section 7.1, storage of stormwater runoff may be concentrated in regional facilities or distributed in on-site facilities throughout an urban drainage system. Regardless of their location, storage facilities shall be designed to attenuate the post-project runoff peak flow rate so that it is equal to or less than the existing 2-year, 10-year, and 100-year peak flow rates of the project. When storage of stormwater runoff is required, detention facilities should be used to attenuate the peak flow rate from developed areas. Retention may be considered case by case with prior approval by the City. The design criteria for storage facilities shall include the following:

- Release rate
- Grading and depth
- Location and downstream analysis
- Storage volume
- Outlet works

7.3.2 Release Rate

Release rates from the outlet of a storage facility shall be such that the runoff peak flow rate at the downstream property line or downstream limit of a proposed project is equal to or less than the existing peak flow rate for the 2-year, 10-year, and 100-year discharges. Upon meeting these criteria, runoff from intermediate storm return periods can be assumed to be adequately controlled.

7.3.3 Storage Volume

The storage volume of a facility shall be adequate to attenuate the runoff peak flow rate at the downstream property line or downstream limit of the proposed project so that it is equal to or less than the existing peak flow rate for the 2-year, 10-year, and 100-year storms. Routing calculations must be provided to demonstrate that the storage volume is adequate. If the storage facility will also be used for water quality, the storage volume required to attenuate the runoff peak flow rate shall be provided in addition to the water quality control volume (WQCV). See Chapter 9 of this manual for additional information on treatment of the WQCV. If sedimentation during construction causes loss of storage volume, design dimensions shall be restored before completion of the project.

7.3.4 Grading and Depth

Storage facilities shall be designed and constructed to meet the following grading and depth criteria.

- Side slopes shall be no steeper than 4:1 (horizontal to vertical).
- The top width of any embankment shall be no narrower than 14 feet.
- Traversable vehicle access for maintenance purposes shall be provided from public right-of-way.
- The bottom area of storage facilities shall be sloped at a minimum of 1% to a centralized low flow channel. The low flow channel shall be sloped at a minimum of 0.5% from the inlet to the outlet of the storage facility.
- Storage facilities that fall under the jurisdiction of the Nebraska Dam Safety Program shall be reviewed and permitted by NeDNR.

7.3.5 Outlet Works

Outlet works selected for storage facilities shall include a principal spillway and an emergency overflow. The discharge from a principal spillway must be released in a nonerosive manner and can be controlled through a combination of drop inlets, pipes, weirs, orifices, chutes, and channels. Slotted-riser-pipe outlets are sometimes used (typically for water quality treatment) but may be prone to clogging problems if not properly designed and protected. Storage facilities shall be designed to pass all required design storms without allowing flow to enter the emergency overflow. Outlet works that provide control for a range of stormwater runoff events, including those smaller than the 2-year design storm, are preferred.

The emergency overflow crest elevation shall be set a minimum of one foot above the maximum water surface elevation for the 100-year design storm being conveyed through the primary spillway. The emergency overflow shall, at minimum, be designed to convey the 100-year discharge with one foot of freeboard above the maximum water surface elevation for the 100-year design storm being conveyed entirely through the emergency overflow. For large storage facilities, selecting a flood magnitude for sizing the emergency overflow shall be consistent with the potential threat to downstream life and property if the basin embankment were to fail. Large storage facilities that fall under the jurisdiction of the Nebraska Dam Safety Program may also have more stringent requirements for the emergency overflow. The emergency overflow for a storage facility shall be armored or protected from erosion to prevent failure of the facility during large events.

Outlet works must operate without requiring attendance or operation. The outlet works for storage facilities shall be designed to drain temporarily stored runoff within 72 hours. If the storage facility will also be used for water quality, minimum time requirements to drain the WQCV from Chapters 8 and 9 of this manual shall be adhered to.

7.3.6 Location and Downstream Analysis

Although storage facilities are designed to control the discharge of stormwater runoff at the outlet works, consideration of the timing of these discharges from the proposed facility and other facilities in the same basin can be critical to the function of the overall stormwater system. The City may require the discharges of the proposed facility to be routed through the downstream stormwater system to ensure that peak discharges from the storage basin do not cause adverse effects downstream.

For developments that discharge directly into or very near major receiving waters (e.g., major rivers), delaying the peak and extending the receding limb of the hydrograph may result in a higher peak on the major drainageway or receiving water. If a routing analysis of the entire drainage basin shows that a storage facility would have adverse effects on the overall stormwater system and all downstream stormwater infrastructure is sized appropriately to convey runoff for the 100-year storm from the proposed project conditions, and all areas in the basin will have similar runoff timing, the City may consider an exemption of these storage facility requirements.

7.4 General Hydraulic Procedure

For the design of storage facilities, a stage-storage-discharge analysis is used, routing the inflow hydrograph through the facility with different basin and outlet geometry until the desired outflow hydrograph is achieved. A general procedure for the design of storage facilities follows. Additional information on this procedure, preliminary storage estimates, detailed hydraulic principles for outlet works, stage/storage and stage/discharge relationships can be found in the most recent edition of the Hydraulic Engineering Circular No. 22: Urban Drainage Design Manual.

1. Compute the inflow hydrograph for stormwater runoff for the 2-year, 10-year, and 100-year design storms using the NRCS Unit Hydrograph method described in Chapter 2: Hydrology. Both existing and post-development hydrographs are required.
2. Perform preliminary calculations to estimate storage requirements for the hydrographs from Step 1.
3. Determine the physical dimensions necessary to hold the estimated storage volume from Step 2, including freeboard. The maximum storage requirement calculated from Step 2 shall be used.
4. Size the outlet works. The estimated peak stage will occur for the estimated volume from Step 2; the outlet works shall be sized to convey the allowable discharge at this stage.
5. Perform routing calculations using inflow hydrographs from Step 1 to check the preliminary design using storage routing equations or an appropriate computer program. If any of the routed post-development runoff peak discharges from the 2-year, 10-year, or 100-year design storms exceed the corresponding existing runoff peak discharges or if the peak stage varies from the estimated peak stage from Step 4, revise the estimated volume and basin geometry and return to Step 3.
6. Design the emergency overflow with established freeboard requirements.
7. Evaluate the downstream effects of storage facility releases to ensure that the routed hydrograph does not cause downstream flooding.
8. Evaluate the outlet works and emergency overflow exit velocities and provide channel and bank stabilization as needed to prevent erosion downstream.

7.5 Safe Dams Act

National responsibility for the promotion and coordination of dam safety lies with the Federal Emergency Management Agency (FEMA). The provisions of the Federal Dam Safety Act are administered by NeDNR through the Nebraska Dam Safety Program.

State of Nebraska regulations define a dam as an artificial barrier with the ability to impound water that a) is 25 feet or greater in height from the maximum storage elevation to the downstream toe of the embankment or b) has a maximum storage volume of 50 acre-feet or more (including surcharge storage). Further information on embankments that may function as a dam should be obtained from NeDNR.

NeDNR classifies dams as indicated below:

- High Hazard Dam: A dam located in areas where failure or misoperation would likely result in the loss of human life. Failure may cause serious damage to homes, industrial or commercial buildings, four-lane highways, or major railroads. Failure may cause shallow flooding of hospitals, nursing homes, or schools.
- Significant Hazard Dam: A dam located in areas where failure or misoperation of the dam would result in no probable loss of human life but could result in major economic loss, environmental damage, or disruption of lifeline facilities. Failure may result in shallow flooding of homes and commercial buildings or damage to main highways, minor railroads, or important public utilities.
- Low Hazard Dam: A dam located in areas where failure would likely result in no probable loss of human life and in low economic loss. Failure may damage storage buildings, agricultural land, and county roads.
- Minimal Hazard Dam: A dam located in areas where failure or misoperation would likely result in no economic loss beyond the cost of the structure itself and losses would be principally limited to the owner's property.

Storage facilities that fall under the jurisdiction of the NeDNR must be designed, reviewed, permitted, and constructed in accordance with the Nebraska Dam Safety Program. An owner proposing a storage facility shall submit documentation of compliance with the Nebraska Dam Safety Program or documentation why the facility does not fall under NDNR jurisdiction.

7.6 Maintenance Considerations

Proper design of storage facilities must take long-term maintenance requirements into account. To provide for acceptable performance and function, storage facilities shall be designed to minimize maintenance problems typical of urban detention facilities and address:

- Weed growth
- Sedimentation control and removal
- Protection from blockage of outlet structures
- Litter accumulation
- Maintenance vehicle access
- Grass and vegetation overgrowth
- Bank stabilization
- Provisions for outlet structures allowing complete drainage of retention basins for maintenance or inspection
- Maintenance of fences and perimeter plantings

7.7 Protective Treatment

Protective treatment may be required to prevent entry to facilities that present a hazard to children or others. Fences and/or a safety bench may be required where one or more of the following conditions exist:

- Rapid stage increases would limit possibility of escape.
- Water depths either exceed 2.5 ft for more than 24 hours or are permanently wet.
- Large and/or deep facilities.
- A low-flow watercourse or ditch passing through the detention area has a depth greater than 5 feet or a flow velocity greater than 5 feet per second.

In some cases, it may be advisable to fence the watercourse or ditch rather than the detention area. Fencing should be considered for normally dry storage facilities with design depths in excess of 2.5 ft for 24 hours, unless the area is within a fenced, limited access facility.

7.8 Trash Racks and Safety Grates

Trash racks and safety grates may be required for large storage facilities. Trash racks trap large debris well away from the entrance to the outlet works so that they will not clog the critical portions of the outlet. They also trap debris in such a way that simplifies removal. Well-designed trash racks serve these purposes without interfering significantly with the hydraulic capacity of the system.

Safety grates at inlets keep people and large animals out of confined conveyance structures. Their use should be evaluated, along with hydraulic forces and clogging potential, to assure that effective flow is maintained. Grating should not be installed at the outlet of a confined conveyance structure as it may cause clogging or hamper rescue efforts.

Further information on trash racks and safety grates can be found in the Mile High Flood District's *Urban Storm Drainage Criteria Manual.*

7.9 References

- City of Lincoln Public Works and Utilities Department, 2004. *Drainage Criteria Manual.*
- City of Omaha Environmental Quality Control Division, 2014. *Omaha Regional Stormwater Design Manual.*
- Federal Highway Administration, 2009. *Hydraulic Engineering Circular No. 22, Third Edition, Urban Drainage Design Manual.*
- Nebraska Department of Transportation, 2006. *Drainage and Erosion Control Manual.*
- Mile High Flood District (formerly the Urban Drainage Flood Control District), 2016. *Urban Storm Drainage Criteria Manual.*

8. EROSION AND SEDIMENT CONTROL

8.1 Purpose and Scope

This chapter provides criteria for measures that should be taken for construction site stormwater discharges to meet the requirements of the Federal Clean Water Act, the Nebraska Environmental Protection Act, and City ordinances adopted to meet state and federal requirements. Through implementation of the guidelines in this chapter, including development of a Stormwater Pollution Prevention Plan (SWPPP), adverse water quality impacts associated with erosion and sedimentation can be prevented or minimized.

Requirements for Construction Activity SWPPPs are in Section 8.2. The remainder of this chapter embodies a range of guidelines, criteria, and alternatives for meeting the preparation and implementation requirements of the SWPPP. Section 8.3 covers SWPPP Design Considerations and Best Management Practice (BMP) selection. Section 8.4 addresses Erosion and Sediment Control BMP, and Section 8.5 addresses Good Housekeeping BMPs.

The guidelines in this section are consistent with *National Pollutant Discharge Elimination System (NPDES) General Permit Number NER160000 for Stormwater Discharges from Construction Sites to Waters of the State of Nebraska* (issued September 30, 2016).

8.1.1 General Information for SWPPPs

A SWPPP is more than just a sediment and erosion control plan. It is a comprehensive, written document that describes the pollution prevention practices and activities that will be used during each phase of construction. It describes the site and each major phase of the planned activity, the roles and responsibilities of contractors, and the inspection schedules and logs. It is also a place to document changes and modifications to the construction plans and associated stormwater pollution prevention activities.

1. The SWPPP must be implemented either prior to or concurrent with the initiation of construction activity. SWPPP activities must be maintained throughout the period construction activities are ongoing until final site stabilization is achieved. A current and updated copy of the SWPPP must be retained at the construction site where the construction is being performed or other nearby location easily accessible during normal business hours. Persons and/or subcontractors responsible for carrying out duties pursuant to the SWPPP must be properly trained and informed of their responsibilities.
2. The SWPPP shall be dynamic. If deficiencies in the plan arise during the project or differing site conditions warrant, the applicant must implement effective corrective actions that may require modification of the SWPPP.
3. The City may require modification of the SWPPP:
    a. If it is not effective in minimizing erosion or the release of stormwater pollutants from the site.
    b. If more effective procedures are available and practical.
    c. If previous experience has shown the control methods specified have proven to be inadequate in similar circumstances.
    d. To meet basin specific NDEE water quality requirements or goals.
    e. To correspond to changes in the development plan for the site.
    f. In the event of repetitive failure to adequately maintain practices.

