CITY AND COUNTY OF DENVER

STORM DRAINAGE DESIGN & TECHNICAL CRITERIA

DEPARTMENT OF PUBLIC WORKS
WASTEWATER MANAGEMENT DIVISION
ENGINEERING DIVISION

REVISED JANUARY 2006
Amended November 2013

This page intentionally left blank.

Relationship to Previous Versions of Denver Storm Drainage Criteria Manual

This *Denver Storm Drainage Design and Technical Criteria Manual* (DENVER CRITERIA) updates and supersedes the previous *Denver Storm Drainage Criteria Manual*, as published in 1992. A few noteworthy changes include:

November 2013 revision amends Chapter 4:

- Wholesale revision to this chapter to incorporate revised floodplain ordinance which was passed by City Council on November 4, 2013.

April 2013 revision amends Chapters 1, 14, and 15:

- The DENVER CRITERIA are adopted as a part of the Manager's *Rules and Regulations Governing Sewerage Charges and Fees and Management of Wastewater*, having been adopted and incorporated by reference in the April 2013 revised Sewerage Regulation.
- Revisions to definitions of types of projects and inclusion of Linear Projects (Construction, Rehab, and Maintenance) definitions. These new definitions are applicable for water quality only.
- Revised BMP requirements depending on type of project. Linear Construction Projects require post-construction water quality best management practices per Table 14.3, whereas Linear Rehabilitation & Linear Maintenance Projects do not require water quality.
- Inclusion of option for regional and subregional water quality treatment, pending completion of pilot project and program approval from the Colorado Department of Public Health and Environment (CDPHE).
- Inclusion of maintenance requirements for water quality facilities.
- Replace references to "Erosion & Sediment Control Permit" with "Construction Activities Stormwater Discharge Permit (CASDP)" and revises associated requirements in accordance with current Construction Activities Stormwater Manual (CASM).
- Additional cross-referencing to the Urban Drainage and Flood Control District (UDFCD) *Urban Storm Drainage Criteria Manual*, *Volumes 1-3* (DISTRICT MANUAL) as updated in 2001 and 2010 and as

may be periodically amended. Some of the cross-references are adopted and incorporated by reference into the DENVER CRITERIA; others are referenced only as guidance.

- Consolidate into chapter 15 (from various other documents previously published by the department) the requirements for construction site stormwater management and erosion control.

January 2006 revision:

- Extensive cross-referencing to the Urban Drainage and Flood Control District (UDFCD) *Urban Storm Drainage Criteria Manual*, *Volumes 1-3* (DISTRICT MANUAL) as updated in 2001 and as may be periodically amended. This has resulted in removal of many equations, tables, figures, and text from these DENVER CRITERIA and significant revision of all chapters. The purpose of this change is to ensure that the DENVER CRITERIA remain consistent with the DISTRICT MANUAL as technical changes are made to the DISTRICT MANUAL in the future and to eliminate unnecessary redundancy between the manuals.
- New inlet and street capacity charts.
- New details for detention and water quality facilities.
- New emphasis on stormwater quality and construction requirements to reflect Colorado Discharge Permit System (CDPS) requirements.
- Revised drainage and construction plan submittal checklists to improve user friendliness for developers and their engineers.
- Addition of an appendix describing commonly encountered problems to help avoid common pitfalls.

Acknowledgements

The City and County of Denver acknowledges and thanks the following individuals and organizations for their contributions to this manual.

Denver Public Works Department

Saeed Farahmandi, P.E., Co-project Director

Ted Christianson, P.E.

Alan Sorrel, P.E.

Lynn Brown-Jones

Terry Baus, P.E.

Kevin Lewis, P.E.

Dave Stever

Urban Drainage and Flood Control District

Ben Urbonas, P.E., Co-project Director

Ken Mackenzie, P.E., Project Engineer

Wright Water Engineers, Inc., Consultant Team

Jonathan Jones, P.E., Project Manager

Jane Clary, Project Coordinator/Technical Editor

T. Andrew Earles, P.E., Ph.D.

David W. Foss, P.E.

Kurt Loptien, Drafting

Joe J. Nye, P.E.

James C.Y. Guo, P.E., Ph.D.

This manual relies significantly on work previously completed by others in several existing storm drainage manuals including:

Urban Storm Drainage Criteria Manual, Volumes 1-3 (UDFCD 1999, 2001, 2010)

Denver Water Quality Management Plan (WWE et al. 2004)

Draft Arapahoe County Storm Drainage Criteria Manual (Muller Engineering 2005)

Draft Douglas County Storm Drainage Criteria Manual (Muller Engineering 2005)

This page intentionally left blank.

Acronyms

BMP	Best Management Practice
CAP	Corrugated Aluminum Pipe
CASDP	Construction Activities Stormwater Discharge Permit
CASM	Construction Activities Stormwater Manual
CDOT	Colorado Department of Transportation
CDPS	Colorado Discharge Permit System
cfs	cubic feet per second
CDPHE	Colorado Department of Public Health and Environment
CLOMR	Conditional Letter of Map Revision
CMP	Corrugated Metal Pipe
CUHP	Colorado Urban Hydrograph Procedure
CWCB	Colorado Water Conservation Board
EGL	Energy Grade Line
FEMA	Federal Emergency Management Agency
FHAD	Flood Hazard Area Delineation
FHWA	Federal Highway Administration
FIRM	Flood Insurance Rate Map
ft	feet
ft/sec	feet per second
HGL	Hydraulic Grade Line
IBC	International Building Code
in	inches
LID	Low Impact Development
LOMR	Letter of Map Revision
MDCIA	Minimizing Directly Connected Impervious Area
MS4	Municipal Separate Storm Sewer System
NOAA	National Oceanic and Atmospheric Administration
NRCS	Natural Resources Conservation Service
RCP	Reinforced Concrete Pipe
ROW	Right-of-Way
SEO	State Engineer’s Office
SWMM	Stormwater Management Model
SWMP	Stormwater Management Plan
UDFCD	Urban Drainage and Flood Control District
WQCV	Water Quality Capture Volume

This page intentionally left blank.

Table of Contents

RELATIONSHIP TO PREVIOUS VERSIONS OF DENVER STORM DRAINAGE CRITERIA MANUAL PRE-1

ACKNOWLEDGEMENTS PRE-3

ACRONYMS PRE-5

1.0 GENERAL PROVISIONS GEN-1
- 1.1 Short Title GEN-1
- 1.2 Jurisdiction GEN-1
- 1.3 Purpose and Effect GEN-1
- 1.4 Enactment Authority GEN-2
- 1.5 Amendment and Revisions GEN-2
- 1.6 Enforcement Responsibility GEN-2
- 1.7 Review and Approval GEN-2
- 1.8 Interpretation GEN-3
- 1.9 Additional Standards GEN-3
- 1.10 Waivers and Variances GEN-4
- 1.11 Use of Modeling Software and Design Spreadsheets GEN-5

2.0 DRAINAGE REPORT AND CONSTRUCTION DRAWING SUBMITTAL REQUIREMENTS SUB-1
- 2.1 Introduction SUB-1
- 2.2 Review Process SUB-1
  - 2.2.1 Subdivision Process SUB-1
  - 2.2.2 Permit Process SUB-1
  - 2.2.3 Pre-application Conference SUB-1
  - 2.2.4 Review by Referral Agencies SUB-1
  - 2.2.5 Stand-alone Drainage Report SUB-2
  - 2.2.6 Submittal Adequacy SUB-2
- 2.3 Acceptance SUB-2
  - 2.3.1 Final Drainage Report and Construction Drawings Approval Required for Construction SUB-2
  - 2.3.2 One-year Approval Period SUB-2
  - 2.3.3 Expired Acceptance SUB-2
- 2.4 Preliminary Drainage Report SUB-2
  - 2.4.1 Preliminary Drainage Report Contents SUB-3
  - 2.4.2 Preliminary Drainage Plan Contents SUB-5
- 2.5 Final Drainage Report SUB-8
  - 2.5.1 Certification Statement SUB-8
  - 2.5.2 Final Drainage Report Contents SUB-8
  - 2.5.3 Final Drainage Plan Contents SUB-11
- 2.6 Construction Drawings SUB-12
  - 2.6.1 Improvement Requirements SUB-12
  - 2.6.2 Certification SUB-12
  - 2.6.3 Construction Plan Requirements SUB-12
- 2.7 As-built Drawings and Certifications SUB-14
- 2.8 Submittal Checklists and Design Aids SUB-16

3.0 DRAINAGE POLICY POL-1
- 3.1 Introduction POL-1
- 3.2 Principles POL-1
- 3.3 Policies POL-3
  - 3.3.1 Planning POL-3
  - 3.3.2 Design POL-6
  - 3.3.3 Operation and Maintenance of Drainage Facilities POL-7

3.3.4 Irrigation Conveyance and Storage POL-8
3.3.5 Water Quality POL-10

4.0 FLOODPLAIN REGULATIONS FLD-1
4.1 Introduction FLD-1
4.2 Denver Floodplain Ordinance FLD-2

5.0 RAINFALL RF-1
5.1 Introduction RF-1
5.2 Rainfall Depth-Duration-Frequency Values RF-1

6.0 RUNOFF RO-1
6.1 Introduction RO-1
6.2 Runoff Calculation Methods RO-1
6.3 Assumptions for Storm Flow Analysis RO-2

7.0 STREETS ST-1
7.1 Introduction ST-1
7.2 Function of Streets in the Drainage System ST-1
7.3 Allowable Use of Streets for Storm Flows ST-1
7.4 Hydraulic Evaluation Techniques ST-2
7.4.1 Allowable Gutter Flow Depths and Spreads ST-3
7.4.2 Allowable Street Capacities and Assumptions for Capacity Curves ST-3
7.5 Checklist and Design Aids ST-4

8.0 INLETS IN-1
8.1 Introduction IN-1
8.2 Standard Inlets IN-1
8.3 Inlet Design IN-1
8.3.1 Hydraulic Design IN-1
8.3.2 Assumptions for Figures 8.1 and 8.2 ..... IN-2
8.3.3 Inlet Location and Spacing IN-2
8.4 Checklist and Design Aids IN-3

9.0 STORM SEWERS SS-1
9.1 Introduction SS-1
9.2 Design Storms for Sizing Storm Sewers SS-1
9.2.1 Minor Event Design Storm SS-1
9.2.2 Major Event Design Storm SS-1
9.3 Hydraulic Design SS-2
9.4 Construction Materials SS-2
9.5 Pipe Size SS-2
9.6 Vertical and Horizontal Alignments SS-3
9.7 Manholes/Cleanouts SS-4
9.8 Outlets SS-4
9.8.1 Erosion Protection at Storm Sewer Outlets SS-4
9.8.2 Safety SS-5
9.9 Checklist and Design Aids SS-5

10.0 OPEN CHANNELS OC-1
10.1 Introduction OC-1
10.2 Channel Types OC-1
10.2.1 Natural Channels OC-1
10.2.2 Grass-lined Channels OC-1
10.2.3 Concrete-lined Channels OC-2
10.2.4 Riprap or Rock Lined Channels OC-2
10.2.5 Other Channel Types OC-3
10.3 Flow Computations and Design Approach OC-3

10.4 Design Criteria for Natural Channels OC-3
10.5 Design Criteria for Artificial Channels OC-5
10.6 Design Criteria for Channel Rundowns OC-7
10.7 Retrofitting Existing Channels OC-8
10.8 Environmental Permitting OC-8
10.9 Checklist and Design Aids OC-8

11.0 HYDRAULIC STRUCTURES HS-1
11.1 Introduction HS-1
11.2 Application of Hydraulic Structures and Design Guidance HS-1

12.0 CULVERTS CUL-1
12.1 Introduction CUL-1
12.2 General Design and Hydraulic Evaluation CUL-1
12.3 Culvert Sizing Criteria CUL-1
12.4 Construction Material and Pipe Size CUL-2
12.5 Inlet and Outlet Configuration CUL-2
12.6 Velocity Considerations CUL-2
12.7 Headwater Considerations CUL-3
12.8 Structural Design CUL-3
12.9 Trash Racks CUL-3
12.10 Checklist and Design Aids CUL-3

13.0 DETENTION (STORAGE) DET-1
13.1 Introduction DET-1
13.2 Design Criteria DET-1
13.2.1 Design Storm Event Frequency DET-1
13.2.2 Sizing Methodology for Volumes and Release Rates DET-1
13.2.3 Relationship to Adjacent Properties and Structures DET-2
13.2.4 Maintenance DET-3
13.3 Detention Methods DET-3
13.4 Design Standards for Above-ground Detention Basins DET-4
13.4.1 State Engineer's Office DET-4
13.4.2 Grading Requirements DET-4
13.4.3 Use of Retaining Walls DET-4
13.4.4 Freeboard Requirements DET-5
13.4.5 Inlet Configuration DET-5
13.4.6 Trickle Channel (Low Flow) Control DET-5
13.4.7 Outlet Configuration DET-5
13.4.8 Embankment Protection/Emergency Spillway Requirements DET-6
13.4.9 Landscaping Requirements DET-6
13.4.10 Multiple Use Considerations DET-7
13.5 Design Standards for Parking Lot Detention DET-8
13.5.1 Depth Limitation DET-8
13.5.2 Outlet Configuration DET-8
13.5.3 Performance DET-8
13.5.4 Flood Hazard Warning DET-8
13.6 Design Standards for Underground Detention DET-8
13.6.1 Materials DET-9
13.6.2 Configuration DET-9
13.6.3 Inlet and Outlet Design DET-9
13.6.4 Maintenance Access DET-10
13.7 Design Standards for 100-year Runoff Retention Ponds DET-10
13.7.1 Allowable Use DET-10
13.7.2 Calculation of Retention Volume DET-10
13.7.3 Design Standards for Retention Ponds DET-11
13.8 Checklist and Design Aids DET-13

14.0 WATER QUALITY WQ-1
14.1 Introduction WQ-1
14.2 Definitions WQ-1
14.3 Basic Design Principles and Procedure WQ-4
14.4 Requirements WQ-8
14.5 Selection of BMPs WQ-10
14.6 Maintenance WQ-12
14.7 Checklist and Design Aids WQ-12

15.0 CONSTRUCTION SITE STORMWATER MANAGEMENT AND EROSION CONTROL ESC-1
15.1 Introduction ESC-1
15.2 Construction Activities Stormwater Discharge Permits ESC-1
15.2.1 Permit Triggers ESC-1
15.2.2 Basis of Project Site Size Determination ESC-2
15.2.3 Co-Permittees ESC-2
15.2.4 Transfer of Permit ESC-2
15.2.5 Term, Expiration or Suspension of Permit ESC-3
15.3 Principles and Performance Standards ESC-3
15.3.1 Principles ESC-3
15.3.2 Performance Standards ESC-4
15.4 Construction Stormwater Planning ESC-4
15.4.1 Stormwater Management Plan Requirements ESC-4
15.4.2 Professional Engineer Requirements ESC-6
15.4.3 Structural and Non-Structural Best Management Practices (BMPs) ESC-6
15.4.4 Minimum BMPs ESC-6
15.4.5 Site Specific BMP Requirements ESC-8
15.4.6 BMP Selection Criteria: ESC-9
15.4.7 Site Drawings and Installation Details ESC-9
15.4.8 Supporting Technical Information and Documents ESC-10
15.5 Responsibilities of Permittees ESC-11
15.5.1 Copy onsite ESC-11
15.5.2 SWMP Modifications, Permit Amendments ESC-11
15.5.3 Operation and Maintenance. ESC-12
15.5.4 Inspections. ESC-12
15.6 Commonly Observed Problems at Construction Sites ESC-12
15.7 Submittal Requirements ESC-12

16.0 REFERENCES REF-1
16.1 Primary References REF-1
16.2 Supplemental References REF-1

APPENDIX A. STANDARD FORMS ..... APP A-1
Standard Form SF-1. Time of Concentration ..... APP A-1
Standard Form SF-2. Storm Drainage System Design (Rational Method Procedure) ..... APP A-2

APPENDIX B. COMMONLY OBSERVED PROBLEMS IN DENVER DRAINAGE PROJECTS ..... APP B-1
Planning ..... APP B-1
General Drainage and Flooding ..... APP B-1
Public Safety ..... APP B-2
Streets, Inlets and Storm Sewers ..... APP B-2
Detention and Water Quality ..... APP B-3
Construction Sites ..... APP B-7

Tables

Table 2.1. Drawing Symbol Criteria and Hydrology Review Table SUB-7
Table 2.2. Detention Basin Summary Table to be Placed on Drainage and Construction Plan SUB-7
Table 2.3. Drainage Report Checklist SUB-16
Table 2.4. Drainage Plan Checklist SUB-18
Table 2.5. Construction Plan Checklist SUB-19
Table 3.1. Design Storms for the Minor and Major Systems POL-6
Table 3.2. Required Maintenance Easements for Drainage Facilities POL-8
Table 5.1. One-hour Point Rainfall Depths RF-1
Table 5.2. Calculation of Rainfall Durations Less than One Hour RF-2
Table 5.3. Rainfall Intensity Duration Values for Use with the Rational Method RF-3
Table 6.1. Runoff Calculation Methods Acceptable for Use in Denver RO-2
Table 6.2. Assumptions for Onsite and Offsite Storm Flow Analysis in Denver RO-3
Table 7.1. Allowable Use of Streets for Minor Storm Runoff ST-2
Table 7.2. Allowable Use of Streets for Major Storm Runoff ST-2
Table 7.3. Allowable Cross-street Flow When Cross Pans Are Allowed[1] ST-2
Table 7.4. Permitted Flow Depths for Minor Storm for 6-inch Curb and 2-percent Cross Slope ST-3
Table 8.1. Inlet Types IN-1
Table 9.1. Public Storm Sewer Size Criteria SS-3
Table 9.2. Vertical Alignment Requirements for Storm Sewers SS-3
Table 9.3. Manhole Sizes for Straight Sewers SS-4
Table 9.4. Erosion Protection at Conduit Outlets SS-5
Table 10.1. Channel Rundown Design Criteria OC-7
Table 11.1. Summary of Hydraulic Structure Types and Criteria HS-2
Table 12.1. Allowable Roadway Overtopping at Culvert Crossings CUL-2
Table 12.2. Allowable Velocities at Culvert Outlets CUL-3
Table 13.1. Detention Sizing Methodologies DET-2
Table 13.2. Maximum Allowable Unit Flow Release Rates (cfs/acre) per Tributary Area DET-2
Table 13.3. Grading Criteria for Embankments DET-4
Table 13.4. Required Retention Rainfall DET-11
Table 14.1. Collection System Basins WQ-3
Table 14.2. Development Type Summary WQ-7
Table 14.3. Permanent Stormwater BMP Requirements WQ-10
Table 14.4. Recommended Selection of Structural BMPs WQ-11

Figures

Figure 7.1. Allowable Street Capacity for Minor and Major Events ST-5
Figure 7.2. Reduction Factors for Gutter Flow ST-6
Figure 8.1. Allowable Inlet Capacity— Sump Conditions IN-4
Figure 8.2. Allowable Inlet Capacity—On Grade Conditions IN-5
Figure 8.3. Inlet Placement at Intersections IN-6
Figure 9.1. Hydraulic Properties of Circular Pipe SS-7
Figure 13.1. Pond Forebay with Dissipator DET-14
Figure 13.2. Concrete Trickle Channel Sections for Detention Basins DET-15
Figure 13.3. Typical Detention Outlet Structure DET-16
Figure 13.4. Outlet for Small On-site Detention Basin DET-17
Figure 13.5. Curb and Gutter Outlet Grate DET-18
Figure 13.6. Underground Detention Schematic DET-19
Figure 14.1. Bioretention WQ-13
Figure 14.2. Sand Filter Details for Use on Small Sites ≤ 1 Acre WQ-14

This page intentionally left blank.

1.0 GENERAL PROVISIONS

1.1 Short Title

This manual shall be known as the *City and County of Denver Storm Drainage Design and Technical Criteria Manual* (hereafter called DENVER CRITERIA) as adopted and incorporated by referenced in the *Public Works Rules and Regulations Governing Sewerage Charges and Fees and Management of Wastewater* (hereafter called DENVER RULES and REGULATIONS).

1.2 Jurisdiction

These DENVER CRITERIA shall apply to all land within the incorporated areas of the City and County of Denver (Denver), including any public lands. These DENVER CRITERIA shall apply to all facilities constructed on Denver rights-of-way (ROW), easements dedicated for public use, and to all privately owned and maintained drainage facilities, including, but not limited to, detention facilities, storm sewers, inlets, manholes, culverts, swales, and channels; or as otherwise approved.