8.1.2 Common SWPPP Objectives

For a SWPPP to be effective, it must be developed in the project planning stage and effectively applied during construction. In most cases, the most practical method of controlling erosion and the associated production and transport of sediment includes a combination of limited time of soil exposure and judicious selection of erosion control practices and sediment trapping facilities. The SWPPP should be prepared to meet the following objectives:

1. Minimize the extent and the duration of soil exposure and minimize offsite impacts to waterbodies and adjoining properties. The duration of soil exposure can be minimized through construction phasing, prompt revegetation and mulching. Grading should be completed as soon as possible and followed by permanent revegetation. As cut slopes are made and as fill slopes are brought up to grade, these areas should be revegetated. Minimizing grading of large or critical areas during the seasons of maximum erosion potential (April through September) reduces the risk of erosion.
2. Apply erosion control practices to prevent excessive sediment production. Keep soil covered to the extent practicable with temporary or permanent vegetation or mulch. Special grading methods such as roughening a slope on the contour or tracking with a cleated dozer may be used. Other practices include diversion structures to divert surface runoff from exposed soils and grade stabilization structures to control surface water. "Gross" erosion in the form of gullies must be prevented by these water control devices.
3. Apply perimeter sediment control practices to protect the disturbed area from offsite runoff and to prevent sedimentation damage to areas below the construction site. This principle relates to using practices that effectively isolate the construction site from surrounding properties and especially to controlling sediment once it is produced and preventing its transport from the site. Generally, sediment can be retained by two methods: (a) filtering runoff as it flows through an area and (b) impounding the sediment-laden runoff for a period of time so that the soil particles settle out. Diversions, dikes, sediment traps, vegetative and structural sediment control measures can be used to control sediment. These measures may be temporary or permanent, depending on whether they will remain in use after construction is complete. The best way to control sediment, however, is to prevent erosion.
4. Keep runoff velocities low and retain runoff on the site. The removal of existing vegetative cover and the resulting increase in impermeable surface area during construction will increase both the volume and velocity of runoff. These increases must be considered when providing for erosion control. Keeping slope lengths short and gradients low and preserving natural vegetative cover can keep stormwater velocities low and limit erosion hazards. Runoff from the development should be safely conveyed to a stable outlet using storm drains, diversions, stable waterways, or similar measures. Conveyance systems should be designed to withstand the velocities of projected peak discharges. These facilities should be operational as soon as possible.
5. Stabilize disturbed areas as soon as practicable, but in no case more than 14 days after final grade has been attained. Permanent structures, temporary or permanent vegetation, mulch, stabilizing emulsions, or a combination of these measures should be used as quickly as possible after the land is disturbed. Temporary vegetation and mulches and other control materials can be most effective when it is not practical to establish permanent vegetation or until permanent vegetation is established. Such temporary measures should be used as soon as practicable, but in no case more than 14 days after rough grading is completed if a delay is anticipated in obtaining finished grade. The finished slope of a cut or fill should be designed to be stable and easily maintained. Stabilize roadways, parking areas, and paved areas with a gravel sub-base whenever possible.

6. Implement a thorough maintenance and follow-up program. This last principle is vital to the success of the five other principles. A site cannot be effectively controlled without thorough, periodic checks of the erosion and sediment control practices. These practices must be maintained just as construction equipment must be maintained and material checked and inventoried. An example of applying this principle would be to start a routine "end of day check" to make sure that all control practices are working properly.

8.2 SWPPP Requirements for Construction Activity

Construction activity is the disturbance of one acre or more of land area and less than one acre if part of a common plan of development or sale. Prior to construction activity, a permit application must be submitted in the form of a Notice of Intent (NOI) to the Nebraska Department of Environment and Energy (NDEE) via the state's online application portal.

Submittals to the City for review should include a Stormwater Pollution Prevention Plan (SWPPP) with the information identified in this chapter, as well as a copy of the NPDES Authorization to Discharge letter from NDEE. The SWPPP must identify the appropriate Best Management Practices (BMPs) to be implemented to control erosion, sedimentation, and pollutants, such as those described in Section 8.3.

Prior to construction activity for sites less than one acre that are part of a common plan of development or sale (i.e., residential lots), an individual lot notice of intent (INOI) permit must be submitted to the City through the building permit process.

The SWPPP must be prepared and signed by a qualified individual as defined in the NDEE Construction Stormwater General Permit. Review approval or comments are scheduled to be reviewed within seven (7) calendar days after receipt of application by the City. Prior to actual initiation of the construction activity, the applicant must have received approval from both the City and NDEE.

When responsibility for stormwater discharges at a construction site changes from one entity to another, the permittee shall complete a new Construction Stormwater (CSW) NOI to NDEE via the state's online application portal. Any change in NPDES permit status should be provided to the City.

Once the construction is complete in accordance with the design standards, and the site has achieved Final Stabilization, the applicant must submit to NDEE a Notice of Termination. Final Stabilization is a condition where all soil disturbing activities at the site have been completed and a uniform perennial vegetative cover with a minimum density of 70 percent of the native background vegetative cover has been established on all non-impervious surfaces and areas not covered by permanent structures unless equivalent permanent stabilization measures have been employed (i.e., riprap, gabions, or geotextiles).

The State permit will expire with the approved Notice of Termination or with the expiration of the State of Nebraska Construction General Permit. Permits that expired with the expiration of the State permit can be extended up to one year with NDEE approval. If not extended or upon end of extension, a new permit with current information must be requested that meets current standards.

In preparing the SWPPP, individuals should review this section and those that follow. Specifically, those preparing plans should be familiar with SWPPP requirements (Section 8.2), as well as the selection and design of BMPs, and the fundamentals of the erosion process.

8.2.1 Summary of Required SWPPP Items for Construction Activity

The following is a summary of required SWPPP items for Construction Activity to be prepared in accordance with Section 8.2 and 8.3 of this chapter.

8.2.1.1 Narrative

1. **Project Description –** Briefly describes the nature and purpose of the construction activity (i.e., low-density residential, site grading for future commercial development, roadway, etc.), and the area (acres) to be disturbed.
3. **Adjacent Areas –** Describe neighboring areas such as streams, lakes, residential areas, roads, etc., that might be affected by the construction activity.
4. **Offsite Areas –** Describe any offsite construction activities that will occur (including borrow sites, waste, or surplus areas, etc.). Will any other areas be disturbed?
5. **Soils –** Briefly describe the soils on the site giving such information as soil name, erodibility, permeability, depth, texture, and soil structure.
6. **Critical Areas –** Describe areas on the site that have potentially serious erosion problems (steep slopes, channels, etc.).
7. **Construction Sequencing –** Briefly describes the anticipated sequence and timing of land disturbance activity.
8. **Temporary Erosion and Sediment Controls –** Describe the methods that will be used to control erosion and sedimentation on the site during construction, as well as temporary construction stormwater management measures that retain/detain flows or otherwise limit runoff and the discharge of pollutants from exposed areas of the construction site. Controls must meet the minimum specified requirements as found in Section 8.4 of this manual.
9. **Permanent Stabilization –** Briefly describes, including specifications, how the site will be stabilized after construction is completed.
10. **Post-Construction Stormwater Management Measures –** Describe all post-construction stormwater management measures that retain/detain flows or otherwise limit runoff and the discharge of pollutants.
11. **Controls for Prohibited Discharges** – Describe the controls to be used to prevent the following prohibited discharges:
    a. Wastewater from washout of concrete.
    b. Wastewater from the washout and cleanout of stucco, paint, form release oils, curing compounds, and other construction materials.
    c. Fuels, oils, or other pollutants used in vehicle and equipment operation and maintenance.
    d. Soaps, solvents, or detergents used in vehicle and equipment washing.
    e. Toxic or hazardous substances from a spill or other release.
12. **Offsite Vehicle Tracking Prevention** – Describes measures to minimize vehicle tracking of sediments offsite onto paved surfaces and the generation of dust.
13. **Non-Sediment Pollutant Management** – Describes construction materials, products, and waste materials expected to be stored at the construction site or supporting areas. The description should include controls and storage practices to minimize exposure of the materials to stormwater and stormwater runoff.

14. **Spill Prevention and Response Plan –** When developing a spill prevention plan, include, at a minimum, the following:
    - Note the location of chemical storage areas, storm drains, tributary drainage areas, surface waterbodies on or near the site, and measures to stop spills from leaving the site.
    - Specify how to notify the appropriate authorities to request assistance.
    - Describe the procedures for immediate cleanup for spills and proper disposal.
    - Identify personnel responsible for implementing the plan in the event of a spill.

8.2.1.2 Site Plan

1. **Vicinity Map** – A small map locating the site in relation to the surrounding area. Include any landmarks that might assist in locating the site.
2. **Indicate North** – The direction of north in relation to the site.
3. **Limits of Clearing and Grading** – Areas that are to be cleared and graded.
4. **Existing Contours** – The existing contours of the site.
5. **Final Contours** – Changes to the existing contours, including final drainage patterns.
6. **Existing Vegetation** – The existing tree lines, grassed areas, or unique vegetation.
7. **Existing Drainage Patterns** – The dividing lines and the direction of flow for the drainage areas. Include the size (acreage) of each drainage area.
9. **Site Development** – Show all improvements such as buildings, parking lots, access roads, utility roads, etc.
10. **Location of Best Management Practices** – The locations of erosion and sediment controls and stormwater management practices used on the site for all phases of construction. For phases prior to final stabilization, show known BMP locations, if possible. While the project is ongoing, amend the SWPPP as needed to reflect current site conditions.
11. **Offsite Areas** – Identify any offsite construction activities (borrow sites, waste sites, etc.). Show location of erosion controls.
12. **Detailed Drawings** – Enlarged, dimensioned drawings of such key features as sediment basin drainage structures, energy dissipators, and waterway cross-sections.
13. **Detailed Specifications** – Specifications for specific items such as seeding mix and planting schedule, filter fabric size, rock gradations, etc.
14. **Construction Sequencing** – Typically provided by the general contractor prior to project startup, this information provides specifications for the sequence of construction operations describing the relationship between the implementation and maintenance of sediment controls, including permanent and temporary stabilization and the various stages or phases of earth disturbance and construction (i.e., infrastructure, water main flushing).
15. **Documentation of Site and Activity Records** – The SWPPP must be amended to include dates when major grading activities occur, dates when construction activities temporarily or permanently cease on a portion of the site, and dates when stabilization measures are initiated.
16. **Maintenance Program** – Describes inspection schedules, spare materials needed, stockpile locations, instructions for sediment removal and disposal, and for repair of damaged structures should be provided. A clear statement defining maintenance responsibility should also be included.

8.2.1.3 Calculations

1. **Calculations and Assumptions** – Provide data for design storm used to size pipes, channels, sediment basins, and traps. Include calculations for post-development runoff, as well as any other calculations necessary to support drainage, erosion and sediment, and stormwater management systems.

8.2.2 SWPPP Development – Site Assessment and Planning

The following section describes five critical steps in the SWPPP development process that will help provide a good foundation for the SWPPP.

1. **Assess the site and proposed project** – The SWPPP should describe the undeveloped site and identify land features that can be incorporated into the final plan and natural resources that should be protected. The SWPPP is a legal, binding document and, therefore, must be followed as per design.

   a. **Visit the site** – The people responsible for site design drafting the SWPPP should conduct a thorough walk-through of the entire construction site to assess site-specific conditions such as soil types, drainage patterns, existing vegetation, and topography. Avoid copying SWPPPs from other projects to save time and money. Each construction site is unique, and visiting the site is the only way to create a SWPPP to addresses the unique conditions at that site.

   b. **Assess existing construction site conditions** – Assess the existing conditions at the construction site, including topography, drainage, and soil type. This assessment is the foundation for building the SWPPP and for developing the final site plan. In this assessment, use or create a topographic drawing that:

      i. Indicates how stormwater currently drains from the site, and identify the location of discharge points or areas.

      ii. Identifies slopes and slope lengths. The topographic features of the site are a major factor affecting erosion from the site.

      iii. Identifies soil type(s) and any highly erodible soils and the soil's infiltration capacity.

      iv. Identifies any past soil contamination at the site.

      v. Identifies natural features, including trees, streams, wetlands, slopes, and other features to be protected.

      In most cases, the site designer can compile all this information on a digitized drawing that can then be adapted to show the planned construction activity, the phases of construction, and the final site plan.

   c. **Identify receiving waters, storm drains, and other stormwater conveyance systems** – The SWPPP should clearly identify the receiving waters and stormwater systems through which stormwater from the site could flow. If the site's stormwater flows into a municipal drain system, the plan designer will need to determine the ultimate destination of that system's discharge. If the site's stormwater runs off to areas not connected to the storm drain system, the designer should consider the land's topography and then identify the waterbodies that it could reach.

   d. **Describe the construction project** – The SWPPP should briefly describe and identify the construction activity, including:

      i. Project type or function (i.e., low-density residential, industrial center, street widening)

      ii. Project location, including latitude and longitude, and section-township-range

      iii. Estimated project start and end dates

iv. Sequence and timing of activities that will disturb soils at the site
v. Size of the project
vi. Estimated total area expected to be disturbed by excavation, grading, or other construction activities, including dedicated offsite borrow and fill areas
vii. Soil types
viii. Location of other potential sources of stormwater contamination, such as asphalt and concrete plants, paint and concrete washout areas, etc.

e. **Identify pollutants and pollution sources** – Identify the pollutants and sources that are likely to be found on the site. Sediment is the main pollution of concern, but other pollutants may be found, usually in substantially smaller amounts, in stormwater runoff from construction sites. These can include nutrients, heavy metals, organic compounds, pesticides, oil and grease, bacteria and viruses, trash and debris, and other chemicals (i.e., fuel storage and/or refueling location). After identifying the pollutants and sources, be as specific as possible in the SWPPP about the BMPs that will be used to address them.

2. **Identify approaches to protect natural resources** – The SWPPP should describe methods to be used to protect and preserve any streams, wetlands, ponds, or other waterbodies that are on the property or immediately adjoining it. Riparian areas around headwater streams are especially important to the overall health of the entire river system. Contact the Nebraska Department of Environment and Energy to determine if any impaired waters designation has been placed on any adjacent streams, rivers, or waterbodies. A permittee might be subject to additional requirements to protect these waterbodies.

   Wetland areas, including bogs marshes, and sloughs, may be found in areas adjacent to rivers, streams, and lakes but may also be found in isolated places far from other surface waters. Many types of wetlands, especially saline wetlands, are protected under the Clean Water Act, and construction activities in and around these areas may require an additional permit from the U.S. Army Corps of Engineers (i.e., 404 permit). Construction site operators should make every effort to preserve wetlands and must follow local, state, and federal requirements before disturbing them or the areas around them.

3. **Assess whether there are endangered plant or animal species in the area** – The Federal Endangered Species Act protects endangered and threatened species and their critical habitat areas. In developing the assessment of the site, determine whether listed endangered species are on or near the property. Critical habitat areas are often designated to support the continued existence of listed species. The SWPPP designer will also need to determine whether critical habitat areas have been designated near the project. Contact local offices of the U.S. Fish and Wildlife Service (FWS) or the Nebraska Game and Parks Service.

4. **Assess whether there are historic sites that require protection –** The National Historic Preservation Act applies to construction activities. As with endangered species, some permits may specifically require the SWPPP designer to assess the potential impact of the stormwater discharges on historic properties. However, whether or not this is listed as a condition for permit coverage, the National Historic Preservation Act and any applicable state laws apply to the project. Contact the State Historic Preservation Officer at the Nebraska State Historical Society for more information.

5. **Develop site maps** – The final step in the site evaluation process is to document the results of the site assessment and the planned phases of construction activity on a detailed site map or maps. This includes developing site maps showing planned construction activities and stormwater practices for the various major stages of construction, protected areas, natural features, slopes, erodible soils, nearby waterbodies, permanent stormwater controls, and so on.

The permittee must keep the SWPPP and the site maps up to date to reflect changes at the site during the construction process.

a. If a marked-up site map is too full to be easily read, the SWPPP designer should date and fold it, put it in the SWPPP for documentation, and start a new one. That way, there is a good hard copy record of what has occurred onsite.

8.2.3 SWPPP Erosion and Sediment Control Requirements

1. The applicant must incorporate erosion and sediment control practices into the SWPPP and implement said practices at all locations undergoing construction activity. The erosion and sediment control practices used must consider site-specific variables, including slope, soil types, size of the project, duration of construction activities, proximity of perennial and seasonal streams, and existence of impounded waters downstream of the project. The controls used may vary from site to site, but the controls used must be effective in minimizing erosion and sediment release from the site and in protecting the water quality in the receiving stream or waterbody.
2. The existence of downstream lakes or other impounded water increases water quality concerns relative to sediment release. In these instances, more stringent erosion and sediment controls may need to be implemented.
3. The applicant must upgrade the erosion and sediment control practices used in the SWPPP and implement additional controls, if existing controls prove inadequate in minimizing erosion and sediment releases, or in protecting the water quality of the receiving stream or waterbody. The applicant must comply with City/State requests to implement additional controls to minimize erosion and sediment releases and to protect receiving waterbodies.
4. All SWPPPs submitted for approval must include the following statement: "Unless otherwise indicated, all vegetative and structural erosion and sediment control practices and stormwater management practices will be constructed and maintained according to the minimum standards and specifications of the Drainage Criteria Manual."
5. Stabilize soils properly. Where construction activities have temporarily or permanently ceased, the area must be temporarily or permanently stabilized as soon as practicable, but in no case more than 14 days.
   a. All SWPPP plans submitted for approval must include placement of the following statement, "Following soil disturbance, permanent or temporary stabilization must be completed as soon as practicable, but in no case more than 14 days to the surface of all perimeter sediment controls, topsoil stockpiles, and any other disturbed or graded areas on the project site which are not being used for material storage, or on which actual earth moving activities are not being performed." In subdivisions, this permanent or temporary stabilization must be maintained until development commences on street work or, utility work on individual lots within the subdivision.
   b. Temporary measures are necessary when an area of a site is disturbed but where activities in that area are not completed or until permanent BMPs are established. Topsoil stockpiles should also be protected to minimize any erosion from these areas. Silt fence and other sediment control measures are NOT stabilization measures.
   c. Temporary cover BMPs include:
      i. Mulches
      ii. Bonded fiber matrices (hydroseeding/mulching)
      iii. Blankets and mats

iv. Use of soil binders/tackifiers
v. Temporary or Cover Crop Seeding, combined with one of the BMPs above to protect the seed from erosion, promoting germination

d. Permanent-cover BMPs include:
   i. Permanent seeding and planting
   ii. Sodding
   iii. Channel stabilization
   iv. Vegetative buffer strips

6. Protect slopes. Protect all slopes with appropriate erosion controls. Steeper slopes, slopes with highly erodible soils, or long slopes require a more complex combination of controls. Cut and fill slopes must be designed and constructed in a manner that will minimize erosion. Slopes that are found to be eroding excessively within one year of permanent stabilization must be provided with additional slope stabilization measures until the problem is corrected. Examples of BMPs for slope stabilization include:
   a. Erosion Control Blankets
   b. Turf Reinforcement Mats
   c. Bonded Fiber Matrices (hydroseeding/mulching)
   d. Wattles (Straw or wood) may also be used as slope interruptions help control erosion on moderate to shallow slopes and should be installed on level contours spaced at 10 to 20-foot intervals. The SWPPP designer can also use diversion dikes and berms to keep stormwater off slopes. Concentrated runoff must not flow down cut or fill slopes unless contained within an adequate temporary or permanent channel, flume or slope drain structure.

7. Protect storm drain inlets. Protect all inlets that could receive stormwater from the project until final stabilization of the site has been achieved. If necessary, install protection before soil disturbing activities begin. Install inlet protection before soil-disturbing activities begin, if possible. Maintenance throughout the construction process is important. Storm drain inlet protection should be used not only for storm drains within the active construction project but also for storm drains outside the project area that might receive stormwater discharges from the project. If storm drains on private property could receive stormwater runoff from the project, coordinate with the property owners to ensure proper inlet protection. Inlet protection should be removed during winter conditions (November through March).

8. Establish perimeter controls. Maintain natural areas and supplement them with perimeter sediment controls to help stop sediment from leaving the site. Install controls on the downslope perimeter of the project (it is typically not necessary to surround the entire site with silt fence). Sediment barriers can be used to protect stream buffers, riparian areas, wetlands, adjacent public right-of-way, and neighboring private properties. They are effective only in small areas and should not be used in areas of concentrated flow. Sediment basins and traps, perimeter dikes, sediment barriers, and other measures intended to trap sediment must be constructed as a first step in any land-disturbing activity and must be made functional before upslope land disturbance takes place.

9. Retain sediment onsite and control dewatering practices. When sediment retention from a larger area is required, consider using a sediment trap or basin. These practices detain sediment-laden runoff for a period, allowing sediment to settle before runoff is discharged. Proper design and maintenance are essential to ensure that these practices are effective.

a. When a site is discharging from basins and impoundments, the site must use outlet structures that withdraw water from the surface, unless infeasible.

b. Where a large sediment basin is not practical, use smaller sediment basins and traps (or both) where feasible. At a minimum, use silt fences, vegetative buffer strips, or equivalent sediment controls for all down-gradient boundaries (and for those side-slope boundaries deemed appropriate for individual site conditions).

10. Dewatering practices as used to remove groundwater or accumulated rainwater from excavated areas.

    a. Pump muddy water from these areas to a temporary or permanent sedimentation basin or to an area completely enclosed by silt fence or other sediment retention device (i.e., sediment bag) in a flat vegetated area where discharges can infiltrate into the ground.

    b. Never discharge muddy water into storm drains, streams, lakes, or wetlands unless sediment has been removed before discharge.

11. Establish stabilized construction exits. Vehicles entering or leaving the site have the potential to track significant amounts of sediment onto streets. Identify and clearly mark one or two locations where vehicles will enter and exit the site and focus stabilizing measures at those locations. Construction exits are commonly made with crushed rock. They can be further stabilized using stone pads or concrete. No system is perfect, so sweeping/vacuuming the street regularly completes this BMP.

12. Stabilize channels and watercourses. When work in a live watercourse is performed, precautions must be taken to minimize encroachment, control sediment transport and stabilize the work area to the greatest extent possible during construction. Non-erodible material shall be used for the construction of causeways and cofferdams. Earthen fill may be used for these structures if armored by non-erodible cover materials.

    a. When live watercourse must be crossed by construction vehicles more than twice in any six-month period, a temporary stream crossing constructed of non-erodible material must be provided. The bed and banks of a watercourse must be stabilized immediately after work in the watercourse is completed.

8.2.4 Good Housekeeping Requirements

Construction projects generate large amounts of building-related waste, which can end up polluting stormwater runoff if not properly managed. The suite of BMPs described in the SWPPP must include pollution prevention practices that are designed to prevent contamination of stormwater from a wide range of materials and wastes at the site. The five principles described in this section are designed to help the SWPPP designer identify the pollution prevention practices that should be described in the SWPPP and implement at the site.

1. Provide for waste management.

    a. Design proper management procedures and practices to prevent or reduce the discharge of pollutants to stormwater from solid or liquid wastes that will be generated at the site. Practices such as trash disposal, recycling, proper material handling, and cleanup measures can reduce the potential for stormwater runoff to pick up construction site wastes and discharge them to surface waters.

    b. Design proper management procedures and practices to prevent or reduce the discharge of pollutants to stormwater from solid or liquid wastes that will be generated at the site. Practices such as trash disposal, recycling, proper material handling, and cleanup measures can reduce the potential for stormwater runoff to pick up construction site wastes and discharge them to surface waters.

2. Design proper management procedures and practices to prevent or reduce the discharge of pollutants to stormwater from solid or liquid wastes that will be generated at the site. Practices such as trash disposal, recycling, proper material handling, and cleanup measures can reduce the potential for stormwater runoff to pick up construction site wastes and discharge them to surface waters.

    a. Provide well-maintained and properly located toilet facilities. Provide for regular inspections, service, and disposal. Locate portable toilet facilities at least 20 feet away from storm drain inlets and at least 10 feet back from the edge of curb and gutter conveyance systems.

    b. Establish proper building material handling and staging areas.

3. The SWPPP must include comprehensive handling and management procedures for building materials, especially those that are hazardous and toxic. Paints, solvents, pesticides, fuels and oils, other hazardous materials, or any building materials that have the potential to contaminate stormwater should be stored indoors or under cover whenever possible, or in areas with secondary containment. Secondary containment prevents a spill from spreading across the site and includes dikes, berms, curbing, or other containment methods. Secondary containment systems should also ensure protection of groundwater.

4. Designate staging areas for activities such as fueling vehicles, mixing paints, plaster, mortar, etc. Designated staging areas will help monitor the use of materials and to clean up any spills. Training employees and subcontractors is essential to the success of this pollution prevention principle.

5. Designate washout areas.

    a. All concrete contractors and any subcontractors installing concrete must be required to use designated and marked concrete washout areas on the permitted construction site. Designate specific washout areas and design facilities to handle anticipated washout with water.

    b. Washout areas must also be provided for paint and stucco operations. Because washout areas can be a source of pollutants from leaks or spills, it is required that they be located at least 50 yards away from storm drains and watercourses.

    c. Regular inspection and maintenance are important for these BMPs. If there is evidence that contractors are dumping materials into drainage facilities or if the washout areas are not being used regularly, the SWPPP designer must consider posting additional signage, relocating the facilities to more convenient locations, or providing training to workers and contractors.

6. Establish proper equipment/vehicle fueling and maintenance practices.

    a. If offsite fueling and maintenance is not feasible, create an onsite fueling and maintenance area that is clean and dry. Onsite fuel storage tanks must be double walled. The onsite fueling area should have a spill kit, and staff should know how to use it. If possible, conduct vehicle fueling and maintenance activities in a covered area; outdoor vehicle maintenance is a potentially significant source of stormwater pollution. Significant maintenance on vehicles and equipment should be conducted offsite.

    b. Clearly designate vehicle/equipment service areas away from drainage facilities and watercourses to prevent stormwater run-on and runoff.

7. Develop a Spill Prevention and Response Plan. A Spill Prevention and Response Plan is required for the SWPPP to addresses fueling, maintenance, or storage areas on the site. The plan must comply with the requirements of the City, and Nebraska Department of Environment and Energy (NDEE) Title 126, Chapter 18-Rules and Regulations Pertaining to the Management of Wastes. If the permittee knows or has reason to believe that oil or hazardous substances were released at the facility and could enter Waters of the State or any of the outfall discharges authorized by the permit, it shall be the duty of the present property owner, occupant, or person responsible to notify the City and NDEE of an illicit discharge in the following manner:
   a. Hazardous substances. In the event such illicit discharge contains hazardous substances, emergency response agencies shall immediately be notified of the discharge by calling 911. If the Hazardous Material team is needed, 911 will dispatch them to the scene. The Hazmat Team will then make the necessary contact with Local Authorities (Fire Dept, NDEE, etc.) as per the NDEE Title 126 Chapter 18 Rules and Regulations requirement.
   b. Nonhazardous substances. In the event such illicit discharge is composed entirely of nonhazardous substances, the City shall be notified in person, by phone, or by email no later than the next business day. Notifications in person or by phone shall be confirmed in writing, addressed, and mailed to the City within three business days of such notice.
   c. The plan should clearly identify ways to reduce the chance of spills, stop the source of spills, contain and clean up spills, dispose of materials contaminated by spills, and train personnel responsible for spill prevention and response. The plan should also specify material handling procedures and storage requirements and ensure that clear and concise spill cleanup procedure are provided and posted for areas in which spills may potentially occur.
8. When developing a spill prevention plan, include, at a minimum, the following:
   a. Note the locations of chemical storage areas, storm drains, tributary drainage areas, surface waterbodies on or near the site, and measures to stop spills from leaving the site.
   b. Specify how to notify the appropriate authorities to request assistance.
   c. Describe the procedures for immediate cleanup for spills and proper disposal.
   d. Identify personnel responsible for implementing the plan in the event of a spill.

8.3 Best Management Practice (BMP) Selection

This section provides a decision-making process that can be used to select best management practices (BMPs) to control erosion and sedimentation. It also provides principles for the selection of BMPs for "good housekeeping" on a construction site.

8.3.1 Steps in Selection of Control Measures

1. **Identify Control Method(s) –** On any construction site, the objective in erosion and sediment control is to prevent offsite sedimentation damage. Three basic methods are used to control sediment transport from construction sites: runoff control, soil stabilization, and sediment control. Controlling erosion (runoff control and soil stabilization) should be the first line of defense. Controlling erosion is effective for small disturbed areas, such as single lots or small areas of a development that do not drain to a sediment trapping facility. Sediment trapping facilities should be used on large developments where mass grading is planned, where it is impossible or impractical to control erosion, and where sediment particles are relatively large. Runoff control and soil stabilization should be used together where soil properties and site topography make the design of sediment trapping facilities impractical. Cost-effective erosion and sediment control typically include a combination of vegetative and structural erosion and sedimentation control measures.
2. **Identify Problem Areas –** Potential erosion and sediment control problem areas should be identified. Areas where erosion is to be controlled will usually fall into categories of slopes, graded areas, or drainageways. Slopes include graded rights-of-way, stockpile areas, and all cut and fill slopes. Graded areas include all stripped areas other than slopes. Drainageways are areas where concentrations of water flow naturally or artificially and the potential for gully erosion is high.
3. **Identify Required Strategy –** The third step in erosion and sediment control planning is to develop a strategy that can be taken to resolve the problem. For example, if a cut slope is to be protected from erosion, the strategies may include protecting the ground surface, diverting water from the slope, or shortening the slope. Any combination of the above can be used. If no rainfall except that which falls on the slope has the potential to cause erosion and if the slope is relatively short, protecting the soil surface is often all that is required to resolve the problem.
4. **Select Specific Control Measures –** The final step in erosion and sediment control planning can be accomplished by selecting and adapting specific control measures that accomplish the strategy developed in Step 3. Items to consider when selecting a final BMP are as follows:
   - **Timing –** Consider the life span of the needed BMP based on the phase of construction. BMP selection will vary during construction phases. A short-term, temporary BMP would be selected for areas where construction activity has stopped for a short period of time, whereas a construction site that is nearing completion will be ready for BMPs suitable for final stabilization.
   - **Cost –** Consider material cost, add-ons, installation, maintenance, preparation costs, and any cleanup for impacts to adjacent properties should they occur.
   - **Effectiveness –** Compare effectiveness of BMPs. Use manufacturer specifications to compare engineering properties. BMP technology has improved dramatically; it is important to be familiar with new, effective techniques and products for effective erosion and sediment control.
   - **Installation –** Consider ease of installation and durability once installed.
   - **Vegetation –** Consider compatibility of BMP to foster vegetation.
   - **Operation –** Consider maintenance requirements for the various BMPs and care for establishing vegetation.