1.3 Purpose and Effect

The purpose of these DENVER CRITERIA is to provide requirements and guidance for the selection, design and maintenance of publicly and privately owned, and publicly or privately constructed, drainage, and flood control, and water quality facilities. The DENVER CRITERIA are adopted to protect the public health, safety and welfare and minimize adverse impacts to the environment.

Presented in these DENVER CRITERIA are the **minimum** design and technical criteria for the analysis and design of storm drainage facilities for both water quantity and water quality during and following construction.

All new development or redevelopment projects, construction or grading projects, demolition, or any disturbance of existing ground surface shall comply with these DENVER CRITERIA. Hereinafter, such projects are referred to as “development and redevelopment projects” except as the terms are used differently in chapter 14 pertaining to post-construction water quality.[1] All projects submitted for approval under the provisions of the DENVER RULES and REGULATIONS shall provide adequate analysis and design of drainage systems for both water quantity and water quality during and following construction in accordance with these DENVER CRITERIA. Implementing structural controls that go beyond the minimum is encouraged.

[1] Unfortunately, different usage of the terms is the outcome of the difference between industry practice to refer broadly to development/redevelopment projects and the use of the term in the City’s discharge permit establishing water quality requirements for projects of a particular size.

The applicant may request approval of alternatives to the provisions of these DENVER CRITERIA. The applicant shall have the burden of showing that the alternative measures are, at a minimum, equivalent to the criteria contained herein. Drainage facilities in place or under construction at the time of adoption or revision of the DENVER CRITERIA shall be accepted in accordance with the criteria in effect at the time of plan approval by the City and County of Denver.

1.4 Enactment Authority

The DENVER RULES and REGULATIONS have been adopted, issued, and amended by the Denver Manager of Public Works (Manager) in accordance with the authority contained in the Charter and Chapter 56 of the Revised Municipal Code of the City and County of Denver. These DENVER CRITERIA have been adopted and incorporated by reference into the DENVER RULES AND REGULATIONS.

1.5 Amendment and Revisions

The DENVER CRITERIA may be amended as new technology is developed and/or if experience gained through the use of these DENVER CRITERIA indicates a need for revision. Revisions will be made by the Manager as an amendment to the DENVER RULES and REGULATIONS. It is the applicant's responsibility to check the Public Works page of Denver's website for amendments (www.denvergov.org/publicworks/).

1.6 Enforcement Responsibility

It shall be the duty of the Manager of Public Works to enforce the provisions of these DENVER CRITERIA in coordination with the City Attorney, as appropriate.

1.7 Review and Approval

Denver will review all drainage submittals for general compliance with these DENVER CRITERIA. An approval by Denver does not relieve the owner, engineer, or designer from responsibility for ensuring that the calculations, plans, specifications, construction and record drawings are in compliance with the DENVER CRITERIA and will accomplish the necessary or desired drainage objectives.

Urban Drainage and Flood Control District (UDFCD) may be requested to review reports and construction plans required by these DENVER CRITERIA. Where major drainageway improvements or floodplain delineation are involved or where UDFCD maintenance eligibility is anticipated, UDFCD approval will be required. To be eligible for UDFCD maintenance, the most current version of UDFCD's maintenance eligibility requirements (downloadable from www.udfcd.org) must be met.

Submittals that impact Federal Emergency Management Agency (FEMA)-designated floodplains shall be submitted to FEMA for review.

Denver may refer submittals to other agencies that have an interest or responsibility for drainage and/or water quality issues. Other review agencies may include federal and state agencies responsible for floodplains, water quality, wetlands, water rights and other stormwater related issues, as well as other impacted jurisdictions.

1.8 Interpretation

In the interpretation and application of the provisions of the DENVER CRITERIA, the following shall govern:

- In interpretation and application, the DENVER CRITERIA shall be regarded as the **minimum** requirements for the protection of the public health, safety and welfare of the residents of Denver.
- If other laws, ordinances, or regulations cover the same subject as these DENVER CRITERIA, the stricter standard shall apply.
- These DENVER CRITERIA shall not abrogate or annul any permits or approved drainage reports, construction plans, easements, or covenants issued before the effective date of these DENVER CRITERIA.

The Manager of Public Works shall have final authority to resolve any conflicting interpretation of these DENVER CRITERIA.

1.9 Additional Standards

The reader is advised to consult the reference documents listed below as well as the documents listed in Chapter 16 - References.

- UDFCD *Urban Storm Drainage Criteria Manual*, *Volumes 1-3* (hereinafter called DISTRICT MANUAL), as updated and periodically amended, including design spreadsheets and modeling software appropriate for use in Denver. The most up-to-date version of the UDFCD criteria, design spreadsheets and software may be obtained from the UDFCD website (www.udfcd.org). The DISTRICT MANUAL is considered guidance except for those provisions that are specifically adopted and incorporated by reference herein.
- City and County of Denver *Storm Drainage and Sanitary Sewer Construction Details and Technical Specifications* (hereinafter called DETAILS AND SPECIFICATIONS).
- City and County of Denver *Municipal Separate Storm Sewer System (MS4) Colorado Discharge Permit System (CDPS) Permit No. COS-000001,* and Denver's Stormwater Management and Construction Sites Programs established under this permit.
- City and County of Denver *Water Quality Management Plan* (2004 and as amended).

- City and County of Denver *Construction Activities Stormwater Manual (CASM)* provides guidance – see chapters 14 and 15 of these DENVER CRITERIA for the requirements.
- City and County of Denver *Aesthetically Enhanced Detention and Water Quality Ponds* (September 2010) and as amended.
- City and County of Denver *Storm Drainage Master Plan* (2009 and June 2010 Errata) and as amended.
- City and County of Denver *Sanitary Sewer Master Plan* (October 2009) and as amended.

See www.denvergov.org/publicworks/ for the latest versions of these and other publications posted on the Denver Public Works website.

If the State or Federal Government requires the City to impose stricter criteria, standards, or requirements, these shall apply in addition to these DENVER CRITERIA.

The DENVER CRITERIA do not supersede other regulatory requirements and do not replace permits that may be required by other regulatory agencies for some of the work covered by these DENVER CRITERIA. The property owner has the responsibility to apply for, and comply with, all requirements.

1.10 Waivers and Variances

The Manager of Public Works or his designee may authorize at his sole discretion, upon application in specific cases, such waiver or variance from the requirements of these DENVER CRITERIA, subject to terms and conditions fixed by the Manager or designee, as will not be contrary to the purposes of these DENVER CRITERIA upon a finding of infeasibility or undue hardship and where no significant deleterious effects to public safety, health, welfare and the environment will be caused by such waiver or variance. Waiver and variance requests (collectively "variance requests") will be considered on a case-by-case basis. Variance requests must be submitted to the Department of Public Works in writing, and at a minimum, must contain the following information:

1. Identify criteria for which a waiver or variance is requested.

2. Explain why the criteria cannot be met.

3. Demonstrate that no significant deleterious effects to public safety, health, welfare, and environment will be caused if wavier or variance is granted.

4. Define alternative standard(s) to meet the intent of the criteria.

5. Provide supporting documentation, necessary calculations and other relevant information supporting the request.

6. Signature and stamp upon the variance request of a licensed engineer in the State of Colorado if the request or alternative proposal includes an engineering design or consideration; and,

7. Signature of landowner or owner's authorized representative.

1.11 Use of Modeling Software and Design Spreadsheets

UDFCD computer software programs, models and spreadsheets are referenced in these CRITERIA as design aids that may be useful in designing drainage improvements. Use of these design aids is in no way a substitute for sound engineering judgment, proper engineering qualifications and common sense. Although the design aids recommended in these DENVER CRITERIA have been developed using a high standard of care, it is likely that some nonconformities, defects, bugs, and errors with the software programs will be discovered as they become more widely used. The City and County of Denver does not warrant that any version of these design aids will be error free or applicable to all conditions encountered by the designer, and the City and County of Denver shall not be held liable for their use.

This page intentionally left blank.

2.0 DRAINAGE REPORT AND CONSTRUCTION DRAWING SUBMITTAL REQUIREMENTS

2.1 Introduction

The requirements presented in this section shall be used to aid the design engineer or applicant in the preparation of drainage reports and construction drawings for stormwater management facilities. The requirements presented are the minimum necessary and will be used to determine the adequacy of all submittals to Denver.

2.2 Review Process

All development and redevelopment projects (as defined in Section 1.3) in Denver's jurisdiction shall be required to submit drainage reports, construction drawings, specifications and as-constructed information in conformance with the requirements of these DENVER CRITERIA. Complete submittal requirements (Application, General Notes, Permit, etc.) can be found on the Department of Public Works website (www.denvergov.org/publicworks/).

2.2.1 Subdivision Process

The general requirements and conditions for the subdivision of land in Denver are set forth in Chapter 50 of the Revised Municipal Code. See the Subdivision Rules and Regulations for standards and procedures for the review and approval of subdivision plats.

2.2.2 Permit Process

Any structure or other development or redevelopment which requires a building permit under the Denver Building Code may also require a Sewer Use and Drainage Permit to be issued by the Wastewater Management Division. A Sewer Use and Drainage Permit will only be issued upon conformance with requirements contained in these DENVER CRITERIA, as evidenced by approval of the Final Drainage Report (as described in Section 2.5) and Construction Drawings (as described in Section 2.6).

2.2.3 Pre-application Conference

A pre-submittal conference may be suggested in some cases and is particularly important for large developments, redevelopments or where special conditions or problems have become apparent during the development review process. The applicant shall consult with Denver for general information regarding regulations, required procedures, possible drainage problems, and specific submittal requirements for projects.

2.2.4 Review by Referral Agencies

The review and approval by others, such as state or federal agencies, other local governments, affected jurisdictions, and other referral agencies may be required for some submittals. The applicant shall be required to address referral agency comments and obtain approvals when necessary.

2.2.5 Stand-alone Drainage Report

The drainage report shall be a stand-alone document. When references are made or assumptions are based on previously approved submitted reports, the drainage report must include the appropriate excerpts, pages, tables, and maps containing the referenced information. Assumptions made in previous reports must be verified and substantiated. All submitted reports should be clearly and cleanly reproduced. Photocopies of charts, tables, nomographs, calculations, or any other referenced material must be legible.

2.2.6 Submittal Adequacy

The submittal checklist provided at the end of this chapter and the requirements specified in Sections 2.4 through 2.6 will be used by Denver to determine the adequacy of the submittal. Incomplete or absent information may result in the report being returned to the author without review. Denver reserves the right to require additional information with any submittal.

2.3 Acceptance

2.3.1 Final Drainage Report and Construction Drawings Approval Required for Construction

Acceptance of a final drainage report and construction drawings must be obtained prior to construction of any drainage improvements within Denver. Preliminary drainage reports are conceptual and are reviewed by Denver, but they do not receive a formal acceptance and cannot be used for construction. The approval of a drainage report based on submitted documents and information shall not prevent the Department of Public Works from requiring the correction of errors.

2.3.2 One-year Approval Period

Final drainage reports will be considered approved for a period of one (1) year. Construction based upon any approved drainage report must commence within this one-year period.

2.3.3 Expired Acceptance

Approved drainage reports that have exceeded the one-year period may be re-approved on a case-by-case basis. In order to be re-approved, it must be demonstrated that the report is consistent with the current DENVER CRITERIA. If new drainage concepts and standards have been developed, or if any drainage concept or pattern has changed, a new report will be required. Preliminary and Master Drainage Reports conducted for a Master Development Plan are conceptual and are not affected by the approval period.

2.4 Preliminary Drainage Report

If it is determined during the development review process that the project is of sufficient size or complexity, a preliminary drainage report may be required in advance of the final drainage report. This may also be done at the developer's request. Two copies of the preliminary drainage report, prepared

and signed by a professional engineer licensed in the State of Colorado, shall be submitted to the Department of Public Works for review.

2.4.1 Preliminary Drainage Report Contents

The purpose of the Preliminary Drainage Report is to conceptually define the nature of the proposed development or project, describe all existing conditions and propose facilities needed to conform to the requirements of these DENVER CRITERIA. The following is an outline of the minimum Preliminary Drainage Report requirements: (Note: Denver reserves the right to require additional information with any submittal.)

1. General Location and Description

    A. Location

        i. City, county, state highway and local streets within and adjacent to the site or the area to be served by the drainage improvements.

        ii. Township, range, section, ¼ section, subdivision, lot and block.

        iii. Names of surrounding developments.

    B. Description of Property

        i. General project description, including proposed land use.

        ii. Area in acres.

        iii. Ground cover (type of trees, shrubs, vegetation, hydrologic soil group, topography, and slope).

        iv. Major drainageways and drainage facilities.

        v. Existing major irrigation facilities such as ditches and canals.

        vi. History of flooding.

        vii. Easements within and adjacent to the site.

2. Major Drainage Basins and Sub-basins

    A. Major Basin Description

        i. Reference to major drainageway planning studies such as flood hazard area delineation (FHAD) reports, major drainageway master planning reports and flood insurance rate maps (FIRMs); include a copy of current FIRM showing the location of subject property.

ii. Major basin drainage characteristics, existing and planned land uses within the basin, as defined by the Planning Department.

iii. All nearby irrigation facilities within 100 feet of the property, which will influence or be influenced by the local drainage.

B. Sub-basin Description

i. Historic drainage patterns of the property in question.

ii. Onsite and offsite sub-basin characteristics.

3. Drainage Facility Design

A. General Concept

i. Drainage concept and typical drainage patterns.

ii. Compliance with offsite runoff considerations.

iii. Anticipated and proposed drainage patterns.

iv. Content of tables, charts, figures, or drawings presented in the report.

B. Specific Details

i. Flows, volumes and water quality capture volumes (WQCV).

ii. Existing stormwater conveyance and storage facilities.

iii. Proposed stormwater conveyances, storage facilities and outlet structures.

iv. Relationship to both upstream and downstream properties and impact of the development's drainage on these properties; include discussion of offsite drainage flow patterns and impact on development under existing and fully developed basin conditions as defined by the Planning Department.

v. Drainage problems encountered and solutions at specific design points.

vi. Maintenance (whose responsibility and frequency), public safety and access aspects of the drainage facilities.

vii. Compliance with other local, state and federal requirements.

viii. Structural and non-structural best management practices (BMPs) that will be part of stormwater management design.

ix. When deemed necessary by the Review Engineer, electronic update to the Denver Drainage Master Plan in a format specified by the Review Engineer.

4. Conclusions

A. Compliance with Standards

i. DENVER CRITERIA.

ii. Major Drainageway Planning Studies.

iii. DISTRICT MANUAL.

iv. Denver's Municipal Colorado Discharge Permit System (CDPS) Stormwater Permit.

v. Justification for any requested waiver.

B. Drainage Concept

i. Effectiveness of drainage design to control damage from storm runoff.

ii. Influence of proposed development on master drainage plan recommendation(s).

iii. Drainage impacts of proposed development on upstream and downstream properties.

C. Water Quality

i. Measures implemented to treat the WQCV.

5. References

Reference all criteria, master plans, and technical information used in support of concept. The Preliminary Design Report must be a stand-alone document including portions of relevant documents referenced in the report. This supporting information may be included as an appendix.

6. Appendices

Appendices should be provided, as needed, to provide supporting information for the report.

2.4.2 Preliminary Drainage Plan Contents

1. Overall Drainage Plan

A. 24" X 36" in size.

B. Boundaries of entire development or project.

C. Limits of all major basins, including offsite basins.

D. General drainage patterns and flow paths, including those entering and leaving the site.

E. Any existing or proposed major stormwater management facilities, upstream, downstream or within the site.

F. Title block, legend, P.E. stamp, North arrow, flow arrow, scale.

2. Detailed Drainage Plan

A. 24” X 36” in size at a scale of 1” = 20’ to 1”= 100’.

B. Existing (dashed or screened) and proposed (solid) contours (use NAVD 88 Datum) with a 2-foot maximum interval. The contours must extend a minimum of 100 feet beyond property lines.

C. All existing and proposed drainage facilities (e.g., detention facilities, storm sewers, swales, riprap, outlet structures, irrigation ditches, culverts, cross pans).

D. Floodplain boundary based on the most current information (e.g., FHAD, master plan, FIRM, etc.).

E. Major basin and sub-basin boundaries.

F. Any offsite feature or basin influencing development.

G. Runoff summary table. See Table 2.1 (at the end of this section).

H. Detention basin summary table. See Table 2.2 (at the end of this section).

I. Location and footprints of detention facilities.

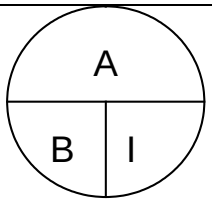
J. Include North arrow, scale, benchmark, and flow arrow.

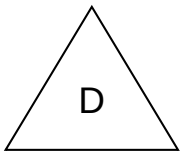
K. Legend to define map symbols. See Table 2.1 (at the end of this section).

L. Project name, address, engineering firm and seal, and date in title block in lower right corner.

M. Denver Drainage Master Plan I.D. number.

Table 2.1. Drawing Symbol Criteria and Hydrology Review Table





A = Basin Designation

B = Area in Acres

I = % imperviousness

D = Design Point Designation

Summary Runoff Table

(to be placed on Drainage Plan)

Design Point	Contributing Basin(s)	Contributing Area (acres)	2 or 5-Year Runoff (cfs)	100-Year Runoff (cfs)
x	xx	xx.xx	xx.x	xx.x

Date: July, 1992 **Revised: Jan 2006**	

Table 2.2. Detention Basin Summary Table to be Placed on Drainage and Construction Plan

	Water Surface Elevation (feet)	Volume (cubic feet or acre-feet)	Release Rate (cfs)
Water Quality Capture Volume			
10-yr + Water Quality Capture Volume			
100-yr + ½ Water Quality Capture Volume			

Date: Jan 2006 **Revised:**	

2.5 Final Drainage Report

The Final Drainage Report serves to define and expand the concepts shown in the Preliminary Drainage Report and to assure conformance to these DENVER CRITERIA. The final report may be submitted at any point during the permitting and platting process, but must be reviewed and approved prior to approval of the subdivision plat or issuance of the Sewer Use and Drainage Permit. Two copies of the report shall be submitted to the Public Works Department. Reports shall be typed and bound on 8½" X 11" paper with all pages numbered. The report shall include a cover letter presenting the design review.

2.5.1 Certification Statement

The report shall contain a certification page with the following statement:

> This report for the drainage design of (Name of Development) was prepared by me (or under my supervision) in accordance with the provisions of City and County of Denver Storm Drainage Design and Technical Criteria, and was designed to comply with the provisions thereof. I understand that the City and County of Denver does not, and will not, assume liability for drainage facilities designed by others.
>
> By: _____
> Licensed Professional Engineer
> State of Colorado
> No. _____
> Affix Seal

2.5.2 Final Drainage Report Contents

The report shall be in accordance with, but not limited to, the following outline and contain the applicable information listed below. Denver reserves the right to require additional information with any submittal.

1. General Location and Description. See Section 2.4.1, #1

2. Major Drainage Basins and Sub-basins. See Section 2.4.1, #2

3. Drainage Design Criteria

    A. Regulations: Discuss optional provisions selected or deviation from the DENVER CRITERIA, if any, and their justification.

    B. Development Criteria References and Constraints.

        i. Previous drainage studies (e.g., project master plans, Urban Drainage and Flood Control District [UDFCD] outfall system plans, Denver Drainage Master Plan) for the site that influence, or are influenced by, the proposed drainage design and how the studies will affect drainage design for the site.

        ii. Relationship to and implications of adjacent drainage studies.

iii. Drainage impact of site constraints such as streets, utilities, transit ways, existing structures, and development or site plans.

C. Hydrologic Criteria

i. Design rainfall.

ii. Hydrologic soil group.

iii. Runoff calculation method(s).

iv. Detention discharge and storage calculation method.

v. Design storm recurrence intervals.

vi. Justification for other criteria or calculation methods used that are not presented in or referenced by the DENVER CRITERIA.

D. Hydraulic Criteria

i. Various capacity methods.

ii. Hydraulic grade line (HGL) calculation method and head loss coefficients.

iii. Routing method used.

iv. Other drainage facility design criteria used that are not presented in the DENVER CRITERIA.

E. Water Quality Requirements Under Denver's Municipal CDPS Stormwater Permit

i. Design procedures and WQCV for the site.

ii. Permanent, post-construction best management practices (BMPs) for treatment of the WQCV.

iii. Landscaping requirements.

iv. Maintenance requirements for BMPs.

F. Waivers from Criteria

i. Provisions by section number for which a waiver is requested.

ii. Justification for each waiver requested.

4. Drainage Facility Design

A. General Concept. See Section 2.4.1, #3 (A).

B. Specific Details. See Section 2.4.1, #3 (B) and in addition include:

i. Easements and tracts for drainage purposes, including the conditions and limitations for use.

ii. All structural and non-structural BMPs, including tributary areas, sizing, treatment volumes, design features, etc.