8.3.1.1 Erosion Control BMPs

Erosion prevention and control should be the primary line of defense in reducing erosion and sedimentation. Erosion control minimizes, to the maximum extent practicable, runoff from interacting with disturbed soil, thus preventing the erosion process from occurring. This can be accomplished by preserving existing vegetation, redirecting runoff around disturbed areas of the site, or preventing concentrated flows as much as possible. Erosion Control BMPs listed in Table 8-1 can be used in selecting BMPs for stabilizing exposed soils on a construction site or streambank. Refer to the appropriate selection listed in Table 8-1 for more information in Section 8.4 for each BMP.

Table 8-1 Erosion Control BMP Selection Matrix

Erosion Control BMP	Section	Protection for Slopes			Controlling Run-On	Protection for Streambanks/ Channels
		0–7%	7–15%	>15%		
Diversion Dikes	8.4.7				×	×
Temporary Fill Diversions	8.4.8				×	
Level Spreader	8.4.10				×	×
Temporary Slope Drain	8.4.11	×	×	×	×	×
Vegetative Streambank Stabilization	8.4.17					×
Temporary Seeding	8.4.19	×				
Permanent Seeding	8.4.20	×				
Sodding	8.4.21	×	×	☐		
Mulching	8.4.22	×	×	☐		☐
Soil Stabilization Blankets & Matting	8.4.23	×				×
Preservation of Natural Vegetation	8.4.24	×	×	×	×	×
Compost Blanket	8.4.28	×				
Soil Binders	8.4.30	×				

× = Designates where BMP is appropriate for use.

☐ = Designates where BMP may be applied with careful consideration of design criteria.

8.3.1.2 Sediment Control BMPs

Sediment control shall be used to prevent sediment from leaving the site during development. Sediment control is used when the displacement of soil material is unavoidable and capture is necessary. BMPs that provide sediment control are listed in Table 8-2 and can be used to help select sediment control BMPs based on slope length, drainage area, or site activity. Refer to the appropriate selection listed in Table 8-2 for more information in Section 8.4 for each BMP.

Table 8-2 Sediment Control BMP Selection Matrix

Sediment Control BMP	Section	Slope Length		Drainage Area		Site Activity	
		<100 ft	>100 ft	<5 acres	>5 acres	Construction Traffic	Enhance Settling
Stabilized Construction Entrance	8.4.2					×	
Construction Road Stabilization	8.4.3					×	
Silt Fence	8.4.4	×					
Storm Drain Inlet Protection	8.4.5			×			
Culvert Inlet Protection	8.4.6			×			
Check Dam	8.4.9		×	×			
Temporary Vehicular Crossing	8.4.12			×		×	
Turbidity Curtain	8.4.13			×	×		
Temporary Sediment Trap	8.4.14			×			×
Temporary Sediment Basin	8.4.15		×	×	×		×
Wattles	8.4.25		×				
Compost Sock	8.4.26	×		×			
Compost Berm	8.4.27	×		×			
Wheel Wash	8.4.29	×		×		×	

× = Designates where BMP is appropriate for use.

8.4 Erosion and Sediment Control Best Management Practices

This section discusses commonly used erosion and sediment control practices with specific emphasis on their definition, purpose, and where the practice would apply. **For complete design criteria, please refer to the current City of Omaha Regional Stormwater Design Manual-Chapter 9.** Use of the BMP guidelines in conjunction with the minimum standards outlined in Section 8.2 will allow the designer of the Site Map greater flexibility in selecting BMPs, while complying with the requirements necessary for approval of a SWPPP.

8.4.1 Safety Fence

8.4.1.1 Definition

A protective barrier installed to prevent access to an erosion prevention measure.

8.4.1.2 Purpose

To prohibit the undesirable use of an erosion prevention measure by the public.

8.4.1.3 Conditions Where Practice Applies

Applicable to any control measure or series of measures that can be considered unsafe by virtue of potential for access by the public.

8.4.2 Stabilized Construction Entrance

8.4.2.1 Definition

A stabilized construction entrance consists of a stabilized aggregate pad with a filter fabric under-liner located at any point where vehicular traffic will be entering or leaving a construction site to or from a public right-of-way, street, alley, sidewalk, or parking area.

8.4.2.2 Purpose

To reduce or eliminate the tracking of sediment onto public rights-of-way or streets.

8.4.2.3 Conditions Where Practice Applies

A stabilized construction entrance is required any place traffic will be leaving a construction site and move directly onto a public road or other paved area.

8.4.3 Construction Road Stabilization

8.4.3.1 Definition

The temporary stabilization of access roads, subdivision roads, parking areas, and other on-site vehicle transportation routes with aggregate immediately after grading.

8.4.3.2 Purpose

To reduce the erosion of temporary roadbeds by construction traffic during wet weather, and to reduce the erosion and subsequent regrading of permanent roadbeds between the time of initial grading and final stabilization.

8.4.3.3 Conditions Where Practice Applies

Wherever aggregate base roads or parking areas are constructed, whether permanent or temporary, for use by construction traffic.

8.4.4 Silt Fence

8.4.4.1 Definition

An entrenched, temporary sediment barrier consisting of synthetic filter fabric stretched across and attached to supporting posts. A silt fence may have wood or steel posts and may be supported by additional wire fencing.

8.4.4.2 Purpose

To decrease the velocity of sheet flows and intercept and detain small amounts of sediment from disturbed areas to prevent sediment from leaving a construction site.

8.4.4.3 Conditions Where Practice Applies

- Below disturbed areas subject to sheet and rill erosion.
- Where the size of the drainage area is no greater than one-fourth of an ac. per 100 ft. of silt fence length, the maximum slope length behind the barrier is 100 ft., and the maximum slope gradient behind the barrier is 50 percent (2:1). Multiple lines of silt fence spaced 100 ft. apart may be used.
- In areas where rock or other hard surface would not prevent the full and uniform depth anchoring of the barrier.
- Areas where standing water created by the silt fence will not cause a problem.

Silt fences shall not be used as ditch checks. Refer to Section 8.4.25, Wattles, and Section 8.4.9, Check Dams.

8.4.5 Storm Drain Inlet Protection

8.4.5.1 Definition

Involves installing a sediment filter or an excavated impounding area around a storm drain drop inlet or curb inlet.

8.4.5.2 Purpose

To prevent sediment from entering storm drainage systems prior to permanent stabilization of the disturbed area.

8.4.5.3 Conditions Where Practice Applies

Where the drainage area to an inlet is disturbed, it is not possible to temporarily divert the storm drain outfall into a trapping device and watertight blocking of the inlets is not advisable. This practice is not to be used in place of sediment trapping devices. It may be used in conjunction with storm drain diversion to help prevent siltation of pipes installed with low slope angle. There are five specific types of storm drain inlet protection practices that vary according to their function, location, drainage area, and availability of materials:

1. Excavated Drop Inlet Sediment Trap
2. Silt Fence Drop Inlet Protection
3. Block and Aggregate Drop Inlet Sediment Filter
4. Block and Aggregate Curb Inlet Sediment Filter
5. Filter Sock Curb Inlet Sediment Filter

8.4.6 Culvert Inlet Protection

8.4.6.1 Definition

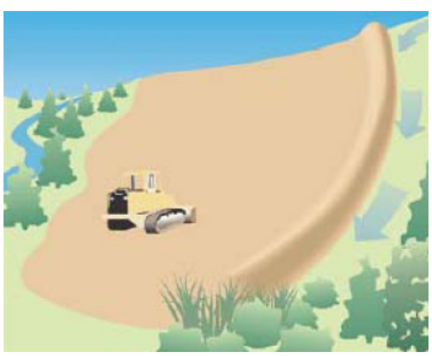
Provided by constructing a sediment filter located at the inlet to storm sewer culverts.

8.4.6.2 Purpose

To prevent sediment from entering, accumulating in, and being transferred by a culvert and associated drainage system prior to permanent stabilization and to prevent erosion at culvert inlets during the phase of a project where elevation and drainage patterns change, causing original control measures to be ineffective or in need of removal.

8.4.6.3 Conditions Where Practice Applies

Where culvert and associated drainage system is to be made operational prior to permanent stabilization of the disturbed drainage area. Different types of structures are applicable to different conditions.



8.4.7 Temporary Diversion Dike

8.4.7.1 Definition

A temporary ridge of compacted soil constructed at the top or base of a sloping disturbed area.

8.4.7.2 Purpose

To divert storm runoff from upslope drainage areas away from unprotected disturbed areas and slopes to a stabilized outlet or to divert sediment laden runoff from a disturbed area to a sediment trapping facility such as a sediment trap or sediment basin.

8.4.7.3 Conditions Where Practice Applies

Wherever stormwater runoff must be temporarily diverted to protect disturbed areas and slopes or retain sediment on-site during construction. These structures generally have a life expectancy of 18 months or less, which can be prolonged with proper maintenance.

8.4.8 Temporary Fill Diversion

8.4.8.1 Definition

A channel with a supporting ridge of soil on the lower side, constructed along the top of an active earth fill.

8.4.8.2 Purpose

To divert storm runoff away from the unprotected slope of the fill to a stabilized outlet or sediment trapping facility.

8.4.8.3 Conditions Where Practice Applies

Whenever the drainage area at the top of an active earth fill slopes toward the exposed slope, this temporary structure should remain in place for less than one week.

8.4.9 Check Dams

8.4.9.1 Definition

Small temporary aggregate dams constructed across a swale or drainage ditch.

8.4.9.2 Purpose

To reduce the velocity of concentrated stormwater flows, thereby reducing erosion of the swale or ditch. This practice also traps sediment generated from adjacent areas or the ditch itself, mainly by ponding of the stormwater runoff. Field experience has shown it to perform more effectively than silt fence in the effort to stabilize wet-weather ditches.

8.4.9.3 Conditions Where Practice Applies

Using a combination of aggregate sizes, this practice is limited to use in small open channels that drain 10 ac. or less. It should not be used in a perennial or an intermittent stream as the objective or regulated waterbody. Some specific applications include:

1. Temporary ditches or swales that, because of their short length of service, cannot receive a non-erodible lining but still need protection to reduce erosion.
2. Temporary ditches or swales that need protection during the establishment of grass linings.
3. An aid in the sediment trapping strategy for a construction site. This practice is not a substitute for major perimeter trapping measures such as a Sediment Trap or a Sediment Basin.

8.4.10 Level Spreader

8.4.10.1 Definition

An outlet for dikes and diversions consisting of an excavated depression constructed at zero grade across a slope.

8.4.10.2 Purpose

To convert concentrated runoff to sheet flow and release it uniformly onto areas stabilized by existing vegetation.

8.4.10.3 Conditions Where Practice Applies

Where there is a need to divert stormwater away from disturbed areas to avoid overstressing erosion prevention measures, and where sediment free storm runoff can be released in sheet flow down a stabilized slope without causing erosion. This practice applies only in those situations where the spreader can be constructed on undisturbed soil and the area below the level lip is uniform with a slope of 10 percent or less and is stabilized by natural vegetation. The runoff water should not be allowed to reconcentrate after release unless it occurs during interception by another measure (such as a permanent pond or detention basin) located below the level spreader.

8.4.11 Temporary Slope Drain

8.4.11.1 Definition

Consists of flexible tubing or conduit extending from the top to the bottom of a cut or fill slope.

8.4.11.2 Purpose

To temporarily conduct concentrated stormwater runoff safely down the face of a cut or fill slope without causing erosion on or below the slope.

8.4.11.3 Conditions Where Practice Applies

Temporary slope drains can be used on cut or fill slopes where there is a potential for upslope flows to move over the face of the slope causing erosion and preventing adequate stabilization.

8.4.12 Temporary Vehicular Stream Crossing

8.4.12.1 Definition

A temporary structural span installed across a flowing watercourse for use by construction traffic. Structures may include bridges, round pipes, pipe arches, or oval pipes.

8.4.12.2 Purpose

To provide a means for construction traffic to cross flowing steams without damaging the channel or banks and to keep sediment generated by construction traffic out of the watercourse.

8.4.12.3 Conditions Where Practice Applies

Generally applicable to flowing streams with drainage areas less than 1 sq. mile. Structures that must handle flow from larger drainage areas should be designed using methods that more accurately define the actual hydrologic and hydraulic parameters that will affect the functioning of the structure.

8.4.13 Turbidity Curtain

8.4.13.1 Definition

A floating geotextile material that minimizes sediment transport from a disturbed area adjacent to or within a body of water.

8.4.13.2 Purpose

To isolate an active construction area within a lake or pond and to provide sedimentation protection for a watercourse from up-slope land disturbance or from dredging or filling within the watercourse.

8.4.13.3 Conditions Where Practice Applies

Applicable to watercourses or lakes where intrusion into the areas by construction activities and subsequent sediment movement is unavoidable. This practice will not reduce the amount of disturbance from work performed in water, but it will minimize the area that is affected.

8.4.14 Temporary Sediment Trap

8.4.14.1 Definition

A temporary ponding area formed by constructing an earthen embankment with an aggregate outlet.

8.4.14.2 Purpose

To detain sediment-laden runoff from small disturbed areas long enough to allow most of the sediment to settle out.

8.4.14.3 Conditions Where Practice Applies

Below disturbed areas where the total contributing area is less than 3 ac. The sediment trap may be constructed either independently or in conjunction with a Temporary Diversion Dike, Section 8.4.7.