5. Conclusions. See Section 2.4.1, #4.

6. References

Reference all criteria and technical information used. The final report must be a stand-alone document including portions of relevant documents referenced in the report. This supporting information may be included as an appendix.

7. Appendices

A. Hydrologic Computations

i. Land use assumptions regarding adjacent properties.

ii. Time of concentration and runoff coefficients for each basin.

iii. Minor and major storm runoff at specific design points.

iv. Connectivity diagram showing relationship/connectivity of basins, conveyance facilities, detention basins and design points.

v. Electronic copy and hard copy of input/output listings for computer models used.

B. Hydraulic Computations

i. Street capacity as compared to allowable capacity using Figure 7.1.

ii. Inlet capacity as compared to allowable capacity using Figures 8.1 and 8.2.

iii. Storm sewer capacity, including HGL elevations and head loss coefficients.

iv. Energy grade line (EGL) when the storm sewer is designed for events higher than the minor event or is requested by the Public Works Review Engineer.

v. Open channel design, low flow and trickle channel design, stabilization and grade control improvements.

vi. Energy dissipation at pipe outlets.

vii. Water surface profiles.

viii. Culvert capacities.

ix. Stage-Storage-Discharge determination for detention basins.

x. Downstream/outfall system capacity of the major drainageway.

xi. Charts, figures and tables related to hydraulic computations.

xii. Electronic and hard copy of input/output listings for computer models used.

C. Water Quality Enhancement BMPs

i. Completed DISTRICT MANUAL Volume 3 design procedure form.

ii. Design and sizing.

iii. Charts, figures, tables, and details related to design.

D. Excerpts from supporting documents, if referenced in report.

2.5.3 Final Drainage Plan Contents

1. Overall Drainage Plan. See Section 2.4.2, #1

2. Detailed Drainage Plan. See Section 2.4.2, #2 and in addition include:

A. Property lines and easements with purposes noted.

B. Adjacent developments or property ownerships.

C. Street cross-section indicating ROW width, flow-line width, cross slope, sidewalk, and curb type.

D. Street slope and flow direction and cross-pan.

E. Proposed storm sewers and open drainageways, including inlets, manholes, culverts, and other appurtenances, including riprap protection.

F. Proposed outfalls or exit points for runoff from the developed area and facilities to convey flows to the final outfall point without damage to downstream properties.

G. Finished floor elevation of proposed and existing structures.

H. Proposed detention basin grading and detention basin outlet schematic, include overflow directions and amounts and emergency spillway.

I. Water quality enhancement BMPs schematic.

2.6 Construction Drawings

2.6.1 Improvement Requirements

Drainage improvements within Denver are required to be designed, constructed and accepted in accordance with Denver standards and criteria. Construction plans are required to be approved by the Department of Public Works for all facilities within Denver.

The information required for the plans shall be in accordance with sound engineering principles, these DENVER CRITERIA, Denver's Municipal CDPS Stormwater Permit, and other applicable Denver ordinances, regulations, criteria or design guidelines. The plans may also be subject to review by outside agencies such as UDFCD, Federal Emergency Management Agency (FEMA), U.S. Army Corps of Engineers, U.S. Environmental Protection Agency or others as required. All plans must comply with the requirements of the current *International Building Code,* as may be amended. The approval of construction plans based on submitted documents and information shall not prevent Public Works from requiring correction of errors.

2.6.2 Certification

Construction drawings submitted for review and acceptance shall be prepared by a professional engineer licensed in the State of Colorado. The construction drawings must include the following statement on the cover sheet:

> "These construction drawings for (name of subdivision, development, or project) were prepared by me (or under my direct supervision) in accordance with the requirements of the Storm Drainage and Sanitary Construction Details and Technical Specifications and the Storm Drainage Design and Technical Criteria of the City and County of Denver.
>
> By: _____
> Licensed Professional Engineer
> State of Colorado
> No. _____
> Affix Seal
>
> Name of Firm_____

2.6.3 Construction Plan Requirements

The construction plans (24" X 36") for drainage improvements shall include both general drainage improvement and specific design feature information, as described below. Denver reserves the right to require additional information with any submittal.

1. General Information Required for All Drainage Improvement Projects

   A. Cover sheet

      i. Vicinity map.

      ii. Professional engineer certification.

iii. Title block, sheet index.

iv. Denver standard notes (see www.denvergov.org/publicworks/) for the most current version).

B. Overall utility plan showing water, sanitary and storm sewer facilities.

C. Grading plan (Use NAVD 88 Datum).

D. Drainage plan.

E. Erosion and sedimentation control plan (refer to Chapter 15).

F. Basic information.

i. Property and right-of-way lines, existing and proposed easements, tracts, structures, fences, and other land features.

ii. Relation of site to current floodplain boundaries.

iii. Maintenance access.

iv. Utilities adjacent to or crossing stormwater management facilities.

v. Additional design details as required.

vi. Any non-Denver standard details.

2. Specific Design Feature Information

A. Storm Sewers and Culverts

i. Plan and profile of proposed pipe installations, inlets, manholes, junction boxes and outlet structures with pertinent elevations, dimensions, types, designs and pipe full flow rates and horizontal controls shown. Plan and profile shall be included on same sheet.

ii. Minor storm HGLs.

iii. Major storm HGLs if the facility is designed for events greater than the minor storm.

iv. Pipe outlet protection on plan and profile views.

v. Utilities adjacent to or crossing storm sewer or culvert alignment in plan and profile.

vi. 1” = 20’ scale, minimum, grading details for all pipe and culvert inlets and outlets.

B. Detention/Storage Facilities

i. Detention basin grading, trickle channel, inlet, outlet, and emergency overflow spillway locations.

ii. Detention facility summary, Table 2.2 (at the end of Section 2.4.2).

iii. Forebay, micropool, trickle channel and outlet construction details, including safety features, such as racks at openings.

iv. Finished floor of structures adjacent to detention basins.

C. Open Channels, Swales, Channel Stabilization

i. Plan view showing horizontal locations of existing and proposed channels and swales, including locations of grade control structures and stabilization measures, such as check structures, drop structures, toe protection, bank stabilization, low-flow or trickle channels, with appropriate horizontal controls, safety features, etc.

ii. Profile along channel alignment with all invert elevations and top-of-channel bank elevations and design flow rates.

iii. Water surface limits in plan view.

iv. Water surface profiles for the minor and major storms.

v. Side tributary channels and pipe outlets.

D. Water Quality Enhancement BMPs

i. Plan and profile of improvements as required.

ii. Design details as required.

2.7 As-built Drawings and Certifications

Upon completion of construction, as-built drawings shall be submitted in hard copy (paper set and Mylar set) and electronic copy. Certifications of the as-built drawings are required as follows:

- Licensed Land Surveyor: A licensed land surveyor in the State of Colorado shall certify the as-built detention basin volumes and outlet structure sizes and elevations, storm sewer sizes and invert elevations at inlets, manholes and discharge locations, longitudinal slopes and representative cross sections of open channels and dimensions of drainage structures.

- Licensed Professional Engineer: The responsible design engineer shall submit a completed "Certificate of Inspection." See the Department of Public Works website (www.denvergov.org/publicworks/) for requirements.

Certificate of Inspection and as-built drawings and all necessary approvals from all the entities (e.g., UDFCD approval for master drainageway improvements, FEMA approval for floodplain, etc.) will be required prior to the issuance of a sanitary sewer connection permit or the signing of a Certificate of Occupancy.

2.8 Submittal Checklists and Design Aids

The checklists below identify major topics required for reports. The report outlines presented earlier in this chapter identify additional detail that must also be provided. Not all information in these tables is required for preliminary reports.

Table 2.3. Drainage Report Checklist

Drainage Report			**Received or Not Applicable**	**To be Submitted**
i	**Typed, Bound (not 3 ring) Report**			
ii.	**P.E. Certification**			
1	**General Location and Description**			
	A	Location, Name of Surrounding Developments		
	B	Description of Property, Area, Irrigation Facilities, Major Drainageways, Easements		
2	**Major Drainage Basins and Sub-Basins**			
	A	Major Basin Description, Copy of Current FIRM		
	B	Sub-basin Description, Impact from On- and Off-site Basins		
3	**Design Criteria**			
	A	Regulations: Optional Provisions and Deviations		
	B	Development Criteria References/Constraints: Master Plan, Outfall System Plan, Adjacent Studies		
	C	Hydrologic Criteria: Rainfall, Soils, Runoff and Storage Calculation Methods, Design Storm Recurrence Interval		
	D	Hydraulic Criteria: Conveyance Facility Capacities, HGL Calculations, Routing Methods		
	E	Water Quality Requirements: WQCV, BMPs for Treatment of the WQCV; Volume Reduction; Minimizing Directly Connected Impervious Area; Maintenance		
	F	Waivers from Criteria, Justification for each Waiver		
4	**Drainage Facility Design**			
	A	General Concept: Discussion of Drainage Patterns and Impact on Upstream and Downstream Properties		
	B	Specific Details: Flows, Volumes, WQCV; Existing and Proposed Facilities; Detention Storage and Outlet Design; Maintenance Access; Structural and Non-Structural BMPs; Appearance and Safety		
	C	ROW or Easements Provide Adequate Space for Drainage Facilities and Construction Area Requirements		
5	**Conclusions**			
	A	Compliance with Standards		
	B	Drainage Concept, Effectiveness of Drainage Design		
	C	Water Quality Measures Implemented to Treat the WQCV		
6	**References**			

(continued on next page)

Table 2.3. Drainage Report Checklist (continued)

Drainage Report (continued)			**Received or Not Applicable**	**To be Submitted**
7	**Appendices (Final Report Only)**			
	a	Hydrologic Computations		
		1. Land Use Assumptions		
		2. Reasonable Time of Concentration (First Design Point Between 5 to 10 minutes)		
		3. Minor and Major Storm Runoff Calc. for On- and Off-site Basins		
		4. Connectivity Diagram/SWMM Schematic		
		5. Electronic and Hard Copy of Input/Outputs for Computer Models Used.		
	b	Hydraulic Computations		
		1. Street and Inlet Capacities		
		2. Storm Sewer Capacities: HGL in Minor Event within the Pipe and HGL in Major Event 1 Foot Below Ground		
		3. Open Channel, Low Flow and Trickle Channel Design, Stabilization and Grade Control Improvements		
		4. EGL When Storm Sewer Designed for Events Greater than Minor Storm		
		5. Riprap or other Energy Dissipation Design		
		6. Water Surface Profiles and Culvert Capacities		
		7. Stage-Storage-Discharge for Detention Basins		
		8. Downstream/Outfall System Capacity for Major Drainageway		
		9. Charts, Figures, Tables for Related Hydraulic Computations		
		10. Electronic and Hard Copies of Inputs/Outputs of Models		
	c	Water Quality BMP Design Information Including Design Forms from Volume 3 of the DISTRICT MANUAL and Related Charts, Figures, Tables, Forms		
	d	Excerpts from Supporting Documents		

Table 2.4. Drainage Plan Checklist

Drainage Plan			Received or Not Applicable	To be Submitted
1	**Overall Drainage Plan**			
	a	Delineation of Entire Development and Off-site Basins		
	b	Delineation of all Major Basins		
	c	Identification of major storm drainage facilities		
	d	General Drainage Paths with Flow Arrows		
2	**Detailed Drainage Plan**			
	a	Existing (dashed or screened) Contours		
	b	Proposed (solid) Contours, Spot Elevations of Critical Points		
	c	All Existing and Proposed Drainage Facilities (e.g., Detention Facilities, Storm Sewers, Swales, Riprap, Outlet Structures, Irrigation Ditches, Culverts, Cross Pans)		
	d	Existing and Proposed Pipe Sizes		
	e	Floodplain and Floodway Boundaries and Information Source		
	f	Delineation of All Major Basins and Sub-basins, Key Off-site features		
	g	Runoff Summary Table – See Table 2.1		
	h	Detention Basin Summary Table – See Table 2.2		
	i	Cross Sections of Drainage Ditches		
	j	Finished Floor Elevation		
	k	Property and Right-of-Way Lines, Existing and Proposed Easements with Purposes Noted, Tracts, Structures, Fences, Wetlands, Waters of the State and Other Land Features		
	l	Adjacent Developments or Ownerships		
	m	Street Cross Sections Indicating ROW Width, Flow-line to Flow-line Width, Cross Slope, Sidewalk, Curb Type		
	n	Street Slope, Flow Direction and Cross Pan		
	o	Proposed Detention Basin Grading and Detention Basin Outlet Schematics		
	p	Overflow Directions and Amounts, Emergency Spillway		
	q	Water Quality Enhancement BMPs Schematic		

Table 2.5. Construction Plan Checklist

Construction Plan			Received or Not Applicable	To be Submitted
For information on Application to Construct (Private or Public), Surety (if Public) with Cost Estimate and Review Fee, see www.denvergov.org/publicworks/				
General Information Required for All Drainage Improvement Projects				
1	**Cover Sheet**			
	A	Vicinity Map 1"=2000' and North Arrow		
	B	Professional Engineer Certification		
	C	Title Block, Sheet Index, NAVD 88 Bench Mark		
	D	Current Denver Standard Notes (see website)		
2	**Overall Utility Plan Showing Water, Sanitary and Storm Sewer Facilities**			
	A	Pipe Size and Type		
3	**Grading Plan**			
4	**Drainage Plan**			
5	**Erosion and Sedimentation Control Plan (See Chapter 15)**			
6	**General Information**			
	A	Street Names, Property and Right-of-Way Lines, Existing and Proposed Easements, Tracts, Structures, Fences, and Other Land Features, Legend		
	B	Floodplain Boundaries and Information Source		
	C	Maintenance Access		
	D	Utilities Adjacent to or Crossing Stormwater Management Facilities		
	E	Notes and Design Details as required; any **non-Denver** Standard Details		
Specific Facilities or Components Information				
1	**Storm Sewers and Culverts**			
	A	Plan and Profile of Proposed Pipe Installations, Inlets, Manholes, Junction Boxes and Outlet Structures with Pertinent Elevations, Dimensions, Slopes, Types, Sizes, Design and Pipe Full Flow Rates and Horizontal Controls Shown		
	B	Plan and Profile Shall be on Same Sheet; Key Map for Multiple Plans and Profiles		
	C	Design Storm HGLs		
	D	Pipe Outlet Protection on Plan and Profile Views; Rip Rap Details and Cross Sections		
	E	Utilities Adjacent to or Crossing Storm Sewer or Culvert Alignment		
	F	1” = 20’ Scale Minimum, Grading Details for All Pipe and Culvert Inlets and Outlets		

(continued on next page)

Table 2.5. Construction Plan Checklist (continued)

Construction Plan			Received or Not Applicable	To be Submitted
2	**Detention/Storage Facilities**			
	A	Detention Basin Grading, Trickle Channel, Inlet, Outlet, and Emergency Overflow Spillway Locations, Safety Features		
	B	Detention Facility Summary, Table 2.2		
	C	Forebay, Micro Pool and Basin Outlet Construction Details		
	D	Trickle Channels from Forebay to Basin Outlet		
	E	Finished Floor Elevation of Structures Adjacent to Detention Basin		
3	**Open Channels, Swales, Channel Stabilization**			
	A	Plan View Showing Horizontal Locations of Existing and Proposed Channels and Swales, Including Locations of Grade Control Structures and Stabilization Measures, such as Check Structures, Drop Structures, Toe Protection, Bank Stabilization, Low Flow or Trickle Channels, with Appropriate Horizontal Controls		
	B	Profile along Channel Alignment with all Invert Elevations and Top of Channel Bank Elevations, and Design Flow Rates		
	C	Water Surface Limits in Plan View		
	D	Water Surface Profiles for the Minor and Major Storms		
	E	Side Tributary Channels and Pipe Outlets		
4	**Water Quality Enhancement BMPs**			
	A	Plan and Profile of Improvements, as Required		
	B	Design Details Specific to the Site		

3.0 DRAINAGE POLICY

3.1 Introduction

Providing adequate drainage in urban areas is necessary to preserve and promote the general health, safety, welfare, and economic well being of the urban community. When planning for drainage, certain underlying principles provide direction. These principles are made operational through policy statements. The implementation of the policy is, in turn, facilitated by technical criteria and data. Over the past 35 years, the Urban Drainage and Flood Control District (UDFCD) has established strong policies that guide drainage planning in the metro area, as specified in the DRAINAGE POLICY chapter of the DISTRICT MANUAL. **Denver hereby incorporates by reference all principles and policies contained therein.** A brief discussion of the twelve key drainage principles contained in the DISTRICT MANUAL is provided, followed by Denver's policies based on these principles. Background information supporting development of these policies can be obtained from the DRAINAGE POLICY and PLANNING chapters of the DISTRICT MANUAL and is not repeated herein. Additionally, the DRAINAGE LAW chapter of the DISTRICT MANUAL provides information on the legal responsibilities for those involved in design, construction and maintenance of storm drainage facilities.

3.2 Principles

Twelve principles of urban stormwater management identified in the DISTRICT MANUAL are foundational to these DENVER CRITERIA and are repeated herein due to their importance.

1. **Drainage is a regional phenomenon that does not respect the boundaries between government jurisdictions or between properties**. This makes it necessary to formulate programs that include both public and private involvement. Overall, the governmental agencies most directly involved must provide coordination and master planning, but drainage planning must be integrated on a regional level if optimum results are to be achieved.

2. **A stormwater management system is a subsystem of the total urban water resource system.** Stormwater management system planning and design for any site must be compatible with regional comprehensive plans and should be coordinated with planning for land use, open space, and transportation corridors. Urban stormwater management must consider and address the interrelated issues of erosion and sedimentation control, flood control, site grading criteria, and regional water quality.

3. **Every urban area has a minor and major drainage system that must be properly planned and designed.** The minor system is designed to provide public convenience and to accommodate moderate, frequently occurring flows. The major system, which exists regardless of whether it is planned, 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 future generations, and avoid loss of life and major property damage, both systems must be planned and properly engineered.

4. **Runoff routing is primarily a space allocation problem.** The volume of water present at a given time in an urban region cannot be compressed or diminished. Adequate space must be provided during initial planning stages for storm drainage runoff conveyance, quality enhancement, and storage. Otherwise, stormwater runoff will conflict with other land uses, resulting in damages and the disruption of other urban systems.

5. **Planning and design of stormwater drainage systems generally shall not be based on the premise that problems can be transferred from one location to another.** Urbanization tends to increase downstream peak flows by increasing runoff volumes and the speed of runoff conveyance. Stormwater management systems shall be designed and detention storage shall be provided so that downstream properties are not adversely impacted.

6. **An urban storm drainage strategy should be a multi-objective and multi-means effort.** The many competing demands placed upon space and resources require a stormwater management strategy that meets a variety of objectives, including water quality enhancement, groundwater recharge, recreation, wildlife, wetland creation, protection of landmarks/amenities, control of erosion and sediment deposition, and creation of open spaces. The paramount objective must be protection of public, health, safety and welfare.

7. **Design of the stormwater drainage system shall consider the features, capacity, and function of the existing drainage system.** Good designs incorporate the effectiveness of the natural systems rather than negate, replace or ignore them. Existing features such as natural drainageways, depressions, wetlands, floodplains, permeable soils, and vegetation provide for infiltration, help control the velocity of runoff, extend the time of concentration, filter sediment and other pollutants, and recycle nutrients.

8. **In new developments, attempts should be made to reduce stormwater runoff rates and pollutant load increases after development to the maximum extent practicable.** To the extent feasible, the rate of runoff should be slowed by maximizing use of vegetative and porous land cover, infiltration should be encouraged to reduce runoff volumes, and a series of best management practices (BMPs) must be provided for water quality enhancement and protection.

9. **The stormwater management system shall be designed beginning with the outlet or point of outflow from the project, giving full consideration to downstream effects and the effects of off-site flows entering the system.** The design of the stormwater management system shall take into account runoff from upstream sites, assuming fully developed conditions, and shall evaluate the downstream conveyance system to ensure that it has sufficient capacity to accept design discharges

without adverse backwater or downstream impacts such as flooding, stream bank erosion, channel degradation, and sediment deposition.

10. **The stormwater management system must receive regular maintenance to ensure long-term function and effectiveness. Stormwater management facilities shall be designed with ease of maintenance, long-term function, protection of public safety and accessibility as primary considerations.** Operation and maintenance procedures and activities must be developed and documented with the facility design. Clear assignment of maintenance responsibilities must be identified and assigned to an established agency with the resources and understanding that are required to ensure proper maintenance.

11. **Floodplains need to be preserved where feasible and practicable.** Preservation of floodplains serves to minimize hazards, preserve habitat and open space, creates a more livable urban environment, and protects public health, safety, and welfare.

12. **Sufficient right-of-way for lateral channel movement of incised floodplains must be reserved.** Whenever a floodplain is contained within a narrow (i.e., degraded) channel, the channel should be provided with grade control structures and a right-of-way corridor to account for lateral movement. Lateral movement over time can cause extensive damages to public and private structures and facilities.

3.3 Policies

In keeping with the 12 principles of storm drainage planning, Denver has developed specific policies that must be followed. These policies are discussed in the following categories: planning, design, operation and maintenance, irrigation and storage facilities, and water quality.

3.3.1 Planning

3.3.1.1 Storm drainage planning is required for all development and redevelopment projects (as defined in Section 1.3) in accordance with these DENVER CRITERIA and the DISTRICT MANUAL. Requirements for drainage plan submittals must comply with Chapter 2 of these DENVER CRITERIA.

3.3.1.2 Stormwater management planning shall be required in the initial planning stages for all developments and redevelopments (as defined in Section 1.3) to ensure that adequate space is allocated for the drainage facilities.

3.3.1.3 Denver encourages multi-purpose uses of storm drainage facilities that are compatible with adjacent land uses, Colorado Water Law and water quality enhancement objectives. Special care shall be taken when storm drainage facilities are contained within recreational, park and open space areas to ensure that uses are compatible.

3.3.1.4 Denver pursues a jurisdictionally unified approach to promote the overall integrity of regional drainage systems.

3.3.1.5 Denver defines a major drainageway as any drainage flow path with a tributary area of 130 acres or more.

3.3.1.6 Major drainageways shall remain in open channels and shall not be piped.

3.3.1.7 Historic major drainage pathways shall be maintained, and inter-basin transfers of storm drainage shall be avoided to the maximum extent practicable. Deviations from this policy may be granted on a case-by-case basis, only when the following criteria are met:

1. No other viable alternative exists.
2. No additional potential damage is created by the proposed transfer.
3. No impairment of water rights is caused.
4. No other regulatory requirement is violated.

3.3.1.8 Denver encourages and will continue to participate in the development of detailed regional drainage master plans that set forth the requirements for new developments and identify required public improvements.

3.3.1.9 Denver will give careful consideration to implementing the recommendations of master plans, within the context of available public funds and overall priorities specified in the *Denver Comprehensive Plan 2000* (and as amended). Prior to implementing master plan recommendations based on modeling, Denver will require reasonableness checks of modeling results based on site observations and other information (e.g., maintenance records, flooding problems due to existing pipe size), where such information is reasonably available.

3.3.1.10 In areas with known drainage or water quality problems, additional analysis and/or definition of additional facilities to prevent compounding of these problems by development and redevelopment projects (as defined in Section 1.3) must be completed.

3.3.1.11 All development and redevelopment projects (as defined in Section 1.3) must design and construct drainage improvements that drain to an acceptable outfall in accordance with the Denver-approved Final Drainage Report for the minor system (as described in Chapter 2) and the applicable master drainage plan for the major drainage system. Where no UDFCD or other approved master drainage plan exists, the proponent must prepare and obtain approval for a master drainage plan for the affected area.

3.3.1.12 On-site detention of flood flows for all development and redevelopment projects (as defined in Section 1.3) is required in accordance with these DENVER CRITERIA and Chapter 11 of the DENVER RULES and REGULATIONS for the purpose of reducing urban drainage problems and the costs of drainage facilities. Exemptions from flood control detention may be granted under these conditions:

1. Development or redevelopment of a total area of 0.5 acre or less.
2. Development or redevelopment of an area immediately adjacent to a major drainageway that is capable of conveying the fully developed basin 100-year flood. In such a case, the 100-year flood detention requirement may be waived; however, the 10-year event and water quality capture volume (WQCV) shall be required.
3. Development or redevelopment of areas within defined 100-year floodplains. In such a case, the 100-year flood detention requirement may be waived; however, the 10-year event and WQCV shall be required.
4. Development or redevelopment of areas tributary to a publicly owned and maintained regional detention facility designed to accommodate flows from a fully developed basin, provided that adequate conveyance of 100-year developed flows from the development to the regional facility is provided.

All exemptions are subject to approval at the sole discretion of the Public Works Department and may require additional analysis to demonstrate that no adverse effects to the overall drainage system will result from the exemption.

3.3.1.13 Denver requires that flood detention and water quality facilities be safe and maintainable and strongly encourages aesthetically pleasing facilities that are viewed as community assets rather than liabilities.

3.3.1.14 Planning for water quality and flood detention shall be integrated within all development and redevelopment (as defined in Section 1.3). In this context, site planning and design techniques shall reduce runoff volumes and velocities to the maximum extent practicable by implementing measures that minimize directly connected impervious area, as specified in Volume 3 of the DISTRICT MANUAL. Guidelines for implementation of this approach in Denver are provided in Chapter 14 of these DENVER CRITERIA and in Chapter 6 of the *Denver Water Quality Management Pla*n (WWE et al. 2004).

3.3.1.15 Denver requires on-site retention for all new development and redevelopment (as defined in Section 1.3) in areas where downstream outfall systems are inadequate or non-existent and where provision of outfall facilities cannot be reasonably accomplished.

3.3.1.16 Floodplains shall be regulated and managed in accordance with Denver's Floodplain Ordinance (Article V, Chapter 56, Revised Municipal Code, and as contained in Chapter 4 of these DENVER CRITERIA).

3.3.1.17 Denver recognizes the possible effects of the drainage system on water rights. In such cases, the State Engineer's Office should be consulted.

3.3.2 Design

The design criteria presented herein represent Denver's minimum requirements for stormwater management. These criteria will be revised and updated as necessary to reflect advances in the field of urban drainage engineering and water resources management.

3.3.2.1 All storm drainage facilities shall be planned and designed in accordance with these DENVER CRITERIA, the DENVER RULES and REGULATIONS and the DISTRICT MANUAL, all of which may be revised or amended as new technology is developed and as additional experience is gained.

3.3.2.2 All subdivisions shall plan, design and implement the minor and major drainage systems in accordance with the storm recurrence intervals defined in Table 3.1.

Table 3.1. Design Storms for the Minor and Major Systems

Land Use	Minor System	Major System
Residential	2-year	100-year
Commercial	5-year	100-year
Industrial	5-year	100-year
Open Space	2-year	100-year
Sump Conditions	5-year	100-year

3.3.2.3 The minor drainage system shall be designed to transport runoff from the minor storm with minimum disruption to the urban environment and to discharge to an acceptable outfall per these DENVER CRITERIA.

3.3.2.4 The minor drainage system shall be designed and sized without accounting for peak flow reductions from onsite detention, unless otherwise approved by Denver.

3.3.2.5 The capacity of the minor system of the downstream development must be equivalent to, or greater than, the capacity of the upstream system.

3.3.2.6 The major drainage system shall be designed to convey runoff from the 100-year recurrence interval flood to minimize health and life hazards, damage to structures, and interruption to traffic and services and shall be designed to discharge to an acceptable outfall per these DENVER CRITERIA.

3.3.2.7 The major drainage system shall be designed and sized without accounting for peak flow reductions from onsite or offsite detention unless otherwise approved by Denver. In cases where permanently dedicated, publicly maintained detention facilities are in place, Denver will provide credit for flow reduction.

3.3.2.8 Storm runoff shall be determined by the Colorado Urban Hydrograph Procedure (CUHP) Method or the Rational Method, depending on the catchment size and complexity, as determined by the criteria provided in Table 6.1.

3.3.2.9 Streets are an integral part of the urban drainage system and may be used for drainage in accordance with the limitations identified in Tables 7.1 through 7.3 of these DENVER CRITERIA. Streets shall not be used for drainage in a manner that unduly restricts the primary purpose of streets, which is for traffic.

3.3.3 Operation and Maintenance of Drainage Facilities

3.3.3.1 Storm drainage facilities, including channels, flood detention and water quality facilities, storm sewers, and related appurtenances, require on-going maintenance and periodic repair and restoration to ensure proper functioning. Maintenance and access requirements shall be considered during the planning and design of these facilities. Maintenance requirements and access provisions shall be clearly defined in the drainage plan, storm sewer construction plan and site plan submittals. Easement widths should be based on maintenance access needs and overflow widths, if any.

3.3.3.2 The land owner is responsible for maintenance of private drainage facilities located on their land, unless the facilities are designated as public facilities and are within dedicated public easements.

3.3.3.3 Maintenance access shall be provided for all storm drainage facilities. Easements for adequate maintenance shall be as defined in Table 3.2.

Table 3.2. Required Maintenance Easements for Drainage Facilities

Facility Type	Easement Width
Single Pipe	$W = B_c + 2H + 3$ where B_c = outside span of pipe in feet H = depth from top of pipe to final surface elevation in feet W = easement width, which shall be rounded to the next highest 5-foot increment with a minimum width of 20 feet.
Multiple Pipe Installation	Width calculated on a case-by-case basis
Open Channels and Swales	Q_{100} less than 20 cfs: 20 ft Q_{100} less than 100 cfs: 25 ft Q_{100} greater than 100 cfs: See DISTRICT MANUAL
Detention Basin	Width as required to contain storage, freeboard and associated facilities plus no less than 10 feet for maintenance access around the perimeter. When multiple lots are involved, a dedicated tract of land is required.

3.3.3.4 Drainage easements shall be shown on the corrected plats, drainage plan, and storm sewer construction plan and state that Denver has the right of access on the easements, which shall be kept clear of obstructions restricting flow and/or maintenance access.

3.3.3.5 In order to be eligible for maintenance by UDFCD, all drainage facilities shall be designed and constructed in accordance with the most current version of the District Maintenance Eligibility Guidelines (downloadable from www.udfcd.org).

3.3.4 Irrigation Conveyance and Storage

The criteria below define the relationship between irrigation ditches and storm drainage and identify dam safety issues and restrictions associated with irrigation storage facilities.

3.3.4.1 Irrigation facilities such as ditches and reservoirs shall not be used as drainage facilities, except where the requirements of Sections 3.3.4.3 through 3.3.4.6 are met.

3.3.4.2 Irrigation ditches shall not be used as basin boundaries when evaluating the interaction of irrigation ditches with a major drainageway for the purpose of basin delineation. Drainage analysis shall assume that irrigation ditches do not intercept storm runoff from the upper basin and that the upper basin is tributary to the basin area downstream of the ditch. During major storms, ditches will generally be flowing full, near full or sometimes overflowing; therefore, the tributary basin runoff would flow across the ditch.

3.3.4.3 Development and redevelopment projects (as defined in Section 1.3) shall avoid discharging into irrigation canals and ditches, except as required by water rights, and shall instead direct runoff into historic and natural drainageways. As a general rule, the flat slopes,

limited carrying capacities, and potential for abandonment of ditches make them inappropriate for storm drainage usage.

3.3.4.4 Discharge of runoff into irrigation ditches shall be approved only under these conditions:

1. The discharge is consistent with the relevant master drainage plan.
2. Thorough hydrologic and hydraulic analysis indicates the discharge is reasonable.
3. The owner's liability for ditch failure is clearly defined.
4. Written consent of the ditch company is submitted.
5. The practice is determined to be in Denver's best interest.

3.3.4.5 Whenever irrigation ditches cross major drainageways within a developing area, the developer shall design and construct appropriate structures to separate storm runoff from ditch flows.

3.3.4.6 Any modifications to existing topography or placement of drainage structures that affect water quality and/or drainage patterns to ditches or other utilities shall comply with the criteria listed in Section 3.3.4.4.

3.3.4.7 For hydrologic purposes, all private dams shall be ignored in the definition of floodplains.

3.3.4.8 All development and redevelopment projects (as defined in Section 1.3) downstream of irrigation storage facilities shall obtain flood hazard maps from the State Engineer's Office to determine dam hazard classifications pursuant to Section 37-87-123, CRS.

3.3.4.9 All development and redevelopment projects (as defined in Section 1.3) shall be restricted to areas outside of the reservoir's high water line based on the design flood for the structure's emergency spillway.

3.3.4.10 All development and redevelopment projects (as defined in Section 1.3) shall be restricted to areas outside of the high water line based on the breach of a dam (except high hazard classified dams which have passed inspection by the State Engineer's office in accordance with 37-87-105 et seq. CRS 1974).

3.3.4.11 All development and redevelopment (as defined in Section 1.3) shall be restricted to areas outside existing or potential future emergency spillway paths, beginning at the dam and proceeding to the point where the flood water returns to the natural drainage course.

3.3.5 Water Quality

3.3.5.1 All development and redevelopment (as defined in Section 1.3) shall comply with the terms and conditions of Denver's Colorado Discharge Permit System (CDPS) stormwater discharge permit for the purpose of minimizing the discharge of pollutants to receiving waters to the maximum extent practicable.

3.3.5.2 All development and redevelopment projects (as defined in Section 1.3) located within Denver shall provide specific measures to enhance the water quality of storm-generated runoff from the fully developed project site, as specified in Chapter 14 of these DENVER CRITERIA. All BMPs identified in Volume 3 of the DISTRICT MANAUAL are applicable to all development and redevelopment projects within Denver. Water quality BMPs shall be implemented in accordance with the requirements of Chapter 14 of these DENVER CRITERIA.

3.3.5.3 All development and redevelopment projects (as defined in Section 1.3) located within Denver are required to implement BMPs to control erosion, sedimentation, and pollutant laden stormwater discharges during construction activities in accordance with Chapter 15 of these DENVER CRITERIA and Volume 3 of the DISTRICT MANUAL.

3.3.5.4 Denver reserves the right to require implementation of temporary and permanent BMPs on development and redevelopment sites less than one acre in size.

4.0 FLOODPLAIN REGULATIONS

4.1 Introduction

The regulation of floodplains is necessary to preserve and promote the general health, welfare, and economic well being of the region. The general purposes of floodplain regulations are summarized as follows:

1. To reduce the hazard of floods to life and property.
2. To protect and preserve hydraulic characteristics of water courses used for conveyance of flood waters.
3. To protect the public from extraordinary financial expenditures for flood control and relief.

Floodplains shall be regulated and managed in accordance with Denver's Floodplain Ordinance (Article V, Chapter 56, Revised Municipal Code), which is provided in Section 4.2 below. It is the designer's responsibility to use the most current adopted floodplain maps and to ensure compliance with the current Denver ordinances and federal regulations. Floodplains shall be left in a natural state or used as open space recreational areas to the maximum extent practicable. In essence, the Ordinance states that:

1. Most construction within the floodway is prohibited.
2. Residential construction within the floodplain must elevate the lowest floor (including basement), and all associated machinery and equipment, to a minimum of the flood protection elevation.
3. Commercial or industrial development must elevate the lowest floor (including basement) or dry floodproof, including all associated machinery and equipment, to a minimum of the flood protection elevation.
4. Flood protection elevation is 1.5 feet above the base flood elevation or depth of flooding defined for the regulatory floodplain.
5. Elevation certificates are required for all structures built within the regulatory floodplain.

In cases where the floodplain will be altered, it is the developer's responsibility to first obtain a Conditional Letter of Map Revision (CLOMR) early in the planning process and obtain a final Letter of Map Revision (LOMR) when the project is complete. All analysis and associated costs are the responsibility of the developer.

Denver encourages floodproofing of existing structures that are not in compliance with Denver's Floodplain Ordinance. Floodproofing may not necessarily bring the structure into compliance or reduce flood insurance premiums, but floodproofing techniques can be effective at reducing flood losses. In addition to the requirements set forth in the Denver Floodplain Ordinance, floodproofing shall be

completed in accordance with the criteria specified in the FLOOD PROOFING chapter of the DISTRICT MANUAL, the latest version of the *Colorado Flood Proofing Manual* (CWCB 1983), the *City and County of Denver Flood Protection Handbook* (Denver and UDFCD 2003), FEMA guidance, other any other Denver guidance.

Construction of critical facilities such as hospitals, nursing homes, schools, fire stations, etc… in the floodplain should be avoided.

4.2 Denver Floodplain Ordinance

Sec. 56-200. Legislative intent.

(a) *Statutory Authorization.* The Legislature of the State of Colorado has, in Title 29, Article 20 of the Colorado Revised Statutes, delegated the responsibility of local governmental units to adopt regulations designed to minimize flood losses. Therefore, the City and County of Denver does hereby adopt the following floodplain management ordinance:

(b) *Findings of fact.* Due to its general terrain and geographical location, the city is particularly subject to damage from storm waters which, from time to time, overflow from existing watercourses and drainage facilities, and imprudent use of these natural hazard areas called floodplains will pose a continuing and greater danger to life and property in the future unless proper regulations are adopted.

(c) *Statement of purpose.* This article is enacted to promote the public health, safety, and general welfare, and to minimize public and private losses due to flood conditions in specific areas, by provisions designed to:

(1) Protect human life and health;

(2) Minimize expenditure of public money for costly flood control projects;

(3) Minimize the need for rescue and relief efforts associated with flooding and generally undertaken at the expense of the general public;

(4) Minimize prolonged business interruptions;

(5) Minimize damage to critical facilities, infrastructure and other public facilities and utilities such as water, sewer and gas mains; electric and communications facilities; and streets and bridges located in the regulatory floodplain;

(6) Help maintain a stable tax base by providing for the sound use and development of the regulatory floodplain so as to minimize future flood blight areas;

(7) Ensure that potential buyers are notified that property is located in the regulatory floodplain;

(8) Ensure that those who occupy the regulatory floodplain assume responsibility for their actions;

(9) Encourage and facilitate urban water resources management techniques for reduction of pollution and the enhancement of the urban environment.

(d) *Methods of reducing flood losses.* In order to accomplish its purposes, this article:

(1) Requires that all construction of permitted buildings shall be in compliance with the Denver Building Code;

(2) Restricts or prohibits uses which are dangerous to health, safety, and property due to water or erosion hazards, or which result in damaging increases in erosion, flood heights or velocities;

(3) Requires that uses vulnerable to floods, including facilities which serve such uses, be protected against flood damage at the time of initial construction;

(4) Controls the alteration of natural floodplains, stream channels, and natural protective barriers, which help accommodate or channel floodwaters;

(5) Controls filling, grading, dredging, and other development which may increase flood damage; and,

(6) Prevents or regulates the construction of flood barriers which will unnaturally divert floodwaters or which may increase flood hazards in other areas.

(Ord. No. 158-86, § 1, 3-17-86; Ord. No. 547-13, § 1, 11-4-13)

Sec. 56-201. Definitions.

(a) Words, phrases and terms defined herein shall be given the defined meaning.

(b) Words, phrases and terms not defined herein, but defined in the building code or the zoning code of the city, shall be construed as defined in such code.

(c) Words, phrases and terms neither defined herein nor in the building code or the zoning code of the city, shall be given usual and customary meanings except where the context clearly indicates a different meaning.

(d) The word "shall" is mandatory and not permissive; the word "may" is permissive and not mandatory.

Accessory structure: Also known as “appurtenant structure.” A structure which is on the same parcel of property as the principal structure and the use of which is incidental to the use of the principal structure.

Addition: Any activity that expands an existing structure either horizontally or vertically. See “lateral addition” and “vertical addition.”

Appeal: A request for a review of the interpretation of any provisions of this article.

Appurtenant structure: See “accessory structure.”

Area of shallow flooding: A designated AO, AH, AR/AO, AR/AH or VO zone on the Flood Insurance Rate Map (FIRM) where the base flood depths range from one (1) to three (3) feet, a clearly defined channel does not exist, the path of flooding is unpredictable and indeterminate, and velocity flow may be evident. Such flooding is characterized by ponding or sheet flow.

Base flood: Also known as “one-hundred-year flood,” one-percent-annual-chance flood,” and “one-percent-chance flood.” A flood having a one-percent chance of being equaled or exceeded in any given year. The term does not imply that the flood will necessarily happen once every one hundred years,

Base flood elevation (BFE): The elevation shown on a FEMA Flood Insurance Rate Map (FIRM) for Zones AE, AH, A1-A30, AR, AR/AE, AR/A1-A30, AR/AH, AR/AO, V1-V30, and VE that indicates the water surface elevation resulting from the occurrence of the base flood.

Basement: Any area of a building having its floor sub-grade (below ground level) on all sides.

Building: See “structure.”

Channel: The physical confine of stream or waterway consisting of a bed and stream banks, existing in a variety of geometries.

Channelization: The artificial creation, enlargement or realignment of a stream channel.

Code of Federal Regulation (CFR): The codification of the general and permanent Rules published in the Federal Register by the executive departments and agencies of the Federal Government. It is divided into 50 titles that represent broad areas subject to Federal regulation.