8.4.15 Temporary Sediment Basin

8.4.15.1 Definition

A temporary barrier or dam with a controlled stormwater release structure formed by constructing an embankment of compacted soil to capture runoff prior to discharging from the project site.

8.4.15.2 Purpose

To detain sediment-laden runoff from disturbed areas in “wet” and “dry” storage long enough to allow most of the sediment to settle out.

8.4.15.3 Conditions Where Practice Applies

Can be constructed below disturbed areas where the total contributing area is equal to or greater than 3 ac. and less than 100 ac. There must be sufficient space and appropriate topography for the construction of a temporary impoundment. It is recommended that a professional in soil erosion and sediment control, professional engineer, or licensed landscape architect design these measures, by virtue of their potential to impound large volumes of water.

8.4.16 Dust Control

8.4.16.1 Definition

The practice of reducing surface and air movement of dust during land-disturbing, demolition, and construction activities.

8.4.16.2 Purpose

To prevent surface and air movement of dust from exposed soil surfaces and to reduce the presence of airborne substances that may present health hazards, traffic safety problems, or harm animal or plant life.

8.4.16.3 Conditions Where Practice Applies

In areas subject to surface and air movement of dust where on-site and off-site damage is likely to occur if preventative measures are not taken.

8.4.17 Vegetative Stream Bank Stabilization

8.4.17.1 Definition

The use of vegetation in stabilizing streambanks.

8.4.17.2 Purpose

To protect streambanks from the erosive forces of flowing water.

8.4.17.3 Conditions Where Practice Applies

Along banks in creeks, streams, and rivers subject to erosion from excess runoff. This practice is generally applicable where bank-full flow velocity does not exceed 5 ft. per second and soils are erosion resistant. Above 5 ft. per second, structural measures are generally required.

8.4.18 Topsoiling

8.4.18.1 Definition

Methods of preserving and using the surface layer of undisturbed soil, often enriched in organic matter, to obtain a more desirable planting and growth medium.

8.4.18.2 Purpose

To provide a suitable growth medium for final site stabilization with vegetation.

8.4.18.3 Conditions Where Practice Applies

1. Where the preservation or importation of topsoil is determined to be the most effective method of providing a suitable growth medium.
2. Where the subsoil or existing soil presents the following problems:
    a. The texture, pH, or nutrient balance of the available soil cannot be modified by reasonable means to provide an adequate growth medium.
    b. The soil material is too shallow to provide an adequate root zone and to supply necessary moisture and nutrients for plant growth.
    c. The soil contains substances potentially toxic to plant growth.
3. Where high-quality turf is desirable to withstand intense use or meet aesthetic requirements.
4. Where ornamental plants will be established.
5. Only on slopes that are 2:1 or flatter unless other measures are taken to prevent erosion and sloughing.

8.4.19 Temporary Seeding

8.4.19.1 Definition

The establishment of temporary vegetative cover on disturbed areas by seeding with appropriate rapidly growing annual plants.

8.4.19.2 Purpose

To reduce erosion and sedimentation by stabilizing disturbed areas that will not be brought to final grade for a period of 30 days or more, reduce damage from sediment and runoff to downstream or off-site areas, and provide protection to bare soils exposed during construction until permanent vegetation or other erosion prevention measures can be established.

8.4.19.3 Conditions Where Practice Applies

Where exposed soil surfaces are not to be fine graded for periods longer than 14 days. Such areas include denuded areas, soil stockpiles, dikes, dams, sides of sediment basins, temporary road banks, etc. A permanent vegetative cover shall be applied to areas that will be left dormant for a period of more than 1 year.

8.4.20 Permanent Seeding

8.4.20.1 Definition

The establishment of perennial cover on disturbed areas by planting seed.

8.4.20.2 Purpose

To reduce erosion and sediment yield from disturbed areas, to permanently stabilize disturbed areas in a manner that is economical, is adaptable to site conditions, and allows selection of the most appropriate plant materials, to improve wildlife habitat and to enhance natural beauty.

8.4.20.3 Conditions Where Practice Applies

Disturbed areas where permanent, long-lived vegetative cover is needed to stabilize the soil and rough-graded areas that will not be brought to final grade for a year or more.

8.4.21 Sodding

8.4.21.1 Definition

Used to stabilize fine-graded disturbed areas by establishing permanent grass stands with sod.

8.4.21.2 Purpose

To establish permanent turf immediately, to prevent erosion and damage from sediment and runoff by stabilizing the soil surface, to reduce the production of dust and mud associated with bare soil surfaces, to stabilize drainageways where concentrated overland flow will occur, and to use as a filtering device for sediments in areas prior to achieving permanent stabilization.

8.4.21.3 Conditions Where Practice Applies

Disturbed areas that require immediate vegetative cover, or where sodding is preferred to other means of grass establishment. Locations particularly suited to stabilization with sod are waterways carrying intermittent flow, areas around drop inlets or in grassed swales, and residential or commercial lawns where quick use or aesthetics are factors.

8.4.22 Mulching

8.4.22.1 Definition

The application of plant residues or other suitable materials to the soil surface. Mulching materials include straw or hay, wood cellulose fiber, corn stalks, wood chips, grass, or aggregate.

8.4.22.2 Purpose

To prevent erosion by protecting the soil surface from raindrop impact, reducing the velocity of overland flow, and improving infiltration of runoff. Mulching is most effective when used in conjunction with vegetation. Mulch helps foster the growth of soil stabilizing vegetation by holding seeds, fertilizers, and topsoil in place, retaining moisture, and providing insulation against extreme heat and cold.

8.4.22.3 Conditions Where Practice Applies

Used any time protection of the soil surface is desired, particularly on steep slopes and critical areas such as near waterways. Used in conjunction with seeding to establish vegetation in areas where vegetation is difficult to establish or by itself to provide temporary protection of the soil surface.

8.4.23 Soil Stabilization Blankets and Matting

8.4.23.1 Definition

Involve the installation of a protective covering (blanket) or a soil stabilization mat on a prepared surface, slope, channel, or shoreline.

8.4.23.2 Purpose

To stabilize soil, to protect disturbed soil from erosive forces, to increase infiltration, and/or to conserve soil moisture to promote establishment of vegetation.

8.4.23.3 Conditions Where Practice Applies

1. Slopes and disturbed soils where mulch would have to be anchored and other methods such as crimping or tackifying are not feasible and or adequate.
2. Short steep slopes (generally 3:1 or steeper) or slopes where concentrated flows exist or where highly erodible soils are present.
3. Locations where seeding is likely to be too slow in providing adequate protective cover.
4. Critical slopes adjacent to sensitive areas, such as streams, wetlands, shorelines, and existing development.

5. Vegetated channels where the velocity of design flow/concentrated flow exceeds “allowable” velocity.
6. Areas prone to sloughing of topsoil.
7. Seedbed areas that require thermal consistency and moisture retention.
8. Streambanks where moving water is likely to wash out new plantings.
9. Areas where the forces of wind prevent standard mulching practices from remaining in place until vegetation becomes established.
10. Slope areas where underground springs are present and discharging to the surface.

8.4.24 Preserving Natural Vegetation

8.4.24.1 Definition

The practice of identifying and preserving well-established existing vegetation areas by prohibiting land-disturbing activity.

8.4.24.2 Purpose

To maintain existing stabilized ground surface and slopes to reduce erosion potential. To act to filter stormwater runoff and reduce runoff volume, improving runoff water quality and helping to reduce downstream flooding potential.

8.4.24.3 Conditions Where Practice Applies

In areas where vegetation exists as a predevelopment condition of the site. Especially beneficial for floodplains, wetlands, stream banks, and steep slopes. In areas where erosion prevention measures are difficult to establish, install, or maintain; in areas planned for later phased construction activity; and in areas where no construction activity will occur.

8.4.25 Wattles

8.4.25.1 Definition

Tube-shaped erosion prevention devices filled with straw, flax, rice, coconut fiber, or compost material. Also called fiber logs or fiber rolls. Rolls are wrapped in UV-degradable polypropylene netting or 100-percent biodegradable material, depending on longevity requirements.

8.4.25.2 Purpose

To act as a temporary erosion and sediment control barrier. To help slow, filter, and spread overland flows, which, in turn, reduce erosion and minimize rill and gully development. To improve receiving water quality by filtering runoff and capturing sediments. The effects of long or steep slopes can be addressed with wattles installed in combination with straw mulch, erosion prevention blankets, hydraulic mulches, or soil stabilization blankets and matting for slope stabilization.

8.4.25.3 Conditions Where Practice Applies

In areas of low shear stress. Along sidewalks to prevent sediment from bare lots from washing onto sidewalks and streets. Placed in front of drain inlets to prevent sediment from entering the stormwater system.

8.4.26 Compost Socks

8.4.26.1 Definition

A mesh tube filled with composted material that is placed perpendicular to sheet flow runoff to prevent erosion and retain sediment in disturbed areas.

8.4.26.2 Purpose

To provide a three-dimensional filter that retains sediment and other soluble pollutants while allowing filtered water to continue to flow on and around construction sites.

8.4.26.3 Conditions Where Practice Applies

In disturbed areas where unconcentrated stormwater runoff occurs. Compost socks can be used on a steeper slope application if they are spaced closely or used in combination with other BMPs.

Where drainage areas of 0.25 ac. per 100 ft. of compost sock are not exceeded and where flow does not exceed one cu. ft. per second but should not be used in close proximity to a body of water.

Compost socks are typically spaced along the length of the slope as follows (CalTRANS, 2012):

1. 10 ft. on center for slopes steeper than 2:1 (horizontal:vertical)
2. 15 ft. on center for slopes from 2:1 to 4:1 (horizontal:vertical)
3. 20 ft. on center for slopes from 4:1 to 10:1 (horizontal:vertical)
4. 50 ft. on center for slopes flatter than 10:1 (horizontal:vertical)

Compost sock(s) can be used:

1. For perimeter sediment control,
2. On compacted or frozen soils,
3. On slopes up to 2:1 (horizontal:vertical),
4. In sensitive environmental areas where disruption of vegetated root systems or of wildlife migration should be avoided (US EPA, 2012.)

8.4.27 Compost Berm

8.4.27.1 Definition

A dike, trapezoidal in cross section, composed of compost.

8.4.27.2 Purpose

Placed perpendicular to sheet flow runoff to prevent erosion and retain sediment in disturbed areas.

8.4.27.3 Conditions Where Practice Applies

On construction sites with relatively small drainage areas, with slopes up to 2:1 (horizontal:vertical). In steeper slope applications, compost berms can be stacked behind each other along the slope or used in combination with other BMPs. Do not install near water or storm inlet.

8.4.28 Compost Blanket

8.4.28.1 Definition

A layer of loosely applied compost or composted material placed on disturbed areas to prevent erosion and retain sediment.

8.4.28.2 Purpose

To assist in intercepting precipitation and increase infiltration and evapotranspiration of water. To act as a buffer to absorb rainfall energy, thereby reducing soil compaction and erosion while maintaining soil permeability until temporary or permanent vegetation has established.

8.4.28.3 Conditions Where Practice Applies

1. Where land-disturbing activities have ceased to cover open ground and prevent erosion from precipitation.
2. As a means of temporary ground cover to absorb rainfall while temporary and/or permanent vegetation is being established.

8.4.29 Wheel Wash Area

8.4.29.1 Definition

A designated area to wash vehicular or equipment wheels to prevent the transfer of mud, dust, or contaminants from leaving a construction site.

8.4.29.2 Purpose

To reduce or eliminate the tracking of sediment onto streets or other impervious areas thereby reducing the opportunity for sediment to enter storm systems and waterways.

8.4.29.3 Conditions Where Practice Applies

Whenever construction entrance road stabilization (refer to Section 8.4.2) activities do not prevent the tracking of construction site mud, dust, or contaminants onto a public road or other paved area.

8.4.30 Soil Binders

8.4.30.1 Definition

Emulsion materials applied to exposed soil surfaces to penetrate the top soil and bind the soil particles together.

8.4.30.2 Purpose

To temporarily stabilize soils and prevent water and wind erosion of exposed soils at construction sites.

8.4.30.3 Conditions Where Practice Applies

Sprayed onto disturbed areas that require short-term protection. Typically used in areas where vegetation cannot be established, in areas where vegetation is not desired (such as soil stockpiles), or are used prior to establishment of vegetation. Often used in combination with other vegetative or perimeter BMPs to enhance erosion and sediment control.

8.5 Good Housekeeping Best Management Practices

Using the following BMPs will set the minimum criteria for control practices used within a SWPPP. Using the following guidelines in conjunction with the minimum standards outlined in previous sections will allow the designer of the SWPPP greater flexibility in selecting control practices, while complying with the requirements necessary for City ordinance requirements and State Construction General Permit requirements.

8.5.1 Construction Scheduling and Sequencing

8.5.1.1 Description and Purpose

Construction scheduling and sequencing is the development of a written plan that includes sequencing of construction activities. The schedule should include the coordination of land-disturbing activities with the installation of erosion and sediment control measures. The goal is to reduce onsite erosion and offsite sedimentation through scheduling and performing erosion and sediment control measures prior to beginning any land-disturbing activities.

8.5.1.2 Conditions Where Practice Applies

All construction projects should have proper sequencing of erosion prevention activities included in the scheduling process, especially during the rainy periods.

8.5.1.3 Implementation

1. When possible, avoid grading and soil disturbing activities in typically rainy periods.
2. Plan the project and develop the schedule showing every phase of construction. Include seasonal information establishing timeframes when rains would affect soil disturbing activities.
3. Use a schedule to plan sequential activities that support the re-stabilization of disturbed areas as soon as feasible. Sequential activities include closing current trenching prior to initiating more trenching, along with incorporating seeding and vegetation as work progresses.
4. Provide details of each BMP scheduled for implementation and use during the rainy season.
5. Include dates that have non-stormwater discharge activities such as dewatering, drilling, grinding, mortar mixing, painting, pavement cleaning, saw cutting, etc. (CASQA, 2009)
6. Schedule the stabilization activities for non-active areas to occur as soon as feasible.
7. Monitor weather forecasts.
8. Keep erosion prevention measures in place year-round to address unseasonal rainfall, wind, and vehicle tracking.
9. Schedule permanent erosion prevention measures to be performed during appropriate seasons and include establishment of vegetation during appropriate planting times.