Community: Any political subdivision that has the authority to adopt and enforce floodplain management regulations through zoning, including but not limited to: counties, cities, towns, unincorporated areas, Indian tribes, and drainage and flood control districts.

Conditional Letter of Map Revision (CLOMR): FEMA's comment on a proposed project, which does not revise an effective floodplain map, that would, upon construction, affect the hydrologic or hydraulic characteristics of a flooding source and thus result in the modification of the existing regulatory floodplain.

Crawl space: A shallow space beneath the ground floor of a structure with clearances less than human height, generally used for storage or to access plumbing, wiring, etc… A crawlspace cannot be used as living space. A crawlspace may be considered a basement for flood insurance purposes.

Critical facility: A structure or related infrastructure, but not the land on which it is situated, that if flooded may result in significant hazards to public health and safety or interrupt essential services and operations for the community at any time before, during and after a flood. The classification and definition of critical facilities shall be as specified in Rule 6 of the Department of Natural Resources, Colorado Water Conservation Board's "Rules and Regulations for Regulatory Floodplains in Colorado," dated November 17, 2010, or as amended.

Development: Any manmade change to improved or unimproved real estate, including but not limited to buildings or other structures, mining, dredging, filling, grading, paving, excavation, drilling operations, or storage of equipment or materials.

DFIRM database: Database (usually spreadsheets) containing data and analyses that accompany the DFIRM. The FEMA Mapping Specifications and Guidelines outline requirements for the development and maintenance of DFIRM databases.

Digital Flood Insurance Rate Map (DFIRM): FEMA digital floodplain map. These maps serve as regulatory floodplain maps for insurance and floodplain management purposes.

Dry floodproofing: Method of floodproofing in which the intent is to keep the interior of the structure or property, including all machinery and equipment, watertight using walls that are substantially impermeable to the passage of water with structural components having the capability of resisting hydrostatic and hydrodynamic loads and effects of buoyancy. This includes using flood damage-resistant materials and backwater prevention for storm and sanitary sewers.

Elevated Building: A non-basement building which has the top of the lowest elevated floor raised above ground level by foundation walls, shear walls, posts, piers, piles, or columns. In Zones A1-A30, AE, A, A99, AO, AH, B, C, X, and D, it also includes a building elevated by means of fill or solid foundation perimeter walls with openings sufficient to facilitate the unimpeded movement of flood waters.

Existing manufactured home park or subdivision: A manufactured home park or subdivision for which the construction of facilities for servicing the lots on which the manufactured homes are to be affixed (including, at a minimum, the installation of utilities, the construction of streets, and either final site grading or the pouring of concrete pads) is completed before the effective date of the floodplain management regulations adopted by a community.

Expansion to an existing manufactured home park or subdivision: The preparation of additional sites by the construction of facilities for servicing the lots on which the manufactured homes are to be affixed (including the installation of utilities, the construction of streets, and either final site grading or the pouring of concrete pads).

Federal Register: The official daily publication for Rules, proposed Rules, and notices of Federal agencies and organizations, as well as executive orders and other presidential documents.

FEMA: Federal Emergency Management Agency, the agency responsible for administering the National Flood Insurance Program (NFIP).

Flood or Flooding: A general and temporary condition of partial or complete inundation of normally dry land areas from:

1. The overflow of water from channels and reservoir spillways;
2. The unusual and rapid accumulation or runoff of surface waters from any source; or
3. Mudslides or mudflows that occur from excess surface water that is combined with mud or other debris that is sufficiently fluid so as to flow over the surface of normally dry land areas (such as earth carried by a current of water and deposited along the path of the current).

Flood damage-resistant materials: Any building product [material, component or system] capable of withstanding direct and prolonged contact with floodwaters without sustaining significant damage. Flood damage-resistant materials must comply with FEMA Technical Bulletin 2 “Flood Damage-Resistant Materials Requirements,” dated August 2008, or as amended.

Flood fringe: The portion of land in Zone AE of the regulatory floodplain which is located outside of the designated floodway for a specific waterway.

Flood Hazard Zones: Areas designated by FEMA on the FIRM and/or LOMRs that correspond to differing types and levels of flood risk. These zones include, but are not limited to: A, A1-A30, AE, AH, AO, AR, AR/A1-A30, AR/AE, AR/AH, AR/AO, A99, B, C, D, E, M, V, V1-V30, VE, VO, X (shaded) and X (unshaded). The definitions of each zone are as indicated on the associated FIRM.

Flood Insurance Rate Map (FIRM): The official map on which FEMA has delineated both the Special Flood Hazard Areas (SFHA) and the risk premium zones applicable to the community.

Flood Insurance Study (FIS): The official report provided by FEMA which contains the Flood Insurance Rate Map (FIRM), floodway data tables, and flood profiles for studied flooding sources. This information can be used to determine base flood elevations (BFEs) for some areas.

Floodplain: Any land area susceptible to being inundated as the result of a flood.

Floodplain Administrator: The community official designated to administer and enforce the floodplain management regulations and other appropriate sections of Title 44 of the Code of Federal Regulations pertaining to floodplain management.

Flood profile: A graph or longitudinal profile showing the relationship of the water surface elevation of a flood event to a location along a waterway.

Floodproofing: Any combination of structural and/or non-structural provisions, additions, changes, or adjustments to properties and structures subject to flooding, primarily for the reduction or elimination of flood damages to properties, water and sanitary facilities, structures, machinery and equipment, and contents of buildings. The two types of floodproofing are “wet floodproofing” and “dry floodproofing.”

Flood protection elevation (FPE): The elevation of freeboard plus the base flood elevation (BFE), or in an AO Zone freeboard plus depth of flooding (2’ depth if no number specified) above the highest adjacent grade (HAG).

Flood storage area: The flood fringe and areas of shallow flooding portion of the regulatory floodplain in which flows are characteristically of shallow depths and low velocities.

Floodway: The channel of a river or other watercourse and the adjacent land areas that must be reserved in order to discharge the base flood without cumulatively increasing the water surface elevation more than a designated height. The designated height for all newly studied reaches shall be one-half (0.5) foot. A Letter of Map Revision (LOMR) to an existing floodway designation may continue to use the floodway criteria at the time of the existing floodway designation, at the discretion of the Floodplain Administrator. Existing one (1) foot floodway designations may be used until revised on the regulatory floodplain map.

Freeboard: The vertical distance in feet above a predicted water surface elevation intended to provide a margin of safety to compensate for unknown factors that could contribute to flood heights greater than the height calculated for a selected size flood such as debris blockage and increased runoff due to urbanization of the watershed. For purposes of this ordinance, freeboard is measured above the BFE, or above the depth of flooding in AO Zones, defined for the regulatory floodplain.

Highest adjacent grade (HAG): The highest natural elevation of the ground surface prior to construction next to the proposed walls of a structure.

Historic structure: Any structure that is:

1. Listed individually in the National Register of Historic Places (a listing maintained by the Department of Interior) or preliminarily determined by the Secretary of the Interior as meeting the requirements for individual listing on the National Register;
2. Certified or preliminarily determined by the Secretary of the Interior as contributing to the historical significance of a registered historic district or a district preliminarily determined by the Secretary to qualify as a registered historic district;
3. Individually listed on a state inventory of historic places in states with historic preservation programs which have been approved by the Secretary of Interior; or
4. Individually listed on a local inventory of historic places in communities with historic preservation programs that have been certified either:
    a. By an approved state program as determined by the Secretary of the Interior; or
    b. Directly by the Secretary of the Interior in states without approved programs.

Lateral addition: An addition which is horizontal in nature and increases the footprint of the existing structure.

Letter of Map Revision (LOMR): FEMA's official revision of an effective Flood Insurance Rate Map (FIRM). LOMRs are generally based on the implementation of physical measures that affect the hydrologic or hydraulic characteristics of a flooding source and thus result in the modification of the existing regulatory floodway, the effective base flood elevations (BFEs), or the Special Flood Hazard Area (SFHA).

Letter of Map Revision Based on Fill (LOMR-F): FEMA's modification of the Special Flood Hazard Area (SFHA) shown on the Flood Insurance Rate Map (FIRM) based on the placement of fill outside the existing regulatory floodway.

Levee: A man-made structure, usually earthen embankment, designed and constructed in accordance with sound engineering practices to contain, control, or divert the flow of water so as to provide protection from temporary flooding. For a levee structure to be reflected on the FEMA Flood Insurance Rate Map (FIRM) as providing flood protection, the levee structure must meet the requirements set forth in Section 65.10 of the National Flood Insurance Program (NFIP) regulations.

Levee system: A flood protection system which consists of a levee, or levees, and associated structures, such as closure and drainage devices, which are constructed and operated in accordance with sound engineering practices.

Lowest adjacent grade (LAG): The lowest elevation of the ground surface touching a structure.

Lowest floor: The lowest floor of the lowest enclosed area (including basement). An unfinished or flood resistant enclosure, usable solely for parking of vehicles, building access or limited storage in an area other than a basement area is not considered a building's lowest floor; provided that such enclosure is not built so as to render the structure in violation of the applicable non-elevation design requirement of Section 60.3 of the National Flood Insurance Program (NFIP) regulations.

Machinery and equipment: Utilities and mechanical items that service the building. These items include, but are not limited to: elevators and their associated equipment, transformers, electrical panels, electric meters, junction boxes, receptacles, switches, gas meters, furnaces, hot water heaters, heat pumps, air conditioners, generators, ductwork, communications equipment, and other service facilities.

Manager of public works: Hereinafter called the manager, he shall be the officer in full charge and control of the department of public works (refer to section 56-204(a)).

Manufactured home: A structure, transportable in one or more sections, which is built on a permanent chassis and is designed for use with or without a permanent foundation when connected to the required utilities. The term "manufactured home" includes “mobile home” but does not include "recreational vehicle" or “modular home”.

Manufactured home park or subdivision: A parcel (or contiguous parcels) of land divided into two or more manufactured home lots for rent or sale.

Mean Sea Level: For purposes of the National Flood Insurance Program (NFIP), the North American Vertical Datum (NAVD) of 1988 or other datum, to which Base Flood Elevations shown on a community's Flood Insurance Rate Map (FIRM) are referenced.

Mobile home: A type of manufactured home built prior to 1976 and constructed to the American National Standards Institute (ANSI) A-119.1 Standard.

Modular home: A Colorado labeled factory-built residential structure that meets or exceeds the currently adopted building codes in Colorado. Modular housing is custom designed and can be fabricated for both single-family and multi-family use.

National Flood Insurance Program (NFIP): FEMA’s program of flood insurance coverage and floodplain management administered in conjunction with the Robert T. Stafford Relief and Emergency Assistance Act. The NFIP has applicable Federal regulations promulgated in Title 44 of the Code of Federal Regulations. The U.S. Congress established the NFIP in 1968 with the passage of the National Flood Insurance Act of 1968.

New Construction: For the purposes of determining insurance rates, structures for which the “start of construction” commenced on or after the effective date of an initial FIRM or after December 31, 1974, whichever is later, and includes any subsequent improvements to such structures. For floodplain management purposes, “new construction” means structures for which the “start of construction” commenced on or after the effective date of a floodplain management regulation adopted by a community and includes any subsequent improvements to such structures. In Denver, the effective date of the initial FIRM is April 15, 1986 and the effective date of the first adopted floodplain management regulation is March 17, 1986.

New manufactured home park or subdivision: A manufactured home park or subdivision for which the construction of facilities for servicing the lots on which the manufactured homes are to be affixed (including at a minimum, the installation of utilities, the construction of streets, and either final site grading or the pouring of concrete pads) is completed on or after the effective date of floodplain management regulations adopted by a community. In Denver, the effective date of the first adopted floodplain management regulation is March 17, 1986.

No-Rise Certification: A record of the results of an engineering analysis conducted to determine whether a project will increase flood heights in a floodway. A No-Rise Certification must be supported by technical data and signed by a licensed Colorado Professional Engineer. The supporting technical data should be based on the standard step-backwater computer model used to develop the floodway shown on the Flood Insurance Rate Map (FIRM).

Obstruction: Any material or item that may impact the flow or storage of floodwaters. This includes, but is not limited to: fill, structures, bridges, roadways, equipment, walls, and fences.

Occupancy: The use or possession of a building by humans for purposes including, but not limited to, residential, office, hospital, or commercial.

One-hundred-year flood: See “base flood.”

One-percent-annual-chance flood or one-percent-chance flood: See “base flood.”

Phased improvement: Any improvement to a structure that occurs within one (1) year of permit closeout of any previous construction on that structure. Phased improvements may be intentional or unintentional. Examples of phased improvement include, but are not limited to: incomplete work, multiple permits, consecutive permits, modification of existing permits, and unauthorized work. Changes in ownership do not preclude previous improvements. This applies to the entire structure as a whole, including multi-tenant and multi-unit structures.

Recreational vehicle (RV): Means a vehicle which is:

1. Built on a single chassis;
2. 400 square feet or less when measured at the largest horizontal projection;
3. Designed to be self-propelled or permanently towable by a light duty truck; and
4. Designed primarily not for use as a permanent dwelling but as temporary living quarters for recreational, camping, travel, or seasonal use.

Regulatory floodplain: The area of land subject to inundation by the base flood as delineated by the Special Flood Hazard Area (SFHA), any other floodplain maps that have been adopted by the manager of public works, and areas that have been removed from the SFHA by a FEMA issued Letter of Map Revision Based on Fill (LOMR-F).

Regulatory floodway: See “floodway.”

Special Flood Hazard Area (SFHA): The land within a community subject to inundation by the base flood as shown on the Flood Insurance Rate Map (FIRM).

Start of construction: The date the building permit was issued, including substantial improvement, provided the actual start of construction, repair, reconstruction, rehabilitation, addition, placement, or other improvement was within 180 days of the permit date. The actual start means either the first placement of permanent construction of a structure on a site, such as the pouring of slab or footings, the installation of piles, the construction of columns, or any work beyond the stage of excavation; or the placement of a manufactured home on a foundation. Permanent construction does not include land preparation, such as clearing, grading and filling; nor does it include the installation of streets and/or walkways; nor does it include excavation for basement, footings, piers or foundations or the erection of temporary forms; nor does it include the installation on the property of accessory buildings, such as garages or sheds not occupied as dwelling units or not part of the main structure. For a substantial improvement, the actual start of construction means the first alteration of any wall, ceiling, floor, or other structural part of a building, whether or not that alteration affects the external dimensions of the building.

Structure: A walled and roofed building, including a gas or liquid storage tank, which is principally above ground, as well as a manufactured home.

Substantial damage: Damage of any origin sustained by a structure whereby the cost of restoring the structure to its before-damaged condition would equal or exceed 50 percent of the market value of the structure just prior to when the damage occurred.

Substantial improvement: Any reconstruction, rehabilitation, addition, or other improvement of a structure, the cost of which equals or exceeds 50 percent of the market value of the structure before "start of construction" of the improvement. The value of the structure shall be determined by the local jurisdiction having land use authority in the area of interest. This includes structures which have incurred "substantial damage", regardless of the actual repair work performed. “Phased improvements” are calculated cumulatively towards the cost of improvement. The term “substantial improvement” does not, however, include either:

1. Any project for improvement of a structure to correct existing violations of state or local health, sanitary, or safety code specifications which have been identified by the local code enforcement official and which are the minimum necessary conditions, or
2. Any alteration of a "historic structure” provided that the alteration will not preclude the structure's continued designation as a "historic structure."

Use: The purpose for which land or structures thereon is designed, arranged or intended to be occupied or used, or for which it is occupied, maintained, rented or leased.

Variance: A grant of relief from the requirements of this article, when specific enforcement would result in unnecessary hardship (hardship that is solely financial is not grounds for a variance). A variance, therefore, permits construction or development in a manner otherwise prohibited by this article.

Vertical addition: An addition which is vertical in nature, but does not increase the horizontal footprint of the existing structure.

Violation: The failure of a structure or other development to be fully compliant with the community's floodplain management regulations. A structure or other development without the elevation certificate, other certifications, or other evidence of compliance required in National Flood Insurance Program (NFIP) regulations Section 60.3(b)(5), (c)(4), (c)(10), (d)(3), (e)(2), (e)(4), or (e)(5) is presumed to be in violation until such time as that documentation is provided.

Water Surface Elevation (WSEL): The height, in relation to the North American Vertical Datum (NAVD) of 1988 (or other datum, where specified), of floods of various magnitudes and frequencies.

Wet floodproofing: A method of floodproofing to reduce flood damage that typically involves three elements: allowing floodwaters to enter and exit to minimize structural damage, using flood damage-resistant materials, and elevating machinery and equipment. Wet floodproofing cannot be used in lieu of elevation or dry floodproofing requirements.

Zones: See “flood hazard zones.”

(Ord. No. 158-86, § 1, 3-17-86; Ord. No. 547-13, § 2, 11-4-13)

Sec. 56-202. General provisions.

(a) *Disclaimer of liability.* The degree of flood protection required by this article is considered reasonable for regulatory purposes and is based on scientific and engineering considerations. Larger floods can and will occur on rare occasions. Flood heights may be increased by manmade or natural causes. This article does not imply that land outside the regulatory floodplain or uses permitted within such areas will be free from flooding or flood damages. This article shall not create liability on the part of the city, any officer or employee thereof, the Colorado Water Conservation Board, or the Federal Emergency Management Agency (FEMA), for any flood damages that result from reliance on this article or any administrative decision lawfully made thereunder.

(b) *Jurisdiction of this article.* The provisions of this article and implementing regulations adopted by the manager apply to all lands, uses, activities, and structures in all areas of the city located within a regulatory floodplain as defined in section 56-201, "Definitions," of this article.

(c) *Interpretation.* In the interpretation and application of this article, all provisions shall be:

(1) Considered as minimum requirements;

(2) Liberally construed in favor of the governing body; and,

(3) Deemed neither to limit nor repeal any other powers granted under State statutes.

(d) *Regulatory floodplains.*

(1) *Special Flood Hazard Areas (SFHAs).* These areas are identified by FEMA in a scientific and engineering report entitled "Flood Insurance Study for the City and County of Denver," dated November 20, 2013 with accompanying Flood Insurance Rate Maps (FIRM). Any revisions hereto are hereby adopted by reference and declared to be a part of this article.

a. *Zone A.* When base flood elevation data has not been provided in accordance with the foregoing paragraph, and an area has been designated Zone A on the FIRM, the Floodplain Administrator shall obtain, review and reasonably utilize any base flood elevation data available from federal, state or other source in order to administer the applicable conditions of section 56-203, "Regulatory floodplain use and limitations," of this article.

(2) Any other areas that are subject to inundation by the base flood, which are delineated in floodplain maps that have been adopted for regulatory use by the manager in accordance with section 56-202(e).

(3) Areas removed from the SFHA by fill. These areas are identified by FEMA by issuance of a Letter of Map Revision Based on Fill (LOMR-F). For purposes of this article this includes all existing and proposed LOMR-F areas, if the LOMR-F area has not previously been superseded by a standard LOMR.

(e) *Adoption of regulatory floodplain map.*

(1) The maps which define the regulatory floodplains established by this article shall be adopted by the manager. Such adoption shall be accomplished by:

a. Filing one (1) copy thereof with the city clerk;

b. Filing one (1) copy thereof with the city attorney;

c. Concurrently with the filings required under a. and b., above, the manager shall publish a notice stating that the filings have been made and list the dates of such filings. Such notice shall be published once in the official newspaper.

(2) The adopted maps collectively shall constitute the official regulatory floodplain map.

(3) The various individual floodplain maps constituting the official regulatory floodplain map shall be marked and maintained pursuant to a system of identification established by the department of public works.

(4) The manager and the Floodplain Administrator shall make all maps available to public inspection at all reasonable times.

(f) *Amendments to official regulatory floodplain map.*

(1) Upon the recommendation of the Floodplain Administrator, amendments to the official regulatory floodplain map, except as in Sec. 56-202(f)(2) below, shall be referred to the manager for adoption. Amendments shall be adopted as in paragraph (e) above.

(2) Those individual maps constituting a part of the official regulatory floodplain map which were originated by FEMA, shall only be amended following FEMA review and approval of data, and subsequent amendment by FEMA thereof.

(3) All amendments to the official regulatory floodplain map shall be listed in the order in which they were adopted, in a separate register maintained in and kept current by the department of public works.

(g) *Effect of other ordinances and regulations.* Wherever higher or more restrictive standards are established by the provisions of any other applicable statute, ordinance or regulation than are established by the provisions of this article, the provisions of such other statute, ordinance or regulation shall govern.

(h) *Effect of private covenants.* Nothing herein contained shall be construed to render inoperative any restrictions established by covenants running with the land unless such are prohibited by or are contrary to the provisions of this article.

(i) *Floodplain disclaimer.* As a part of the sale of any property within the city, a disclaimer shall be provided to the potential buyer by the seller indicating the relationship of the property to any regulatory floodplain.

(j) *Grandfathering.* The floodplain requirements in effect at the time of submittal of development plans for City review, or at the time of application for building permit, or Sewer Use and Drainage Permit, shall be applied to such development or building project.

(Ord. No. 158-86, § 1, 3-17-86; Ord. No. 711-94, § 1, 9-6-94; Ord. No. 547-13, § 3, 11-4-13)

Sec. 56-203. Regulatory floodplain use and limitations.

(a) *General.* The following provisions shall apply to all uses within all areas of regulatory floodplains as defined and adopted under section 56-202(d) and (e) of this article.

(b) *Existing uses.* An existing use in a regulatory floodplain may be changed to any use which is allowed by the ordinances of the city; provided, however, that such change of an existing use shall be limited by and shall be in accordance with the regulations herein established.

(c) *Regulatory floodplain.* In all areas of the regulatory floodplain, the following provisions are required:

(1) No development, use, fill, excavation, construction or alteration within a regulatory floodplain shall be permitted, which acting alone or in combination with existing or future uses, would cause or result in any of the following:

a. The storage or processing of materials that are buoyant, flammable, explosive or otherwise potentially injurious to human, animal or plant life in time of flooding;

b. The disposal of garbage, sludge, waste materials or other potentially injurious substances;

c. An obstruction or depositing of any material which would impair the flow capacity of a regulatory floodplain or increase floodwater depths or velocities so as to cause probable damage to others wherever located;

d. A substantial increase in sedimentation and/or erosion.

(2) All new construction, lateral additions, and substantial improvements shall be approved by the department of public works for location and shall be:

a. Designed (or modified) and adequately anchored to prevent flotation, collapse, or lateral movement of the structure resulting from hydrodynamic and hydrostatic loads, including the effects of buoyancy; and

b. Designed and constructed with flood damage-resistant materials below the FPE; and

c. Designed and constructed by methods and practices that minimize flood damages; and

d. Designed and constructed with gas, electrical, heating, ventilation, plumbing, air conditioning, and communications equipment and other service facilities that are designed and/or located so as to prevent water from entering or accumulating within the components, or otherwise damaged, during conditions of flooding.

(3) On-site waste disposal systems shall be located to avoid impairment to them or contamination from them during flooding.

(4) No new manufactured home, new manufactured home park, or expansion to an existing manufactured home park shall be located in the regulatory floodplain.

(5) All new and replacement water supply systems shall be designed to minimize or eliminate infiltration of floodwaters into the system.

(6) All new and replacement sanitary sewage systems shall be designed to minimize or eliminate infiltration of floodwaters into the system and discharge from the system into flood waters.

(7) For all proposed uses or developments that alter a watercourse within a regulatory floodplain, the following standards apply:

a. Channelization and flow diversion projects shall appropriately consider issues of sediment transport, erosion, deposition, and channel migration and properly mitigate potential problems through the project as well as upstream and downstream of any improvement activity. A detailed analysis of sediment transport and overall channel stability should be considered, when appropriate, to assist in determining the most appropriate design.

b. Channelization and flow diversion projects shall evaluate the residual floodplains.

c. Any channelization or other stream alteration activity proposed by a project proponent must be evaluated for its impact on the regulatory floodplain and be in compliance with all applicable Federal, State and local floodplain rules, regulations and ordinances.

d. Any stream alteration activity shall be designed and sealed by a licensed Colorado Professional Engineer or Certified Professional Hydrologist.

e. All activities within the regulatory floodplain shall meet all applicable Federal and State requirements and regulations, as well as the provisions of this article and implementing regulations adopted by the manager.

f. Within the floodway, stream alteration activities shall not be constructed unless the project proponent demonstrates through a floodway analysis and report, sealed by a licensed Colorado Professional Engineer, that there is not more than a 0.00-foot rise in the proposed conditions compared to existing conditions floodway resulting from the project, otherwise known as a No-Rise Certification, unless a CLOMR for the floodway revision has been approved by FEMA.

g. Maintenance shall be required for any altered or relocated portions of watercourses so that the flood-carrying capacity is not diminished.

(8) For waterways with base flood elevations for which a regulatory floodway has not been designated, no proposed use or development shall be permitted within Zone AE, unless it is demonstrated that the cumulative effect of the proposed development, when combined with all other existing and anticipated development, will not increase the water surface elevation of the base flood more than one-half (0.5) foot at any point within the community; unless a FEMA approved CLOMR has been issued for that use or development.

(9) Permitted uses: The following uses shall be permitted within the regulatory floodplain to the extent that they will comply with all requirements of this article and the Denver Zoning Code:

a. Agricultural uses such as general farming, pasture, grazing, outdoor plant nurseries, horticulture, truck farming, forestry, sod farming and wild crop harvesting;

b. Uses such as loading areas, parking areas, airport landing strips and storage yards for equipment or machinery easily removed from the site or not subject to flood damage;

c. Private and public recreational uses such as parks, golf courses, driving ranges, archery ranges, picnic grounds, boat launching ramps, and hiking, biking and horseback riding trails;

d. Utility facilities that are not considered to be critical facilities including, but not limited to, wastewater facilities, water, gas and electric distribution facilities, roadways and bridges;

e. Fill, excavation or deposit of materials:

1. Any such fill, excavation or deposit of materials shall be permitted only upon a finding that the fill, excavation or deposit of materials will have some beneficial purpose and the amount thereof will not be greater than is necessary to achieve that purpose, as demonstrated by a plan submitted by the owner showing the final dimensions of the proposed fill, excavation or material and the use to which the altered land will be put;

2. The fill or material does not encroach on the floodway;

3. Any fill or deposit that reduces the hydraulic capacity shall require appropriate hydraulic studies and a review of the urban impact on such reduction;

4. The fill or material will be protected against erosion by rip-rap, strong vegetative cover or bulkheading.

(d) *The floodway.* The floodway is an extremely hazardous area due to the velocity of floodwaters which carry debris, potential projectiles, and erosion potential. In addition to section 56-203(c), the following provisions shall also apply to all uses within the floodway:

(1) No encroachments, including fill, obstructions, new construction, lateral additions, substantial improvements, or other development shall be permitted within the floodway unless it has been demonstrated through hydrologic and hydraulic analyses performed by a licensed Colorado Professional Engineer and in accordance with standard engineering practice that the proposed encroachment would not result in any increase (requiring a No-Rise Certification) in flood levels during the occurrence of the base flood.

(2) No building designed for human occupancy shall be placed in the floodway.

(3) Encroachments may be permitted in the floodway that result in an increase in base flood elevations, provided that a CLOMR for the floodway revision is approved by FEMA.

(e) *Flood storage area.* In addition to the provisions of section 56-203(c), the following requirements shall also apply to all uses in the flood storage area:

(1) *Residential construction.* New construction, lateral addition, and substantial improvement of any residential structure shall meet the following requirements:

a. Have the lowest floor (including basement) and all associated machinery and equipment, elevated with a minimum of one and one-half (1.5) feet of freeboard.

b. Within Zones AH and AO, have adequate drainage paths around structures on slopes, to guide floodwaters around and away from proposed structures.

c. Upon completion of construction, and prior to Certificate of Occupancy, a “finished construction” version of the FEMA Elevation Certificate must be submitted to, and approved by, the Floodplain Administrator.

(2) *Nonresidential construction.* New construction, lateral addition, and substantial improvement of any commercial, industrial, or other nonresidential structure, with the exception of critical facilities, shall meet the following requirements:

a. Either have the lowest floor (including basement) and all associated machinery and equipment:

1. Elevated with a minimum of one and one-half (1.5) feet of freeboard; or,

2. Together with attendant utility and sanitary facilities, be dry floodproofed with a minimum of one and one-half (1.5) feet of freeboard.

b. Within Zones AH and AO, have adequate drainage paths around structures on slopes, to guide floodwaters around and away from proposed structures.

c. Upon completion of construction, and prior to Certificate of Occupancy, a “finished construction” version of the FEMA Elevation Certificate must be submitted to, and approved by, the Floodplain Administrator. If dry floodproofed, a “construction drawings” version of the FEMA Floodproofing Certificate must be submitted to, and approved by, the Floodplain Administrator prior to permit issuance and a “finished construction” version of the FEMA Floodproofing Certificate must be submitted to, and approved by, the Floodplain Administrator prior to validation of Certificate of Occupancy.

(3) *Crawlspaces.* New construction, lateral addition, and substantial improvement involving any crawlspace shall meet the following requirements:

a. The crawlspace, and all machinery and equipment, must either:

1. Have the interior grade elevated with a minimum of one and one-half (1.5) feet of freeboard; or

2. Be wet floodproofed with a minimum of one and one-half (1.5) feet of freeboard.

b. Wet floodproofing shall only be permitted for crawlspaces meeting the following requirements:

1. They shall be used solely for parking of vehicles, building access, or limited storage and not used for human habitation; and

2. All associated machinery and equipment shall be elevated or dry floodproofed to a minimum of the FPE; and

3. The interior grade elevation that is below the FPE shall not be lower than two (2) feet below the lowest adjacent grade; and

4. The height of the crawlspace, measured from the bottom of the floor joist to the top of footing, shall not exceed four (4) feet at any point; and

5. An adequate drainage system that allows floodwaters to drain from the interior area of the crawlspace following a flood shall be provided; and

6. The enclosed area shall be designed to automatically equalize hydrostatic flood forces on exterior walls by allowing for the entry and exit of floodwaters as required under NFIP regulations Sec. 60.3(c)(5).

(4) *Accessory structures.* New construction, lateral addition, and substantial improvement of any accessory structure shall meet the following requirements:

a. Have the lowest floor (including basement) and all associated machinery and equipment be either:

1. Elevated with a minimum of one and one-half (1.5) feet of freeboard; or

2. Wet floodproofed with a minimum of one and one-half (1.5) feet of freeboard.

b. Within Zones AH and AO, have adequate drainage paths around structures on slopes, to guide floodwaters around and away from proposed structures.

c. Upon completion of construction, and prior to Certificate of Occupancy, a FEMA Elevation Certificate must be submitted to, and approved by, the Floodplain Administrator.

d. Wet floodproofing shall only be permitted for accessory structures meeting the following requirements:

1. They shall be used solely for parking of vehicles, building access, or limited storage and not used for human habitation; and

2. They shall be designed to have low flood damage potential, and be no more than 600 square feet; and

3. They shall be constructed and placed on the building site so as to offer the minimum resistance to the flow of floodwaters; and

4. They shall be firmly anchored to prevent floatation, collapse and lateral movement; and

5. All associated machinery and equipment shall be elevated or dry floodproofed to a minimum of the FPE; and

6. The enclosed area shall be designed to automatically equalize hydrostatic flood forces on exterior walls by allowing for the entry and exit of floodwaters as required under NFIP regulations Sec. 60.3(c)(5); and

7. They shall not be placed in the floodway unless it meets the provisions of section 56-203(d).

(5) *Critical facilities.* New construction, lateral addition, and substantial improvement of critical facilities shall be regulated as in section 56-203(e)(2), except critical facilities shall be protected to a higher standard than structures not determined to be critical facilities. For the purposes of this article, protection shall include:

a. Location outside of the regulatory floodplain; or

b. Elevation of the lowest floor (including basement), and all machinery and equipment, with a minimum of two (2) feet of freeboard; or

c. Dry floodproofing (including attendant utility and sanitary facilities) with a minimum of two (2) feet of freeboard.

d. New critical facilities shall, when practicable, have continuous non-inundated access (ingress and egress for evacuation and emergency services) during the base flood.

(6) *Recreational Vehicles (RV):* All RVs placed on sites within Zones A1-30, AH, and AE on the regulatory floodplain map shall either:

a. Be on the site for fewer than 180 consecutive days; or

b. Be fully licensed and ready for highway use. A RV is ready for highway use if it is on wheels or a jacking system, attached to the site only by quick disconnect type utilities and security devices, and has no permanently attached additions.

(f) *Areas removed from SFHA by LOMR-F:* For purposes of this article, areas that have been removed from the SFHA by a FEMA issued LOMR-F are hereby subject to the same provisions as section 56-203(e)(1), (2), (3), (4) and (5). These areas will not be subject to floodplain regulation if the LOMR-F area has since been superseded by a standard LOMR.

(Ord. No. 158-86, § 1, 3-17-86; Ord. No. 547-13, § 4, 11-4-13)

Sec. 56-204. Administration.

(a) *Administration of article by manager of public works.* The administration of the provisions of this article is hereby vested in and shall be exercised by the manager who may, in accordance with article VI of chapter 2 of the Revised Municipal Code, prescribe forms and rules and regulations in conformity with this article for the proper administration and enforcement hereof. The manager may delegate the administration of this article or any part thereof, subject to the limitations of the Charter and this Code, to duly qualified deputies and agents of the manager. For the purposes of this article, the manager shall delegate the administration thereof to the designated Floodplain Administrator except section 56-202(e)(1), "Adoption of regulatory floodplain map," and section 56-204(f), "Administrative review."

(b) *Responsibilities of the Floodplain Administrator.*

(1) Maintain and hold open for public inspection all records pertaining to the provisions of this article, including required FEMA Elevation Certificates and Floodproofing Certificates.

(2) Review, approve, or deny all FEMA Elevation Certificates and Floodproofing Certificates required as a condition of the Sewer Use and Drainage Permit.

(3) Review, approve, or deny all applications related to construction in the regulatory floodplain.

(4) Review applications to determine whether a proposed building site, including the placement of manufactured homes, will be reasonably safe from flooding.

(5) Review permits for proposed development to assure that all necessary water and/or floodplain permits have been obtained from those Federal, State or local governmental agencies (including Section 404 of the Federal Water Pollution Control Act Amendments of 1972, 33 U.S.C. 1334) from which prior approval is required.

(6) Inspect all development at appropriate times during the period of construction to ensure compliance with all provisions of this article, including proper elevation of the structure.

(7) Where interpretation is needed as to the exact location of the boundaries of the regulatory floodplain (for example, where there appears to be a conflict between a mapped boundary and actual field conditions) the Floodplain Administrator shall make the necessary interpretation.

(8) When base flood elevation data has not been provided in accordance with section 56-202(d), the Floodplain Administrator shall obtain, review and reasonably utilize any base flood elevation data and floodway data available from a Federal, State, or other source, in order to administer the provisions of this article.

(9) Notify, in riverine situations, adjacent communities and the Colorado Water Conservation Board, prior to any alteration or relocation of a watercourse, and submit evidence of such notification to FEMA.

(10) Ensure that the flood carrying capacity within the altered or relocated portion of any watercourse is maintained.

(c) *Responsibilities of land developers.*

(1) Each developer of land within the city has a duty to provide on his/her property all reasonably necessary drainage and detention facilities to ensure the adequate drainage and control of storm waters which fall on his/her properties or which contribute runoff to his/her property.

(2) All subdivision or other development proposals shall:

a. Be reasonably safe from flooding and minimize flood damage; and

b. Meet all other requirements of this article; and

c. Generate BFE data for subdivisions greater than 50 lots or 5 acres, whichever is lesser, if not otherwise provided; and

d. Have adequate drainage provided to reduce exposure to flood hazards; and

e. Have public utilities and facilities such as sewer, gas, electrical, communications, and water systems located and constructed to minimize or eliminate flood damage.

(3) A storm drainage plan shall be submitted and approved prior to issuing a wastewater permit for new construction, lateral addition, or substantial improvement of a building located in a regulatory floodplain. Such plan shall be reviewed with regard for generally accepted engineering principles and standards as follows:

a. The storm drainage plan shall provide the base flood elevations for those areas where no base flood elevation had previously been provided, and shall define the alignment and boundary of any natural drainage course, drainage facility or subdrainage area on the land in question, and it shall include drawings, profiles, specifications for the construction of channels, conduits, detention ponds, culverts, bridges and all other drainage facilities reasonably necessary to ensure that flood and storm waters, including drainage from other lands which will contribute runoff to the subject property, will be adequately drained, stored, or otherwise controlled; plans drawn to scale showing the nature, location, dimensions, and elevations of the area in question; size and location of existing and/or proposed structures, fill, storage of materials, drainage facilities; regulatory floodplain area and the location of the foregoing. Specifically, the following information is required:

1. Elevation in relation to mean sea level of the lowest floor (including basement) of all structures;

2. Elevation in relation to mean sea level to which any nonresidential structure shall be floodproofed;

3. A certification from a licensed Colorado Professional Engineer or Architect that the nonresidential floodproofed structure meets the floodproofing criteria of section 56-203(e)(2).

4. Description of the extent to which any watercourse will be altered or relocated as a result of proposed development.

b. Included in the plan shall be a schedule containing the estimated dates of completion of construction for all storm drainage facilities shown on the plan. If and when the plan is approved and the wastewater permit issued, the owner and applicant shall comply with said schedule.

(4) Any improvements to an existing drainageway which will result in a change of the regulatory floodplain will be constructed consistent with applicable city criteria and standards. Development within the regulatory floodplain will not be permitted until the approved drainage improvements have been constructed and the amended floodplain maps have been approved and adopted by the manager and/or FEMA.

(5) Proposed revisions or amendments to the SFHA shall be requested of FEMA by the applicant by submitting all required supporting information to FEMA following approval by the Floodplain Administrator.

(6) Proposed changes or improvement to a watercourse which will result in a request for a physical revision to the SFHA must be preceded by a receipt from FEMA of a CLOMR Request for this letter shall be made as in Section 56-204(c)(5) above. Construction of the proposed improvements may not commence until such letter is received. After construction of the drainageway improvements, "as constructed" information and any additional supporting data shall be submitted to FEMA following approval by the Floodplain Administrator for a LOMR to accomplish revision of the SFHA. Permits for non permitted uses will not be issued until physical map revisions become effective.

(7) Any alteration or relocation of a watercourse or drainageway will require that a notification report be made to adjoining communities, the Colorado Water Conservation Board and FEMA that the conveyance capacity of the watercourse or drainageway shall be maintained within the altered portion of the drainageway. This report shall be the owner's responsibility and shall be made prior to construction, but subsequent to approval by FEMA and coordinated through the Floodplain Administrator.

(8) For waterways with base flood elevations for which a regulatory floodway has not been designated, the land developer shall demonstrate that the cumulative effect of the proposed development, when combined with all other existing and anticipated development, will not increase the water surface elevation of the base flood more than one-half (0.5) foot at any point within the community.

a. Under the provisions of 44 CFR Chapter 1, Section 65.12, of the NFIP regulations, a community may approve certain development in Zones A1-30, AE, AH, on the community's FIRM which increases the water surface elevation of the base flood by more than one-half (0.5) foot, provided that the developer first applies for a FEMA CLOMR, fulfills the requirements for such revisions as established under the provisions of Section 65.12 of the NFIP regulations, and receives FEMA approval.

(9) Obtain a CLOMR whenever an activity in the floodway is known or suspected to cause more than a 0.00-foot rise in the proposed conditions compared to existing conditions BFEs. An exception may be made, at the discretion of the Floodplain Administrator, when the activity is strictly drainageway maintenance in which the intent is to restore the natural conditions or hydraulic capacity of the drainageway provided that the activity does not cause more than a 0.00-foot rise in the proposed conditions compared to effective conditions BFEs and that any BFE rise compared to existing conditions is contained entirely within public property which would not otherwise require adverse impact notification.

(10) Obtain a LOMR:

a. Upon completion of an activity approved in a CLOMR; or,

b. Whenever an activity in the floodway is known or suspected to increase or decrease the BFE in excess of 0.3 vertical feet.

(d) Boundary mapping disputes. The boundaries of the regulatory floodplain shall be as they appear on the official regulatory floodplain maps. Where there appears to be a conflict between the boundary lines illustrated on the map and actual field conditions, the person contesting the location of the boundary shall be given an opportunity to submit his own technical evidence.

No deviation from the boundary line as mapped shall be allowed unless the evidence clearly and conclusively establishes that the mapped location of the line is incorrect. However, if the evidence submitted, after review, clearly shows that the recorded boundary does not reflect the true condition, an exception may be granted. If the location of the boundary line should still be in dispute, that person may appeal as provided in Section 56-204(f).

(e) *Variances.*

(1) The manager or his designee may authorize, upon application in specific cases, such variances from the terms of this article, subject to terms and conditions fixed by the manager or his designee, as will not be contrary to the purposes of this article where, owing to exceptional and extraordinary circumstances, literal enforcement of the provisions of this article will result in unnecessary hardship. No variance shall be authorized hereunder unless the manager or his designee shall find:

a. The variance will not result in an increase in the flood levels in a designated floodway during a base flood discharge;

b. The variance is the minimum necessary to afford relief considering the flood hazard;

c. The variance will not result in an increased risk to public safety, a substantial increase in public expense or a nuisance;

d. The lowest floor, including the basement, of any residential structure will be elevated to a minimum of the FPE;

e. The proposed change or development will not unreasonably endanger the life, health, safety, welfare or property of any person in time of floods, or result in the damming of floodwaters or the contribution of potentially damaging debris to floodwaters;

f. The use requested is a permitted use under the zoning ordinance;

g. The applicant is the owner of the subject property.