8.5.1.4 Inspection and Maintenance

1. Verify work is proceeding according to schedule. Adjust the schedule to address any deviations in progress.
2. Maintain sediment trapping devices to keep them operational throughout the year.
3. Follow the construction sequence throughout the project and modify the schedule before any changes in construction activities are executed. Update the schedule if a site inspection indicates the need for additional erosion and sediment control.

8.5.2 Sanitary Waste Management

8.5.2.1 Description and Purpose

Proper sanitary waste management prevents the discharge of pollutants to stormwater from sanitary waste by providing convenient, well-maintained facilities, and arranging for regular service and disposal.

8.5.2.2 Conditions Where Practice Applies

Sanitary waste management practices are suitable for use at all construction sites that use temporary or portable sanitary waste systems.

8.5.2.3 Implementation

1. Only contract with a supplier of temporary sanitary waste facilities that disposes of or treats the waste in accordance with state and local requirements.
2. Locate temporary sanitary facilities away from drainage facilities, watercourses, traffic circulation, and in a convenient location.
3. When subjected to high winds or risk of high winds, secure temporary sanitary facilities to prevent overturning.
4. Do not discharge or bury wastewater within the project site.
5. Maintain sanitary facilities in good working order by a licensed service.
6. Arrange regular waste collection by a licensed hauler before facilities overflow.

8.5.2.4 Education

1. Employees, subcontractors, and suppliers will be educated on sanitary waste storage, disposal procedures, and potential dangers to humans and the environment from sanitary wastes. Maintain sediment trapping devices to keep them in operational conditions throughout the year.
2. A continuing education program will indoctrinate new employees.

8.5.2.5 Inspection and Maintenance

1. Inspect and verify that temporary sanitary facilities are in place before the commencement of construction activities. While construction activities are under way, inspect weekly.
2. Arrange for regular waste collection.
3. If high winds are expected, secure portable sanitary facilities with spikes or weighed down to prevent overturning.

8.5.3 Solid Waste Management

8.5.3.1 Description and Purpose

Solid waste management procedures and practices have been designed to prevent or reduce the discharge of pollutants to stormwater from solid or construction waste by providing designated waste collection containers, arranging for regular disposal, and training employees and subcontractors.

8.5.3.2 Conditions Where Practice Applies

1. Solid waste generated from trees and shrubs removed during land clearing, demolition of existing structures (rubble), and building construction.
2. Scrap or surplus construction wastes and building materials including scrap metals, rubber, plastic, glass pieces, packaging materials, and masonry products.
3. Domestic wastes including food containers such as beverage cans, coffee cups, paper bags, plastic wrappers, and cigarettes.

8.5.3.3 Implementation

The following steps will be done to keep a clean site and reduce stormwater pollution:

1. Use only watertight dumpsters onsite.
2. Provide an adequate number of containers with lids or covers to keep rain out and to prevent loss of wastes when it is windy.
3. Locate waste containers with liquid in a covered area or provide secondary containment.
4. Collect site litter regularly, especially during rainy and windy conditions.
5. Arrange for regular waste collection before containers overflow.
6. Clean up immediately if a container does spill.

8.5.3.4 Education

1. Prohibit littering by employees, subcontractors, and visitors.
2. Dumpsters will be located at least 50 ft. from drainage facilities and watercourses and will not be in areas prone to flooding or ponding.
3. The contractor's superintendent will oversee and enforce proper solid waste management procedures and practices.
4. The contractor's superintendent will instruct employees and subcontractors on identification of solid waste and hazardous waste.
5. The contractor's superintendent will require that employees and subcontractors follow solid waste handling and storage procedures.
6. The contractor's superintendent will make sure that toxic liquid wastes (used oils, solvents, and paints) and chemicals (acids, pesticides, additives, curing compounds) are not disposed of in dumpsters designated for construction debris.

8.5.3.5 Inspection and Maintenance

1. The contractor's superintendent will verify that the dumpster is in before the commencement of associated activities. While activities associated with the BMP are under way, inspect weekly to verify continued BMP implementation.
2. The contractor's superintendent will inspect the construction dumpster's area regularly.
3. The contractor's superintendent will arrange for regular waste collection.

8.5.4 Material Delivery and Storage

8.5.4.1 Description and Purpose

Prevent, reduce, or eliminate the discharge of pollutants from material delivery and storage to the stormwater system, streams, or lakes by storing materials in specifically designated areas, installing secondary containment, conducting regular inspections, minimizing the storage of hazardous materials onsite, and training employees and subcontractors.

8.5.4.2 Conditions Where Practice Applies

These procedures will be used at all construction sites with delivery and storage of erodible, hazardous, oil based, or other polluting materials.

8.5.4.3 Implementation

The following steps will be taken to minimize risk.

8.5.4.3.1 Deliveries

1. Deliveries will be located away from traffic.
2. Material delivered and stored will be located near the site entrances (lot level near proposed drive way) and away from area or curb inlets, steams, or waterways.
3. If possible, delivery areas will be in locations that are to be paved.

8.5.4.3.2 Storage

1. Temporary storage will be located away from traffic.
2. An up-to-date inventory of all stored material will be kept.
3. Chemicals, drums, or bagged material will be on a pallet, inside a secondary containment (earthen dike, horse trough, or wading pool for non-reactive materials).
4. Chemicals will be kept in their original containers.
5. Storage sites shall be well marked and located away from drainage courses and systems. In no case should any liquid storage drum, tank, or other vessel (including portable toilets) be stored over storm drains.

8.5.4.3.3 Practices

1. An ample supply of appropriate spill cleanup material will be kept near storage areas and be accessible.
2. Drummed, barreled, or bagged materials will be indoors within existing structures when available.
3. Provide secondary containment for liquid storage areas. Containment can include any or all of the following:
    a. Covers or canopies
    b. Reverse grading
    c. Area berms to contain flows
    d. Drain pans or drop cloths to catch spills leaks when removing or changing fluids
    e. Spill control structures
4. A temporary containment facility will:
    a. Be designed to accommodate all pollutants amounting to or exceeding a volume of 55 gallons.
    b. Be designed to provide for a spill of 10 percent of the total stored, or 100 percent of the capacity of the largest container, whichever is greater.
    c. Be designed so that material used to contain a spill should be impervious to the stored material for a minimum contact time of 72 hrs.
    d. Be maintained free of spills or accumulated rainfall.

e. Have space between the stored material and access for emergency response.
f. Not store incompatible materials (i.e., ammonia and chlorine) in the same containment.
g. Drums, barrels, or bags stored outdoors will be tarped during non-working hours.

5. Stockpiles will be located a minimum of 50 ft. from concentrated flows in stormwater, drainage courses and unprotected inlets (area or curb)
   a. Active stockpiles will be protected in accordance with the following practices:
      i. Runoff will be controlled using berms, dikes, fiber rolls, silt fence or other appropriate controls.
   b. Inactive stockpiles will be protected in accordance with the following practices:
      i. Stockpiles will be stabilized with vegetation combines with erosion control BMPs, or tarped.
      ii. Runoff will be controlled using berms, dikes, fiber rolls, silt fence or other controls.

8.5.4.4 Education

Employees, subcontractors, and suppliers will be educated on delivery and storage procedures and their responsibilities.

8.5.4.5 Inspection and Maintenance

1. Inspections will be conducted to verify that all measures are in place and functioning.
2. Repairs and/or replacement of controls and covers as needed.

8.5.5 Street Cleaning/Sweeping

8.5.5.1 Description and Purpose

Street cleaning and maintenance includes the use of front-end loaders, shovels, and sweepers to remove tracked sediment from the streets and paved surfaces. Street cleaning prevents sediment from entering storm drains and loading sediment basins and /or receiving streams.

8.5.5.2 Conditions Where Practice Applies

Street cleaning will be done anywhere sediment is tracked from a site onto a public or private paved street or surface, typically at points of entry. Flushing sediment off the surface into the storm system will never be an acceptable practice.

8.5.5.3 Implementation

The following steps will be taken to keep the streets clean:

1. Access points will be limited and controlled; this allows cleaning efforts to be focused and effective.
2. Entrance points will be evaluated daily for track-out.
3. Visible sediment tracking will be cleaned or swept daily.
4. Kick brooms or dry sweeping will not be used; these spread dirt and generate dust.
5. If sediment is not mixed with debris or trash, it will be incorporated back into the project site.

8.5.5.4 Education

1. Employees, subcontractors, and suppliers will be educated on track-out and street cleaning procedures, and their responsibilities.
2. A continuing education program will indoctrinate new employees.

8.5.5.5 Inspection and Maintenance

The following steps will be taken:

1. Evaluate access points daily for sediment tracking.
2. When tracked or spilled sediment is found on paved surfaces, it will be removed daily. During times of heavy track-out, such as during rains, cleaning may be done several times throughout the day.
3. Unknown spills or objects will not be mixed with the sediment.
4. If sediment is mixed with other pollutants, it will be disposed of properly at an authorized landfill.

8.5.6 Vehicle and Equipment Fueling

8.5.6.1 Description and Purpose

Vehicle equipment fueling procedures and practices are designed to prevent fuel spills and leaks and to reduce or eliminate contamination of stormwater. This will be accomplished by fueling as outlined below, implementing spill controls, training employees, and requiring subcontractors to have personnel trained in proper fueling procedures.

8.5.6.2 Conditions Where Practice Applies

Fueling management practices are suitable for use at all construction sites that use fueling tanks or fueling truck systems.

8.5.6.3 Limitations

With the exception of tracked equipment such as bulldozers and large excavators, mobile construction equipment will be transported to designated fueling areas.

8.5.6.4 Implementation

1. Offsite-fueling stations will be used as much as possible.
2. "Topping-off" of fuel tanks will be discouraged.
3. Absorbent spill cleanup materials and spill kits will be available in fueling areas or on fueling trucks and will be disposed of properly after use.
4. Drip pans or absorbent pads will be used during fueling, unless the fueling is performed over an impermeable surface in a dedicated fueling area.
5. Absorbent materials will be used on small spills. Spills will not be hosed down or buried. Used adsorbent materials will be removed promptly and disposed of properly.
6. Fueling will take place in areas protected from stormwater run-on and runoff and will be located at least 50 ft. away from downstream drainage facilities and watercourses. Designated fueling areas will be identified in the SWPPP.

7. Protect fueling areas with berms or dikes to prevent run-on, runoff, and to contain spills.

8. Nozzles used in fueling will be equipped with an automatic shutoff to control drips. Fueling operations will not be left unattended.

9. All requirements will be observed for any stationary above ground storage tanks.

8.5.6.5 Education

1. Employees, subcontractors, and suppliers will be educated on vehicle equipment fueling, spill cleanup, disposal procedures, and the potential dangers to the environment.

2. A continuing education program will indoctrinate new employees.

8.5.6.6 Inspection and Maintenance

1. Vehicles and equipment will be routinely inspected for leaks. Leaks will be repaired immediately, or problem vehicles or equipment will be removed from the project site.

2. An ample supply of spill cleanup materials will be available. All fuel tanks must have secondary containment.

3. Spills will be cleaned up immediately, and contaminated soil and cleanup materials will be properly disposed of. If mobile fueling operation is used, supplier will have spill equipment and procedures on the truck. If stationary fuel storage is used, the Site Manager will have the equipment and procedures onsite.

8.5.7 Concrete Washout

8.5.7.1 Description and Purpose

A concrete washout is an area used to contain concrete and liquids resulting from cleaning of equipment used to transport and place cementitious material. The purpose of a concrete washout area is to capture and consolidate cementitious liquids and to prevent migration of the material to surface water and groundwater as to prevent environmental and human health impacts. In addition, concrete washout areas make it possible to recycle the collected liquids and solids for reuse.

8.5.7.2 Conditions Where Practice Applies

Concrete washouts should be used at all sites where equipment used to deliver, mix, or place cementitious material (including concrete, mortar, plaster, stucco, grout, or similar material) is being used and subsequently cleaned/washed onsite. Washed equipment can include, but is not limited to, concrete truck drums and chutes, hoppers, wheelbarrows, and hand tools.

8.5.7.3 Design Criteria

1. The concrete washout area should meet all local, state, and federal stormwater quality requirements.

2. The use of the washout facility should be temporary and shall be regularly monitored for capacity. The facility is to be designed with sufficient size and quantity as to contain all liquids generated by washout operations.

3. Concrete washouts should be placed near a location where concrete is being placed, in an accessible and convenient location for concrete trucks and equipment. On larger construction sites, multiple concrete washouts may be required. Signage should be used to indicate the location of the concrete washout(s). Ingress/egress to these locations shall be maintained.

4. Large washout facilities shall be constructed with stabilized construction entrances per Section 8.4.2. If applicable, construction entrances shall be graded such that water generated on the stabilized entrance shall flow toward the washout facility.

5. The washout shall not be located within 50 ft. of storm drains, open ditches/swales, or waterbodies.

6. Concrete washouts can be:

   a. Lined excavated pits in the ground or aboveground lined holding areas constructed of berms, sandbags, or straw bales

   b. Commercially manufactured prefabricated containers

8.5.7.4 Construction Guidelines

1. Below grade holding areas shall:

   a. Be lined with an impermeable liner with a minimum thickness of 10-mil.
   b. Be designed to contain all liquids generated by washout operations.
   c. Include a soil base free of rocks and sharp objects that could compromise the integrity of the liner.
   d. Have a minimum of 10 ft. by 10 ft. flat area at the bottom and a minimum of 3 ft. high sloped embankments.

2. Above-ground holding areas shall:

   a. Be lined with an impermeable liner with a minimum thickness of 10-mil.
   b. Be designed to contain all liquids generated by washout operations.
   c. Include a soil base free of rocks and sharp objects that could compromise the integrity of the liner.
   d. Hay bales shall be used along the perimeter of the facility. The plastic lining shall be wrapped over the top of the hay bale and the hay bale and liner shall be properly anchored.

3. Commercially manufactured prefabricated containers shall be used and maintained in accordance with manufacturer's directions. They should be properly sized to accommodate the flows generated by washout operations. Common container types include:

   a. Vinyl washout containers
   b. Metal washout containers
   c. Chute washout boxes
   d. Chute washout bucket and pumps

4. Concrete washout filters can be used with the intent of recycling washout materials and should be used in conjunction with a containment facility listed above.