(2) The following matters shall be considered by the manager or his designee in determining all applications for variances:

a. The danger that materials may be swept onto other lands to the injury of others;

b. The danger to life and property due to flooding or erosion damage;

c. The susceptibility of the proposed facility and its contents to flood damage and the effect of such damage on the individual owner;

d. The importance of the services provided by the proposed facility to the community;

e. The necessity to the facility of a waterfront location where applicable;

f. The availability of alternative locations, for the proposed use which are not subject to flooding or erosion damage;

g. The compatibility of the proposed use with the existing and anticipated development;

h. The relationship of the proposed use to the comprehensive plan and floodplain management program for that area;

i. The safety of access to the property in times of flood for ordinary and emergency vehicles;

j. The expected height, velocity, duration, rate of rise, and sediment transport of the floodwaters and the effects of wave action, if applicable, expected at the site;

k. The costs of providing governmental services during and after flood conditions including maintenance and repair of public utilities and facilities such as sewer, gas, electrical, communications, and water systems, and streets and bridges.

(3) Each and every application for a variance shall contain adequate technical information certified by a professional engineer licensed in the State which shall include, unless waived in writing by the manager or his designee, the following:

a. A certified topographic survey by a licensed land surveyor of the applicant's property and surrounding areas that may be affected by any proposed change; said survey data shall include plan, profile and cross-sections showing accurate elevations of all points, based upon North American Vertical Datum (NAVD) of 1988 (or other datum, where specified), within the limits of flooding under both existing and proposed conditions;

b. Drawings and descriptions of any proposed change to ground surface, topography or natural features or any proposed construction or modification of any structure or facility within a regulatory floodplain;

c. Drawings and descriptions defining the probable behavior of floodwaters across and in the vicinity of the applicant's property and for a reasonable distance upstream and downstream, under both existing and proposed conditions; together with all supporting hydrologic data and hydraulic analysis, computations, backwater curves, flow quantities and approximate velocities;

d. Any other information either the applicant, Floodplain Administrator, or the manager or his designee may deem necessary for a thorough and informed evaluation of the proposed activity;

(4) Any applicant to whom a variance is granted shall be given written notice that the structure will be permitted to be built, added onto, or substantially improved with a lowest floor elevation below the FPE and that the cost of flood insurance will be commensurate with the increased risk resulting from the reduced lowest story elevation.

(5) The Floodplain Administrator shall maintain the records of all appeal actions and report through a notice the issuance of any variance to FEMA upon request which shall include the following:

a. The owner’s name, address, phone number and the address of the project.

b. An explanation of the variance including justification for granting a variance, base flood elevations, lowest floor elevations, and any other relevant information.

c. Any appropriate hydraulic studies.

(f) *Administrative review.* Any person who disputes any determination made by or on behalf of the city pursuant to and by authority of the manager, which determination adversely affects such person, may petition the manager for a hearing concerning such determination no later than thirty (30) days after

having been notified of any such determination by the procedure described in D.R.M.C. section 56-106.

(g) *Compliance.* No structure in a regulatory floodplain shall hereafter be located, constructed, enlarged, converted, altered and/or the profile of the land changed without full compliance with the terms of this article and other applicable regulations. Nothing herein shall prevent the City and County of Denver from taking such lawful action as is necessary to prevent or remedy any violation. These regulations meet the minimum requirements as set forth by the Colorado Water Conservation Board and the NFIP.

(Ord. No. 158-86, § 1, 3-17-86; Ord. No. 547-13, § 5, 11-4-13)

Sec. 56-205. Enforcement; violations; penalties.

(a) The violation of the provisions of this article or of the rules and regulations of the manager issued pursuant to this article by any person shall be unlawful.

(b) Any person who fails to obey a lawful order to correct any condition which is in violation of this article shall be subject to a civil penalty of not more than nine hundred ninety-nine dollars ($999.00) per day for each day said person remains in violation.

(c) Penalties shall be determined by the manager after a hearing as to propriety and amount thereof. The manager shall consider the history of violations, whether the owner was negligent, the effect of the owner's ability to continue in business, the gravity of the violation, and demonstrated good faith of the owner in attempting to achieve rapid compliance after notification of a violation.

(d) If not paid, penalties may be collected by the manager by action initiated in the district court for collection of such penalty.

(e) If the owner of land, use of land, or structure which is in violation of this article fails to begin activity which will bring the land, the use of land, or the structure into compliance with this article, after notice of said violation or violations and within the time specified in said notice, the department may proceed to correct said violations. If a violation of this article is determined to be an immediate hazard to life, health, property or public welfare, the manager may order and/or cause the immediate correction of the condition. The city's costs in correcting any condition which violated this article shall be recovered as follows:

(1) In the event the owner or owners fail to pay the costs and expenses for correction of the condition, the department shall serve notice upon the person or persons having a recorded interest therein, of the amount of such costs and expenses, and that it will, at a time and place specified in the notice, hold a hearing when and where such persons shall be required to show cause why the amount should not be paid or a lien should not be placed against the property.

(2) In the event said persons fail to show cause as provided herein, the amount shall constitute a lien against the real property upon which the condition existed. The department shall thereafter pay the cost and expense of the correction of the condition violating this article, from any appropriation made available for that purpose, and shall certify a statement thereof to the manager of finance who shall record a notice of such lien with the clerk and recorder. The manager of finance shall assess and charge the same against the property involved, and collect the same due, plus interest thereon, in the manner as are delinquent real property taxes. If the lien remains unsatisfied, the manager of finance shall sell the property involved in the manner prescribed for sales of property for delinquent property taxes. The lien created hereby shall be superior and prior to all other liens, regardless of their dates of recordation, except liens for general taxes and special assessments. In addition to the remedies set forth herein, an action or other process provided by law may be maintained by the city to recover or collect any amounts, including interest, owing under this provision.

(3) The lien created thereby shall be superior and prior to other liens, regardless of date, except liens for general and specific taxes.

(f) The city may also petition the district court for the issuance of a preliminary or permanent injunction, or both, as may be appropriate, restraining any person from the continued violation of this article.

(Ord. No. 158-86, § 1, 3-17-86; Ord. No. 464-98, § 11, 7-6-98; Ord. No. 775-07, § 231, 12-26-07; Ord. No. 547-13, § 6, 11-4-13)

Sec. 56-206. Documents

(a) The following documents shall be maintained by the manager or his designee in perpetuity:

(1) All Sewer Use and Drainage permits issued for floodplain which shall, at a minimum, list the lowest floor elevation of the structure and the base flood elevation at its location.

(2) All FEMA Elevation Certificates or Floodproofing Certificates required as a condition of the Sewer Use and Drainage Permit.

(3) All regulatory floodplain maps and revisions thereto.

(4) All appeals actions.

(5) All variance and administrative review actions.

(Ord. No. 547-13, § 7, 11-4-13)

This page intentionally left blank.

5.0 RAINFALL

5.1 Introduction

The design rainfall data to be used to complete hydrologic analyses described in the RUNOFF chapter of these DENVER CRITERIA are presented in this section. More specifically, this chapter provides: 1) point precipitation values for Denver, 2) information on the Colorado Urban Hydrograph Procedure (CUHP), and 3) an intensity-duration-frequency table for use with the Rational Method. All hydrological analyses within Denver shall use the rainfall data presented herein for calculating storm runoff. There may be cases where the designer needs to consider events more extreme than the 100-year storm (e.g., for public safety).

The design storms and intensity-frequency-duration tables for Denver were developed using the rainfall data and procedures presented in the DISTRICT MANUAL and are presented herein for convenience.

5.2 Rainfall Depth-Duration-Frequency Values

A review of the isopluvial maps presented in the *Precipitation-Frequency Atlas of the Western United States, Volume III-Colorado* (National Oceanic and Atmospheric Administration [NOAA] Atlas) shows that all of Denver can be included in one rainfall zone. The precipitation values for various return periods and duration storms were found to have minimal variation.

The 1-hour point rainfall is necessary for use with both the Rational Method and CUHP and is also the basis for deriving durations less than one hour. For watersheds greater than 10 square miles, the 3-hour rainfall depth is required, and for watersheds 20 square miles and larger, the 6-hour rainfall depth is required for use with CUHP. One-hour point rainfall values are summarized in Table 5.1. To obtain durations less than 1 hour, the factors in Table 5.2 are applied to the 1-hour point rainfall.

Table 5.1. One-hour Point Rainfall Depths

Return Period	One-hour Point Rainfall (inches)
2-Year	0.95
5-Year	1.34
10-Year	1.55
50-Year	2.25
100-Year	2.57
Date: July, 1992 Revised:	Reference: Wastewater Management Division, 1987, as determined based on NOAA Atlas 2, Volume IIII.

Table 5.2. Calculation of Rainfall Durations Less than One Hour

Duration (minutes)	**5**	**10**	**15**	**30**
Relationship to 1-hour Point Precipitation (P_1)	0.29P_1	0.45P_1	0.57P_1	0.79P_1
Reference: UDFCD 2001, Volume 1.				

These point rainfall depths must be distributed temporally (e.g., 5-minute increments) for use with the CUHP model. Area adjustment of these point rainfall values is required based on watershed size when using CUHP. CUHP automatically calculates temporal adjustments to rainfall distribution for various storm events and watershed sizes in accordance with the RAINFALL chapter of the DISTRICT MANUAL.

Table 5.3 provides the rainfall intensity-duration values calculated for use with the Rational Method in small watersheds that are 160 acres or less in size, based on the following equation:

$$I = \frac{28.5\ P_1}{(10 + T_c)^{0.786}} \qquad \text{(Equation 5.1)}$$

in which:

I = rainfall intensity (inches per hour)

P_1 = 1-hour point rainfall depth (inches)

T_c = time of concentration (minutes)

Table 5.3. Rainfall Intensity Duration Values for Use with the Rational Method

Time	Rainfall Intensity in Inches per Hour					Time	Rainfall Intensity in Inches per Hour				
Min.	2-yr	5-yr	10-yr	50-yr	100-yr	Min.	2-yr	5-yr	10-yr	50-yr	100-yr
5	3.22	4.55	5.26	7.63	8.72	35	1.36	1.92	2.22	3.22	3.68
10	2.57	3.63	4.19	6.09	6.95	36	1.34	1.88	2.18	3.16	3.61
11	2.47	3.49	4.04	5.86	6.69	37	1.31	1.85	2.14	3.11	3.55
12	2.38	3.36	3.89	5.65	6.45	38	1.29	1.82	2.11	3.06	3.49
13	2.30	3.25	3.76	5.45	6.23	39	1.27	1.79	2.07	3.01	3.44
14	2.23	3.14	3.63	5.27	6.02	40	1.25	1.76	2.04	2.96	3.38
15	2.16	3.04	3.52	5.11	5.83	41	1.23	1.74	2.01	2.92	3.33
16	2.09	2.95	3.41	4.95	5.66	42	1.21	1.71	1.98	2.87	3.28
17	2.03	2.86	3.31	4.81	5.49	43	1.19	1.69	1.95	2.83	3.23
18	1.97	2.78	3.22	4.67	5.34	44	1.18	1.66	1.92	2.79	3.19
19	1.92	2.71	3.13	4.55	5.19	45	1.16	1.64	1.89	2.75	3.14
20	1.87	2.64	3.05	4.43	5.06	46	1.14	1.61	1.87	2.71	3.10
21	1.82	2.57	2.97	4.31	4.93	47	1.13	1.59	1.84	2.67	3.05
22	1.78	2.51	2.90	4.21	4.81	48	1.11	1.57	1.82	2.64	3.01
23	1.73	2.45	2.83	4.11	4.69	49	1.10	1.55	1.79	2.60	2.97
24	1.69	2.39	2.76	4.01	4.58	50	1.08	1.53	1.77	2.57	2.93
25	1.66	2.34	2.70	3.92	4.48	51	1.07	1.51	1.75	2.53	2.89
26	1.62	2.28	2.64	3.84	4.38	52	1.06	1.49	1.72	2.50	2.86
27	1.58	2.24	2.59	3.75	4.29	53	1.04	1.47	1.70	2.47	2.82
28	1.55	2.19	2.53	3.68	4.20	54	1.03	1.45	1.68	2.44	2.79
29	1.52	2.14	2.48	3.60	4.11	55	1.02	1.44	1.66	2.41	2.75
30	1.49	2.10	2.43	3.53	4.03	56	1.01	1.42	1.64	2.38	2.72
31	1.46	2.06	2.39	3.46	3.95	57	0.99	1.40	1.62	2.35	2.69
32	1.43	2.02	2.34	3.40	3.88	58	0.98	1.39	1.60	2.33	2.66
33	1.41	1.99	2.30	3.34	3.81	59	0.97	1.37	1.58	2.30	2.63
34	1.38	1.95	2.26	3.28	3.74	60	0.96	1.35	1.57	2.27	2.60

Date: Jan 2006 Calculated based on Equation 5.1.

Revised:

This page intentionally left blank.

6.0 RUNOFF

6.1 Introduction

Proper calculation of runoff is critical to proper planning and sizing of storm drainage facilities. Erroneously high runoff calculations can result in higher cost facilities, while erroneously low runoff calculations can result in damage or loss of infrastructure, life, property and natural resources. This chapter identifies the methodology to be used for determining the storm runoff design peaks and volumes for preparation of storm drainage studies, plans, and facility designs in Denver. The background, equations, examples, and spreadsheets (e.g., UD Rational) for these methods should be obtained from the RUNOFF Chapter of the DISTRICT MANUAL. The Colorado Urban Hydrograph Procedure (CUHP) and the Stormwater Management Model (SWMM) computer models for calculating and routing runoff may be downloaded from the Urban Drainage and Flood Control District (UDFCD) website (www.udfcd.org).

6.2 Runoff Calculation Methods

There are several methods for calculating runoff acceptable for use in Denver: the Rational Method, CUHP, and CUHP combined with SWMM, as described in Table 6.1. In some cases, UDFCD and/or Denver have completed detailed hydrologic studies that may also be used. Criteria determining appropriateness of use are also summarized in Table 6.1. All criteria specified in the DISTRICT MANUAL must be followed for preparation of drainage reports and storm drainage facility designs in Denver.

Table 6.1. Runoff Calculation Methods Acceptable for Use in Denver

Runoff Calculation Method	Application Criteria	Requirements for Use in Denver
Rational Method	Simple catchments less than 160 acres in size. Appropriate for small on-site detention designs. Should not be used when routing of hydrographs is required.	The maximum time of concentration to the first design point in an urbanized area shall be 10 minutes. Use Denver's standard forms SF-1 and SF-2 (Appendix A) for the calculation of Time of Concentration and Storm Drainage System Design.
CUHP	Appropriate for use in basins greater than 20 acres in size; required for areas greater than 160 acres in size. Use in combination with SWMM when routing of hydrographs is required. Can be used for smaller catchments 5-20 acres in size with smaller unit hydrograph time.	Use design storm data from Table 5.1 for input to the CUHP computer model. Provide a hard copy of input/output listings for the model and an electronic copy of the modeling results in the Final Drainage Report submittal. A summary table of peak flow rates and time to peak for subbasins in the CUHP model should be included in the Final Drainage Report submittal.
SWMM	Used to route and combine hydrographs for sub-catchments developed using CUHP. Appropriate for use in more complex basins.	Use hydrographs developed using CUHP as inputs. Provide a copy of input/output listings for the model and an electronic copy of the modeling results in the Final Drainage Report submittal. A summary table of peak flow rates at design points should be included in the Final Drainage Report submittal.
Published hydrologic information	May be used where UDFCD and/or Denver have developed detailed hydrologic studies appropriate for use in the study area.	Use values in published reports unless compelling reason to modify published values.

6.3 Assumptions for Storm Flow Analysis

When determining design storm flows, the engineer shall follow the criteria and guidelines specified in the DISTRICT MANUAL and summarized in Table 6.2 to assure that minimum design standards and uniform drainage approaches are maintained throughout Denver.

Table 6.2. Assumptions for Onsite and Offsite Storm Flow Analysis in Denver

Analysis Type	Requirements for Use in Denver
Onsite Analysis	The proposed fully developed land use plan shall be used to determine runoff coefficients. Changes in flow patterns (from the undeveloped site conditions) caused by the proposed street alignments shall be considered. The maximum time of concentration to the first design point in an urbanized area shall be 10 minutes. The proposed lot grading shall be used to calculate the time of concentration or the CUHP parameters.
Offsite Analysis for the Minor Storm Event	The fully developed 2-year runoff will be used without consideration of onsite detention. Inadvertent storage provided by road crossings, railroad embankments and similar structures shall not be credited as runoff reduction.
Offsite Analysis for the Major Storm Event	Where the offsite area is fully or partially undeveloped, the runoff shall be calculated assuming the basin is fully developed as defined by the Planning Department. If this information is not available, then the runoff shall be calculated using the coefficients defined in the RUNOFF Chapter of the DISTRICT MANUAL. No runoff reduction credit will be given for onsite detention in the offsite area for any design frequency unless otherwise approved by Denver; however, credit may be given for permanent, publicly maintained detention facilities. Inadvertent storage provided by road crossings, railroad embankments and similar structures shall not be credited as runoff reduction.

This page intentionally left blank.

7.0 STREETS

7.1 Introduction

The criteria presented in this chapter shall be used in the evaluation of the allowable drainage encroachment within public streets. The criteria, evaluation techniques, and design examples provided in the STREETS/INLETS/STORM SEWERS chapter of the DISTRICT MANUAL are hereby incorporated by reference and not repeated herein, unless modified by Denver or applied to conditions in Denver. The UD-Inlet software program (downloadable from www.udfcd.org) may also be used in the hydraulic evaluation of street flows. When used, the software input and output listings should be submitted in electronic and hard-copy formats to Denver.

7.2 Function of Streets in the Drainage System

The primary function of urban streets is for safe traffic movement; therefore, stormwater drainage and conveyance in streets is subservient to this function and must be properly designed to prevent interference with traffic, especially at intersections. When the drainage in the street exceeds allowable limits set forth in Section 7.3, a storm sewer system (Chapter 9) or an open channel (Chapter 10) is required to convey the excess flows. Streets are also part of the major drainage system when they carry flows in excess of the minor storm, also subject to the limitations of Section 7.3.

7.3 Allowable Use of Streets for Storm Flows

Allowable use of streets for storm flows is summarized in Tables 7.1 through 7.3. The minor storm referenced in these tables is either the 2-year or 5-year event in accordance with Chapter 3, Table 3.1, and the major storm is the 100-year event. No curb overtopping during the minor storm is allowed for any street regardless of classification. The maximum allowable street flow for the minor storm runoff shall be the product of the flow calculated at the “Maximum Theoretical Street Encroachment” and the required reduction factor, following the hydraulic evaluation techniques in the STREETS/INLETS/STORM SEWERS chapter of the DISTRICT MANUAL, or 10 cfs, whichever is more restrictive. In accordance with Table 7.3, cross-street flow is only allowed on local streets when no storm sewers are available and cross pans are provided to carry these flows.

Table 7.1. Allowable Use of Streets for Minor Storm Runoff

Street Classification	Maximum Street Encroachment
Local	No curb overtopping. Flow may spread to crown of street.
Collector	No curb overtopping. Flow spread must leave at least one lane free of water, with 5 feet on either side of the street crown.
Arterial	No curb overtopping. Flow spread must leave at least two 10-foot lanes free of water, providing 10 feet on each side of the street crown or median.

Table 7.2. Allowable Use of Streets for Major Storm Runoff

Street Classification	Maximum Depth and Inundated Area
Local and Collector	Residential dwellings, public, commercial and industrial buildings shall not be less than 12 inches above the 100-year water surface elevation at the ground line or lowest water entry into the building. The depth of water over the gutter flow line shall not exceed 12 inches.
Arterial	Residential dwellings, public, commercial and industrial buildings shall not be less than 12 inches above the 100-year water surface elevation at the ground line or lowest water entry into the building. To allow for emergency vehicles, the depth of water shall not exceed the street crown or 12 inches at the gutter flow line, whichever is more restrictive.

Table 7.3. Allowable Cross-street Flow When Cross Pans Are Allowed[1]

Street Classification	Minor Storm Flow	Major Storm Flow
Local	6 inches of depth in cross pan, if cross pan allowed.	12 inches of depth in cross pan or gutter flow line.