8.5.7.5 Inspection and Maintenance

1. Concrete washout areas should be inspected regularly to verify adequate capacity and integrity of the containment. The washout area must be cleaned, or a new washout area be ready for use when the existing washout capacity reaches 75-percent full. Additionally, the following inspections shall take place weekly at a minimum:

a. Above and below-ground holding areas:

   i. Check that the liner is free of punctures, holes, and tears

   ii. Confirm that the hay bales and liner are adequately anchored.

2. For above and below grade storage facilities and other commercially manufactured containment structures:

   a. Allow liquids to evaporate or vacuum off excess liquids. Vacuumed liquids shall be treated to remove metals and reduce the pH and then conveyed/delivered to the wastewater treatment plant for treatment or other acceptable means of disposal.

   b. Remove hardened solids by breaking up solids as necessary.

   c. Dispose of hardened materials to the landfill or recycle.

3. If recycling of material is desired, the following may be considered:

   a. Cementitious material remaining inside the truck after delivery shall be taken back to the ready-mix plant for reuse in other concrete structures or dumped and allowed to hardened so it can be crushed and recycled as aggregate.

   b. When using concrete washout filters, treated wash water can be reused as wash water for subsequent equipment or as material for making new concrete. The aggregates, sands, and fines can be used on the construction site as needed or returned to the ready-mix plant for reuse in new concrete.

   c. Hardened concrete can be crushed and reused as a construction material.

8.6 SWPPP Inspection and Maintenance Procedures

8.6.1.1 Inspection and Maintenance Requirements

1. SWPPP plans submitted for approval must include placement of the following statement: "All sediment and erosion control practices will be inspected and documented at least once every 14 calendar days and after any storm event of greater than 0.5 inches of precipitation during any 24-hour period by qualified personnel. Any necessary repairs or cleanup to maintain the effectiveness of the best management practices must be made within 7 days or prior to the next storm event whenever practicable. If implementation before the next storm event is impracticable, the situation must be documented in the inspection report and alternative BMPs must be implemented as soon as possible. Failure to provide current inspection records is a violation of the SWPPP requirements and the person responsible will be subject to penalties, fines. or fees."

2. Inspections should be conducted by Qualified Personnel who are knowledgeable in the principles and practices of erosion and sediment control. Qualified personnel should possess the technical skills to assess conditions at the construction site that could impact stormwater quality and assess the effectiveness of any erosion and sediment control measures selected.

3. A log of these inspections must be retained with the SWPPP, along with photographs or other supporting information. Any deficiencies must be noted in an inspection report and include any action taken to correct the deficiency. Inspection reports and follow-up documentation regarding violations and associated corrective actions must be submitted to the City.

4. At a minimum, the inspection report must include:

   a. The inspection time and date

   b. Names and titles of personnel making the inspection

c. Weather information for the period since the last inspection (or since commencement of construction activity if this is the first inspection) including a best estimate using publicly accessible data of the beginning of each storm event, duration of each storm event, approximate amount of rainfall for each storm event (in inches), and whether any discharges occurred
d. Weather information and a description of any discharges occurring at the time of the inspection
e. Location(s) of discharges of sediment or other pollutants from the site
f. Location(s) of BMPs that need to be maintained
g. Location(s) of BMPs that failed to operate as designed or proved inadequate
h. Monitoring results if requested
i. Records of grading activity since last inspection
j. Location(s) where additional BMPs are needed that did not exist at the time of inspection
k. Corrective action that required changes to the SWPPP and the date the plan changes were implemented

5. Record keeping: The permittee must keep copies of the SWPPP, inspection records, copies of all reports required by the permit, and records of all data used to complete the NOI to be covered by the permit for a period of at least three (3) years from the date that permit coverage expires or is terminated. Records should include:
    a. A copy of the SWPPP, with any modifications
    b. A copy of the NOI and Notice of Termination (NOT) and any stormwater-related correspondence with federal, state, and local regulatory authorities
    c. Inspection forms, including the date, place, and time of BMP inspections
    d. Names of inspector(s)
    e. The date, time, exact location, and a characterization of significant observations, including spills and leaks
    f. Records of any non-stormwater discharges
    g. BMP maintenance and corrective actions taken at the site (Corrective Action Log)
    h. Any documentation and correspondence related to endangered species and historic preservation requirements
    i. Date(s) when major land-disturbing (i.e., clearing, grading, and excavating) activities occur in an area
    j. Date(s) when construction activities are either temporarily or permanently ceased in an area
    k. Date(s) when an area is either temporarily or permanently stabilized

8.7 References

- City of Lincoln Public Works and Utilities Department, 2007. *Drainage Criteria Manual.*
- City of Omaha Environmental Quality Control Division, 2014. *Omaha Regional Stormwater Design Manual.*
- Mile High Flood District (formerly Urban Drainage and Flood Control District), 2016. *Urban Storm Drainage Criteria Manual.*

9. POST-CONSTRUCTION BEST MANAGEMENT PRACTICES

9.1 Overview

The physical and chemical characteristics of stormwater runoff change as urbanization occurs. As stormwater flows across roads, rooftops, and other hard surfaces, pollutants are picked up and then discharged to streams and lakes. Additionally, the increased frequency, flow rate, duration, and volume of stormwater discharges due to urbanization can result in the scouring of rivers and streams, degrading the physical integrity of aquatic habitats, stream function, and overall water quality

The intent of this Chapter is the proper selection, design, implementation, and maintenance of post-construction stormwater quality Best Management Practices (BMPs) for new developments and redevelopment efforts. It should be noted that constructed stormwater controls may be referred to as Stormwater Treatment Facilities (STFs) and some references use these terms interchangeably. This Chapter provides information and guidance regarding the selection, design, and maintenance of selected BMPs. Implementation of BMPs is expected to reduce pollutants in stormwater runoff and receiving waters, improving the water quality and environment of the community.

9.1.1 *Clean Water Act Requirements*

The Federal Water Pollution Control Act of 1972, as amended is commonly known as the Clean Water Act and establishes minimum stormwater management requirements for urbanized areas in the United States. At the federal level, the EPA is responsible for administering and enforcing the requirements of the Clean Water Act. Section 402(p) of the Clean Water Act establishes minimum stormwater management requirements for urbanized areas in the United States. It requires urban and industrial stormwater be controlled through the National Pollutant Discharge Elimination System (NPDES) permit program. Requirements affect both construction and post-construction phases of development. As a result, urban areas must meet requirements of Municipal Separate Storm Sewer System (MS4) permits, and many industries and institutions must also meet NPDES stormwater permit requirements. MS4 permittees are required to develop a Stormwater Management Program that includes measurable goals and to implement stormwater management controls (i.e., BMPs). MS4 permittees are also required to assess controls and the effectiveness of their stormwater programs and to reduce the discharge of pollutants to the “maximum extent practicable.”

Although it is not the case for every state, the EPA has delegated Clean Water Act authority to the State of Nebraska. The State must meet the minimum requirements of the federal program. The state rules and regulations are promulgated under the Nebraska Environmental Protection Act, as amended (Neb. Rev. Stat. §81-1501 et seq).

9.2 Applicability

Post-construction stormwater program requirements shall be applicable to all construction activity and land developments including, but not limited to, site plan applications, subdivision applications, building applications, street projects, and right-of-way applications from the City, unless exempt below. These provisions apply to all portions of any common plan of development or sale that would cause the **disturbance of at least one acre of soil** even though multiple, separate, and distinct land development activities may occur at different times on different schedules.

Unless the master planning process has shown that stormwater treatment requirements can be transferred to a regional facility approved by the City, on-site BMPs are required for projects that disturb one acre of soil or more. Even if treatment requirements can be transferred to a regional facility, on-site facilities may still be necessary to protect downstream channels and the receiving stream.

The following activities are exempt from these requirements:

- Any emergency activity that is necessary for the immediate protection of life, property, or natural resources; and
- Construction activity that provides maintenance and repairs performed to maintain the original line and grade, hydraulic capacity, or original purpose of a facility.

9.3 General Planning and Design Guidelines

The following general planning and design guidelines for post-construction stormwater BMPs are recommended when developing a water quality control strategy:

- Promote natural infiltration of urban runoff by minimizing onsite impervious areas and preserving natural, broad drainageways.
- Minimize directly connected impervious areas by providing grassed buffer zones between impervious surfaces. Divert runoff from impervious areas to pervious surfaces before the flows enter surface drainageways.
- Locate BMPs in areas that avoid creating a nuisance and the need for increased maintenance.
- Provide multiple accesses to facilities to improve maintenance capabilities.
- Revegetate and/or stabilize all areas disturbed by construction activities and all drainageways created as a part of a development.
- Ensure the plantings (e.g., grass) are established before the initial owner's obligation is released and maintenance efforts begin.
- Select the appropriate option for the control objectives, specific conditions at the site, and proper implementation and maintenance for the most successful BMP.

9.3.1 Ownership and Maintenance of Best Management Practices

Proposed BMPs, along with all inlet and outlet structures and/or channels, are to be owned and maintained by the developer or a property-owners' association unless the City has approved a different ownership or maintenance arrangement. Post-construction stormwater BMPs are part of the storm drainage system and shall remain permanently functional as such unless or until the City relieves the owner of such responsibility in writing. Documentation of the BMP and owner maintenance responsibility will be made in permanent records such as a plat, agreement, or other record acceptable to the City.

9.4 Design Criteria

The City will require new and redevelopment projects to satisfy minimum site performance standards that address water quality. The methodology for calculating the Water Quality Control Volume (WQCV) and/or Water Quality Volume Discharge Rate (Qwq) is based on average daily rainfall data applied to three zones across the state (Table 9-1). From that data the runoff amount is calculated and applied to the treatment drainage area to get the WQCV or Qwq.

9.4.1 New Development

For new development sites that have a land disturbance of one acre or greater, the WQCV shall be based on the 80th percentile rainfall event, at a minimum. WQCV shall be calculated using Equation 9.1.

New development requirements apply to those areas that are being platted for development or have been platted but not built and are within the extraterritorial jurisdiction of the City:

- Example 1: A parcel that had not been platted or zoned for development (i.e., agricultural land) is being platted as a subdivision for single family residential and is greater than one acre. The subdivision would be required to meet the minimum standard set forth herein for new development.
- Example 2: Several parcels that have never been built on are being re-platted for development and the total area being re-platted is greater than one acre. The re-platted parcels would be required to follow new development standards.
- Example 3: An undeveloped parcel is being rezoned for another use and is greater than one acre. The rezoned parcel would be required to follow new development standards.
- Example 4: A warehouse has been proposed on an undeveloped parcel in an industrial area. Site disturbance is greater than one acre. The proposed development would be required to follow new development standards.

9.4.2 Redevelopment

For redevelopment sites that have land disturbance of one acre or greater, the WQCV shall be based on the 70th percentile rainfall event, at a minimum. The WQCV shall be calculated using Equation 9.1.

Redevelopment requirements apply to those areas that have been platted and built on within an urban area prior to rezoning, re-platting, preliminary platting, or issuance of a building permit for the redevelopment:

- Example 1: A parcel that included a structure that was purchased and demolished by the City or other entity was sold or deeded over to a new property owner for constructing their own building. Site disturbance is greater than one acre. This site would be required to meet the minimum standard for redevelopment.
- Example 2: A parcel with a building has been sold and is being converted into a new use with expanded parking. Site disturbance is greater than one acre. This parcel would be subject to requirements for redevelopment.

9.4.3 Percentile Rainfall Event

The percentile rainfall event varies across the state. Three regional rainfall zones have been established to support the calculation of WQCV or Qwq for MS4s in Nebraska.

Rainfall amounts by region for new and redevelopment are provided in Table 9-1. These values will be used to calculate the WQCV.

Table 9-1. Rainfall Depth (P) By Region for Defined Percentile Rainfall Events

Applicable Region	Rainfall, P	
	80th Percentile Event (New Development)	70th Percentile Event (Redevelopment)
A (West) • Scottsbluff/Gering	0.61”	0.44”
B (Central) • Hastings • Lexington	0.72”	0.53”
C (East) • Beatrice • Columbus • Fremont • Norfolk	0.83”	0.62”

9.4.4 Minimum Design Criteria

Post-construction stormwater BMPs must be sized to handle the appropriate WQCV or Qwq to properly treat stormwater. BMPs include retention-based stormwater treatment practices that typically require or encourage using infiltration, evapotranspiration, or harvest practices to control a specified volume of stormwater.

9.4.4.1 Water Quality Control Volume

Design criteria to meet minimum site performance standards for new and redevelopment are expressed as the runoff from a specified percentile rainfall event applied across the treatment drainage area. The minimum WQCV for new and redevelopment can be calculated as follows:

$$WQCV = P \times (0.05 + 0.009 \times \%Imp) \times A \times 1/12 \times 43{,}560$$

Where:

$$WQCV = Water\ Quality\ Control\ Volume, cubic\ feet$$

$$P = Rainfall\ Depth, inches$$

$$A = Treatment\ Drainage\ Area, acres$$

$$\%Imp = Maximum\ Percent\ Impervious\ Expressed\ as\ a\ Whole\ Number\ (1)$$

(1) The maximum percent imperviousness should be selected for the proposed zoning type if established by the City. If these values are not established by the zoning regulations, maximum percent imperviousness should be selected according to the percent impervious for urban districts and residential districts by average lot sizes provided in Chapter 2, Table 2.7 within the NRCS Curve Number Method procedure.

The following example illustrates use of the WQCV equation:

Example 1) A 4.2-acre parcel was purchased to construct a storage facility. The parcel is one of four in a new development that was zoned limited industrial district (M-1). Light industrial zoning has a maximum impervious percentage of 90 percent. On that parcel, 2.4 acres will be disturbed to construct the facility. An additional 0.4 acres, also zoned M-1, drain directly onto the site from adjacent property. The WQCV for the site Is calculated as follows:

$$WQCV = 0.72 \times (0.05 + 0.009 \times 90) \times (2.4 + 0.4) \times 1/12 \times 43{,}560 = 6{,}294\ cubic\ feet$$

If there are multiple land uses within the treatment drainage area, the effective maximum percent imperviousness should be weighted based on the area of each zone as a percentage of the total area.

Stormwater runoff from all disturbed areas shall be treated before leaving the site. The treatment drainage area shall include all disturbed areas on the site and upstream drainage or "run-on" unless the run-on is diverted or bypasses the disturbed site (i.e., by pipe or swale) so that BMPs are not overwhelmed. BMPs may be distributed across the site to provide the required treatment.

Additional storage in the BMP may be allowed, depending on the type of BMP selected, to address stormwater detention requirements to control runoff from larger storm events such as the 2-, 10-, or 100-year event as described in Chapter 7.

9.4.4.2 Storage Volume

Storage volume of BMPs shall be adequate to hold the WQCV. To maintain the design WQCV, proper implementation of site erosion and sediment measures is necessary to prevent clogging and failure of Structural BMPs. Phasing is also critical as Structural BMPs should typically be the last infrastructure constructed.

9.4.4.3 Water Quality Volume Discharge Rate

BMPs that are sized based on a flow rate (i.e., swales, filter strips, manufactured systems, etc.) shall use the water quality volume discharge rate (Qwq). The Qwq is the peak runoff from the design water quality volume rainfall event. This peak runoff equivalent shall be calculated using the Natural Resources Conservation Service (NRCS) Curve Number (CN) procedure. The calculation is based on the 80th percentile rainfall event depth by region, a 24-hour duration storm event, and a time of concentration of 5 minutes. The area used is the impervious surface only within the treatment drainage area.

Table 9-2 has been prepared to provide the Qwq in each Region for sites with up to 6 acres of impervious area. These values shall be used to size BMPs for the area of impervious surface within a given treatment drainage area. For sites greater than 6 acres, the designer shall use the methods and criteria specified above in a suitable model to calculate the discharge rate.

Table 9-2. Water Quality Discharge Rate (Qwq) for Selected Impervious Areas by Region

Impervious Area (Acres)	Qwq (cfs) West	Central	East	Impervious Area (Acres)	Qwq (cfs) West	Central	East	Impervious Area (Acres)	Qwq (cfs) West	Central	East
0.2	0.1	0.2	0.2	2.2	1.5	1.9	2.2	4.2	2.9	3.6	4.2
0.4	0.3	0.3	0.4	2.4	1.6	2.0	2.4	4.4	3.0	3.7	4.4
0.6	0.4	0.5	0.6	2.6	1.8	2.2	2.6	4.6	3.2	3.9	4.6
0.8	0.5	0.7	0.8	2.8	1.9	2.4	2.8	4.8	3.3	4.1	4.8
1.0	0.7	0.8	1.0	3.0	2.1	2.5	3.0	5.0	3.4	4.2	5.0
1.2	0.8	1.0	1.2	3.2	2.2	2.7	3.2	5.2	3.6	4.4	5.2
1.4	1.0	1.2	1.4	3.4	2.3	2.9	3.4	5.4	3.7	4.6	5.4
1.6	1.1	1.4	1.6	3.6	2.5	3.0	3.6	5.6	3.8	4.7	5.6
1.8	1.2	1.5	1.8	3.8	2.6	3.2	3.8	5.8	4.0	4.9	5.8
2.0	1.4	1.7	2.0	4.0	2.7	3.4	4.0	6.0	4.1	5.1	6.0

9.4.4.4 Infiltration and Release Rates

For facilities that function just for water quality control, the WQCV will be stored for a duration between 24 and 40 hours. For facilities that combine water quality control with flood control, the runoff from the design storms for the flood control criteria shall be "stacked" on top of the WQCV. In this case, the facility shall be drained within 72 hours. These types of facilities may be required to have multi-stage control structures to control runoff from the WQCV, as well as the flood control design storms. Refer to Chapter 7 for further guidance.

For BMPs that are designed for subsurface storage (e.g., pervious pavements, underground stormwater chambers, etc.), the subsurface storage must hold the WQCV for the required period and release or infiltrate into the underlying soil.

Infiltration tests shall be done to determine the local infiltration rates if infiltration is a critical part of the Structural BMP facility. An underdrain is needed if the infiltration rate is inadequate or if infiltration is not desired, as well as for maintenance and cleanout purposes.

9.5 Platting and Site Plan Review

Land development that meets the land disturbance criteria of this memorandum must address storm water runoff quality through the use of BMPs. BMPs shall be provided for in the drainage plan for any subdivision plat, annexation plat, development agreement, subdivision agreement or other local development plan.

9.5.1 Procedures

9.5.1.1 Platting

For major subdivision applications, drainage and post-construction shall be discussed at the pre-application conference. This would be followed by an initial review of the general design at the preliminary platting stage and detailed design carrying over into final design review.

The plat applicant shall identify, through the Subdivision Agreement or other City-approved means, whether post-construction stormwater management facilities will be (1) constructed by each lot owner on their own lot (Lot Level BMPs); (2) constructed for the subdivision by the developer with reimbursement sought from individual lot builders (Neighborhood BMPs); (3) mitigated off-site at regional facilities (Regional BMPs), or (4) addressed by other means approved by the City. Any other conditions agreed to between the two parties, including inspections, maintenance, and funding of maintenance, shall be included in that agreement.

9.5.1.2 Building Permits

If Lot Level BMPs are required per the Subdivision Agreement or other agreement, then the lot builder will need to develop and have approved a drainage study, post-construction stormwater management plan, and maintenance agreement. A maintenance agreement for an individual lot shall include provisions for maintenance that shall be binding on all subsequent owners.

9.5.2 Submittals

The PCSMP submittal will include the following components: plans, calculations, certifications of permanent BMPs, ongoing inspection and maintenance of BMPs, and PCSMP submittal checklist.

9.5.2.1 Plans

Plans showing topographic survey information, along with proposed, grading, stormwater infrastructure (including BMPs), pavement, and structures, shall accompany any PCSMP submittal. Specifically, plans shall include the following information:

- Site topography including existing contours, property lines and easements, utilities, and site features such as existing water bodies, trees and shrubs, pavement and other structures
- Proposed contours
- Proposed inlets, storm sewer, culverts, and drainageways
- Proposed BMPs and/or detention facilities
- Proposed roadways, parking, building footprints, and other structures

Construction drawings shall provide a table that includes, for each BMP, (1) a location identifier, (2) the type of BMP, (3) the location for each BMP in latitude/longitude format, (4) the drainage area, and (5) the water quality volume/water quality volume discharge rate. The designer shall differentiate between the amount required by design and the amount that will be provided. Any discrepancies should be discussed with and approved by the City. The information shall be provided on drawings in a format that is consistent with the following:

BMP Identification Number	BMP Type	BMP Location (Lat/Long)	Drainage Area (Acres)	Design WQCV (cu ft) or Qwq (cfs)	WQCV (cu ft) or Qwq (cfs) Provided

9.5.2.2 Calculations

All calculations for water quality volume and water quality volume discharge rate shall be submitted to the City as part of the site development drainage study. Calculations shall be completed as described herein for the appropriate BMPs. Design criteria specific to the various BMPs shall also be shown in the drainage study (i.e., calculations for drain down and infiltration).

When combining stormwater detention with BMPs, the designer shall provide calculations that address both water quality volume and stormwater detention requirements using methodology found in Chapter 7 of this manual.

BMPs shall be clearly shown on the drainage map, along with other stormwater infrastructure and drainage basin boundaries.

9.5.2.3 Certification of Permanent BMPs

Upon completion of a project, the City shall be provided a written certification, by qualified personnel, stating that the completed project is in compliance with the approved Final Drainage Plan. Qualified personnel shall be a professional civil engineer licensed in the State of Nebraska or person(s) under the direct supervision of a professional engineer licensed in the State of Nebraska.

For commercial and industrial construction, certification will be required before a Certificate of Occupancy is granted (unless authorized by the City). All applicants shall submit "as built" plans certified by a professional engineer licensed in the State of Nebraska once final construction is completed. A final inspection by the City of all post-construction BMPs shall be required before a Certificate of Occupancy will be issued or any public infrastructure is accepted.

9.5.2.4 Ongoing Inspection and Maintenance of BMPs

A maintenance agreement will be required by the developer or builder for proposed BMPs. The maintenance agreement shall include provisions that outline regular maintenance activity, and a schedule of periodic inspections by the Owner or Designees. Inspection frequency shall be consistent with the design criteria manual used and generally includes quarterly inspections during the first year of establishment following construction and annually thereafter.

The Owner or Designees providing routine inspections shall document all inspections and maintenance and repair needs to ensure compliance with the requirements of the agreement and the plan. The agreement shall allow access to City personnel for inspection and maintenance should the owner default in their responsibilities with the intent to invoice the owner for said work, if needed. The Owner shall provide the City information about inspections and maintenance upon request.

9.5.2.5 PCSMP Submittal Checklist

A PCSMP checklist shall be submitted with design plans and be recorded by the City with the project record. The PCSMP checklist can be provided by the City and may be used for reference by developers, designers, and builders.

9.5.3 Off-Site Stormwater Mitigation

In some cases, it may not be practicable to provide the required treatment within project limits due to various constraints such as site limitations, costs, or other obstacles. If shown by the Owner that it is not practicable, off-site mitigation may be allowed at the discretion of the City.

Offsite mitigation may be provided by a private landowner in a City-approved stormwater treatment facility or within a City-approved publicly owned stormwater treatment facility provided the proposed mitigation location meets the following minimum criteria.

- A drainage study confirms that the proposed mitigation location provides excess stormwater treatment that is not required to provide treatment for the drainage area.
- The excess treatment capacity in the proposed mitigation location is not already providing mitigation of required stormwater treatment for another development or redevelopment project.
- The owner of the proposed mitigation location maintains or enters into a maintenance agreement that shall be binding on all subsequent owners and includes all required inspection and maintenance requirements for stormwater treatment practices.

Offsite mitigation requires additional documentation, tracking of water quality debits/credits and an additional fee structure to fund any available BMPs. For these reasons offsite mitigation may or may not be available so the City should be consulted to determine if offsite mitigation is available.

9.6 Post-Construction Stormwater BMPs

BMPs shall be designed using an approved design guidance manual that provides minimum design criteria and considerations. A selection of regional design guides is recommended for design within the City. The most recent versions of the following design guides and manuals are approved for general use in the design of BMPs:

- City of Omaha, "Omaha Regional Stormwater Design Manual – Chapter 8: Stormwater Best Management Practices"
- City of Lincoln, "Drainage Criteria Manual - Chapter 8: Stormwater Best Management Practices"

- NDOR, "Drainage and Erosion Control Manual – Chapter 3: Stormwater Treatment within MS4 Communities"
- Mile High Flood District (formerly Urban Drainage and Flood Control District), "Urban Storm Drainage Criteria Manual, Volume 3: Best Management Practices"

The designer is encouraged to adopt one design guide/manual for use on a project to the extent practicable. Other approved design guides and manuals may be used if design criteria for the desired BMP are not provided in the primary design guide/manual. Any variances from these manuals will require approval of the City. The City may evaluate the suitability of other types of BMPs not referenced in the approved design guides and manuals on a case-by-case basis.

The designer shall discuss the use of the alternative design guidance manuals before starting design along with any variance in BMP design. The designer shall also discuss other requirements for stormwater management within the City including the potential need for stormwater detention. Where one manual conflicts with another, the Engineer shall use sound, cost-effective design practices to resolve the issue. The following minimum design standards are provided to help resolve some identified conflicts.

9.6.1 *BMP Selection*

Each design guidance manual includes a unique selection of BMPs and what is included in one may not be included in another. Furthermore, two manuals may use different names for BMPs with the same or similar function. The function, criteria, and considerations of a specific BMP is what shall be used to determine its use by a design engineer. Table 9-3 provides a general comparison of the types of BMPs included in the approved design guidance manuals.

Table 9-3. BMP Design Guidance for Various Regulatory Agencies

BMP Type	Omaha	Lincoln	NDOR	UDFCD
Vegetated Filter Strip	X		X	X
Grass Swale	X		X	X
Infiltration Trench			X	
Infiltration Basin			X	
Bioretention Basin	X	X	X	X
Media Filter			X	
Sand Filter				X
Extended Dry Detention	X	X	X	X
Wet Detention Ponds	X	X	X	X
Stormwater Wetland	X	X	X	X
Underground Detention		X		X
Pervious Pavement	X	X	X	X
Proprietary Structural Treatment Controls	X		X	X
Green Roofs	X	X		X
Soil Conditioning	X			

NOTE: All BMPs must be sized using WQCV or Qwq design criteria provided in Section 9.4 of this Chapter.

9.7 Maintenance of Controls

BMPs located on private property shall be owned and operated by the owner(s) of the property on which the BMP is located; unless the City agrees in writing that a person or entity other than the Owner shall own or operate such BMP. As a condition of approval of the BMP, the Owner shall also maintain the BMP in perpetuity to its design capacity unless or until the City shall relieve the property owner of that responsibility in writing. The obligation to maintain the BMP shall have been memorialized on a subdivision plat, annexation plat, development agreement, subdivision agreement, or other form acceptable to the City and recorded by the City with the project records.

The City shall continue to maintain public storm sewer infrastructure including public BMPs. Each homeowner's association of a subdivision or individual lot owner shall maintain post-construction BMPs. When the City constructs public infrastructure improvements, such as with the widening of a major arterial or other public improvement, the City shall take responsibility for maintenance of the BMP unless otherwise specified in a maintenance agreement.

9.8 Landscaping

The following resources have been provided to assist in the design of landscaping for a project. It is strongly suggested that a landscape architect or designer assist with plant selection and landscape design.

- UNL Extension, *Stormwater Management: Plant Selection for Rain Gardens in Nebraska*
- UNL Extension, *Nebraska Bioretention and Rain Garden Plants Guide*
- NDOR, *Plan for the Roadside Environment*
- NDOR, *Roadside Flowers and Grasses*
- NDOR, *Roadside Vegetation Establishment and Maintenance*
- Nebraska Statewide Arboretum, Fall 2008. *The Seed*

These documents may contain other references to sources that may be helpful in plant selection and suitability for use with BMPs. Keep in mind regional difference in your selection of plants, along with differences in soil, light, and moisture within the stormwater BMP itself.

9.9 References

- City of Lincoln Public Works and Utilities Department, 2014. *Drainage Criteria Manual.*
- City of Omaha Environmental Quality Control Division, 2014. *Omaha Regional Stormwater Design Manual.*
- Iowa Department of Natural Resources, 2009. *Iowa Storm Water Management Manual.*
- Nebraska H_2O, 2015. *Final Post-Construction Stormwater Program Design Standards and Procedures Memorandum.*
- Mile High Flood District (formerly Urban Drainage and Flood Control District), 2016. *Urban Storm Drainage Criteria Manual.*