[1]Cross pans are not allowed in collector or arterial streets or where a storm sewer is available.

7.4 Hydraulic Evaluation Techniques

Hydraulic calculations shall be completed to determine the capacity of street gutters and the resulting encroachment onto the street section. These calculations will use the hydrology developed in Chapters 5 and 6 and will subsequently be used in calculations for inlets and storm sewer sizing.

The following factors should be taken into consideration when designing street flow:

- Public safety, including the potential for hydroplaning and splashback.
- Pedestrian nuisance in areas with high pedestrian use.
- Future pavement overlays.
- Hail and trash accumulation in the gutter.

7.4.1 Allowable Gutter Flow Depths and Spreads

Table 7.4 summarizes the allowable gutter flow depth and flow spread into the roadway for various Denver street types with a 6-inch curb and a 2-percent cross slope for the minor storm. The allowable flow depth in the gutter is limited by the maximum permitted flow of 10 cfs, no curb overtopping and the street encroachment limitations.

Table 7.4. Permitted Flow Depths for Minor Storm for 6-inch Curb and 2-percent Cross Slope

Street Type	Flowline to Flowline Street Width (ft)	Maximum Allowable Spread (ft)	Maximum Allowable Depth in Gutter Flowline (ft)
Local	30	15	0.43
	32	16	0.45
	36	18	0.49
Collector	36	13	0.39
	40	15	0.43
	44	17	0.47
Arterial (median present, so street width based on half of street)	25	15	0.43
	30	18	0.50
	36	18	0.50

Note: See www.denvergov.org/publicworks for a typical street cross section.

7.4.2 Allowable Street Capacities and Assumptions for Capacity Curves

Figure 7.1 provides the allowable street capacity for the minor and major storm events based on the allowable spread and depths from Tables 7.1, 7.2 and 7.4. These figures are calculated using the Q-Allow worksheet of the UD-Inlet (Version 2.10) spreadsheet model, which completes a hydraulic evaluation of street capacity by calculating street gutter flow capacity based on allowable spread and gutter depth for the minor and major design storms. The following assumptions were used to develop these curves:

- The maximum allowable flow depths presented are 0.43 feet and 0.39 feet. The curves are provided as a guide only and individual hydraulic calculations should be performed using the latest version of UD Inlet.
- The reduction factor has already been applied based on Figure 7.2.
- The allowable flow depth for the major event is 12 inches for local and collector streets.
- The allowable spread in arterial streets is to the crown or median flow line.
- A vertical wall behind the top of the curb was assumed for the major event.
- Gutter depression (“a”) is 1.52 inches.

- Gutter width is 2 feet.
- Manning's "n" is 0.016.
- Cross slope is 2 percent.

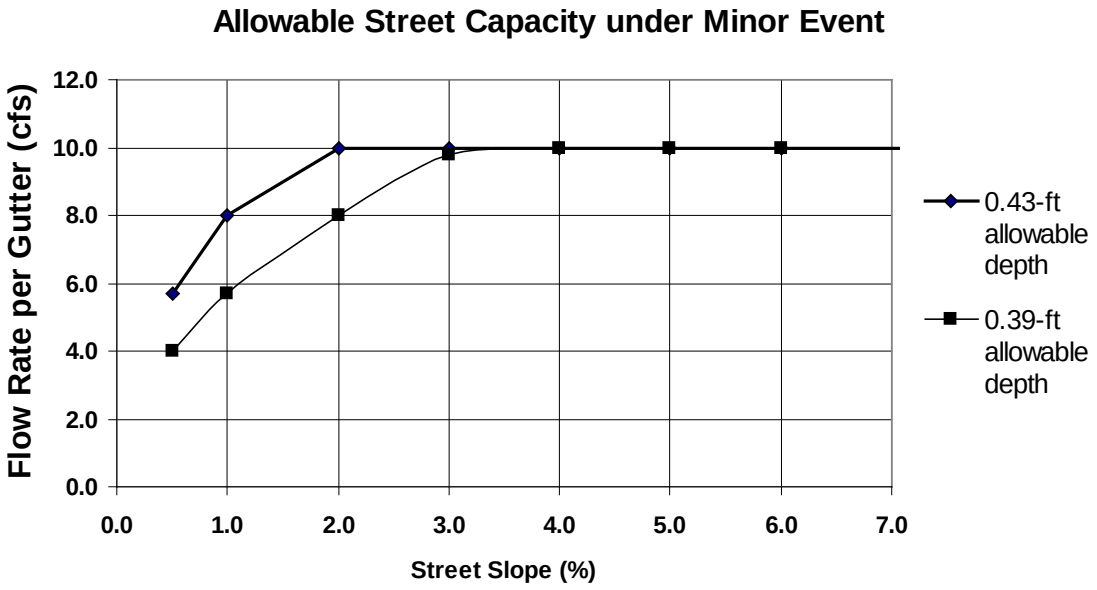
7.5 Checklist and Design Aids

All of the design criteria in this chapter must be followed. Several key considerations that the designer must take care to address include:

1. The primary function of urban streets is for safe traffic movement. Where a storm sewer is available, inlets must be provided at intersections, as shown in Figure 8.3.
2. Provide an inlet where a catch curb changes to a spill curb.
3. Maximum allowable street capacity for minor event is 10 cfs or gutter capacity, whichever is less.
4. Allowable street capacity for major and minor storms is subject to safety considerations using the reduction factor taken from Figure 7.2
5. Nuisance flows must be carried by gutters or pans to an inlet. Nuisance flows are not allowed to cross a driving lane.
6. Cross pans are not allowed on collector or arterial streets or where a storm sewer is available.

Figure 7.1. Allowable Street Capacity for Minor and Major Events

Note: See Section 7.4.2 for assumptions used to generate these curves.



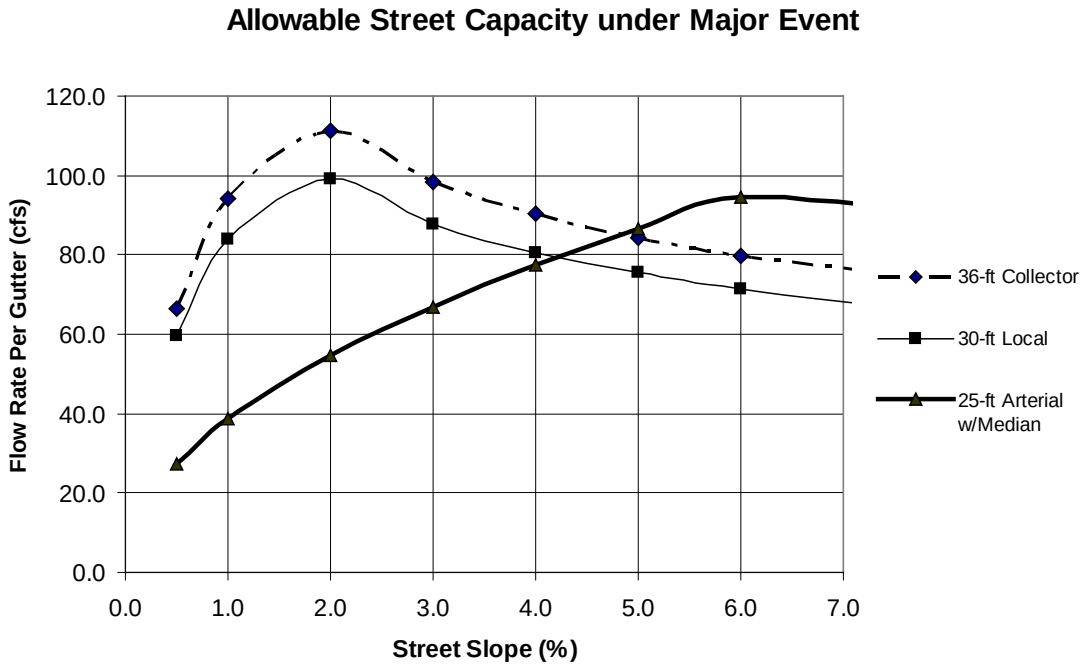
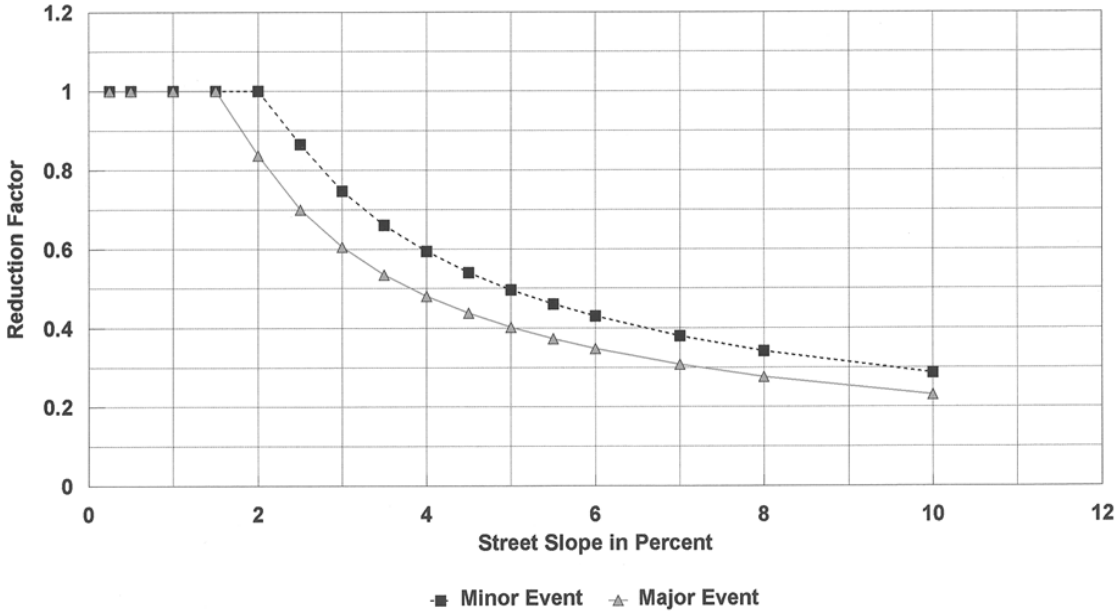


Figure 7.2. Reduction Factors for Gutter Flow

Source: Figure ST-2 in UDFCD 2001



Note: A reduction factor is applied only to a gutter depth of 6 inches or greater for maximum gutter capacity based on allowable gutter depth, per UD Inlet.

8.0 INLETS

8.1 Introduction

Proper design and placement of inlets is necessary for the proper functioning of storm drainage systems. If too few inlets are provided or placed in the wrong locations, then even amply sized pipes do not function as intended. There are three general types of inlets acceptable for use in Denver, including curb opening, valley (grate), and combination inlets. Inlets are further classified based on their use in continuous grade or sump conditions. Inlets used on continuous grades should be located so that the grade of the street has a continuous slope past the inlet, preventing ponding at the inlet. Under sump conditions, the inlet is located at a low point where water ponds.

This chapter provides the criteria and methodology for design and evaluation of storm sewer inlets in Denver. Except as modified herein, all storm sewer inlet criteria shall be in accordance with the STREETS/INLETS/STORM SEWERS chapter of the DISTRICT MANUAL.

8.2 Standard Inlets

The standard inlets permitted for use in Denver are provided in Table 8.1.

Table 8.1. Inlet Types

INLET TYPE	STANDARD DETAIL[1]
No. 14 Inlet (Curb Opening)	S620.1 & S620.2
No. 16 Inlet (Valley)	S616V
No. 16 Inlet (Combination)	S616.1, S616.2, S616.3
Inlet Type C	CDOT M Standard: M-604-10
Inlet Type D	CDOT M Standard: M-604-11

[1]Denver Standard Details can be downloaded from www.denvergov.org/WMDDesign/ and CDOT M Standards can be downloaded from www.dot.state.co.us/DesignSupport/.

8.3 Inlet Design

Proper inlet design includes both the proper inlet hydraulic capacity and appropriate inlet placement. The sizes and types of inlets need to be designed based on the required hydraulic capacity of the inlet. The criteria and procedures in the STREETS/INLETS/STORM SEWERS chapter of the DISTRICT MANUAL shall be followed for inlet design in Denver, except as modified and supplemented herein. Additional information on hydraulic design and placement of inlets follows.

8.3.1 Hydraulic Design

Provided that the DISTRICT MANUAL criteria are met, a variety of approaches can be used to size inlets, including computer programs and charts. UD-Inlet software, which can be downloaded from www.udfcd.org, is appropriate for use with on-grade and sump inlet designs. (Note: If a computer

program is used to size inlets, copies of the input and output listings must be provided in both hard copy and electronic format.)

8.3.2 Assumptions for Figures 8.1 and 8.2

Capacity curves are presented in Figures 8.1 and 8.2 for No. 14, No. 16 Combination, Type C, and Type D inlets. Figure 8.2 on-grade capacity curves only apply when street flow is at the **maximum allowable depth**. For lower gutter depths, the inlet interception rate will decrease. No. 14 and No. 16 Combination inlets may be used in either on-grade or sump conditions. Type C and D inlets may only be used in sump conditions.

The following assumptions were used for developing these curves using UD INLET:

- Local depression at No. 14 inlets is 3 inches.
- Local depression at No. 16 combination inlets is 2 inches.
- A clogging factor of 0.1 was applied to the curb openings (No. 14 and No. 16 combination inlets).
- A clogging factor of 0.7 was applied for single grate inlets (No. 16 combination inlet).

Type C and D charts were developed using orifice and weir equations with the following assumptions:

- The orifice coefficient is 0.67.
- The weir coefficient is 3.0.
- A clogging factor of 0.5 was used for the orifice for the Type C inlet.
- A clogging factor of 0.38 was used for the orifice for the Type D inlet.
- A clogging factor of 0.1 was used for the weir for Type C and D inlets.

8.3.3 Inlet Location and Spacing

Inlets are required in the following locations:

- Sumps.
- Median breaks (e.g., where traffic turns across the median).
- Areas where street capacity (e.g., allowable design flow spread) would be exceeded without them.
- Upstream of pedestrian curb ramps with less than 1 percent slope on the curb return when a storm sewer is available (See Figure 8.3 for example).

Other criteria and guidelines with regard to design and placement of inlets include:

- In general, inlets should be located upstream of pedestrian curb ramps, and spaced in a manner to prevent clogging. This is particularly critical for flat grades and sump conditions; approximately 20-foot spacing is recommended under these conditions.
- Flanking inlets are required in sump conditions without overflow (e.g., underpasses) and in sump conditions requiring more than a triple inlet.
- The type of inlets at intersections should be standardized.
- Type No. 14 inlets are preferred unless utilities are present, in which case No. 16 inlets are allowed.
- A minimum 2-foot apron shall be used with valley inlets when no curb and gutter is present.
- Other common sense considerations regarding placement should also be taken into consideration such as placing inlets upstream rather than downstream of driveways.

8.4 Checklist and Design Aids

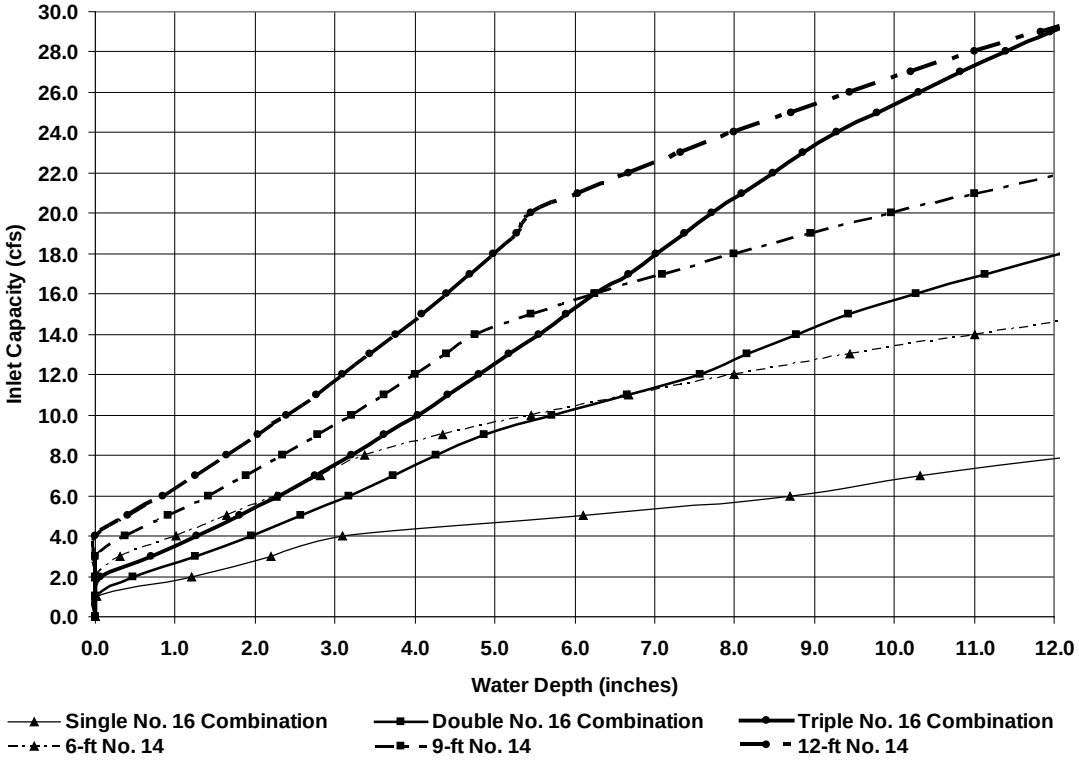
All of the design criteria in this chapter must be followed. Several key considerations that the designer must take care to address include:

1. Inlets are required at sumps, median breaks with catch curbs, locations where allowable street capacity has been exceeded, and intersections (see Figure 8.3).
2. Inlets should generally be located upstream rather than downstream of pedestrian curb ramps and driveways.
3. Inlets should be spaced in a manner to prevent clogging. This is particularly critical for flat grades and sump conditions; approximately 20-foot spacing is recommended under these conditions.
4. Type No. 14 inlets are preferred unless utilities are present, in which case No. 16 inlets are allowed.
5. A minimum 2-foot apron shall be used with valley inlets when no curb and gutter is present.
6. An emergency overflow route must be provided in sump areas.

Figure 8.1. Allowable Inlet Capacity— Sump Conditions

Note: See Section 8.3.2 for assumptions.

Type 16 and Type 14 Inlets for Sump Conditions



Allowable Inlet Capacity for Type C and D Inlets for Sump Conditions

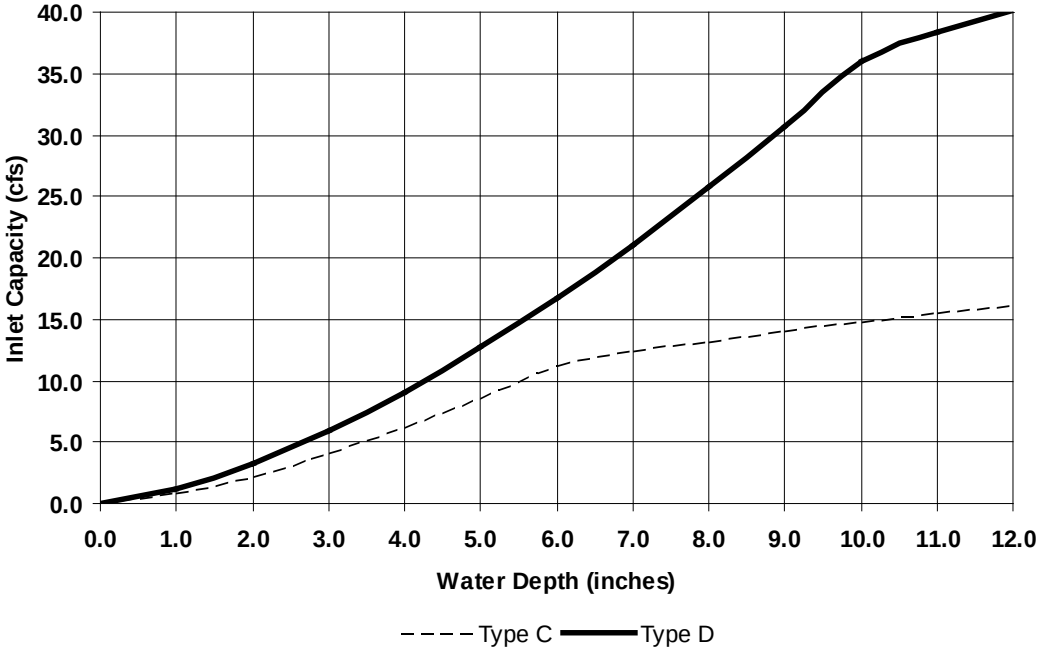
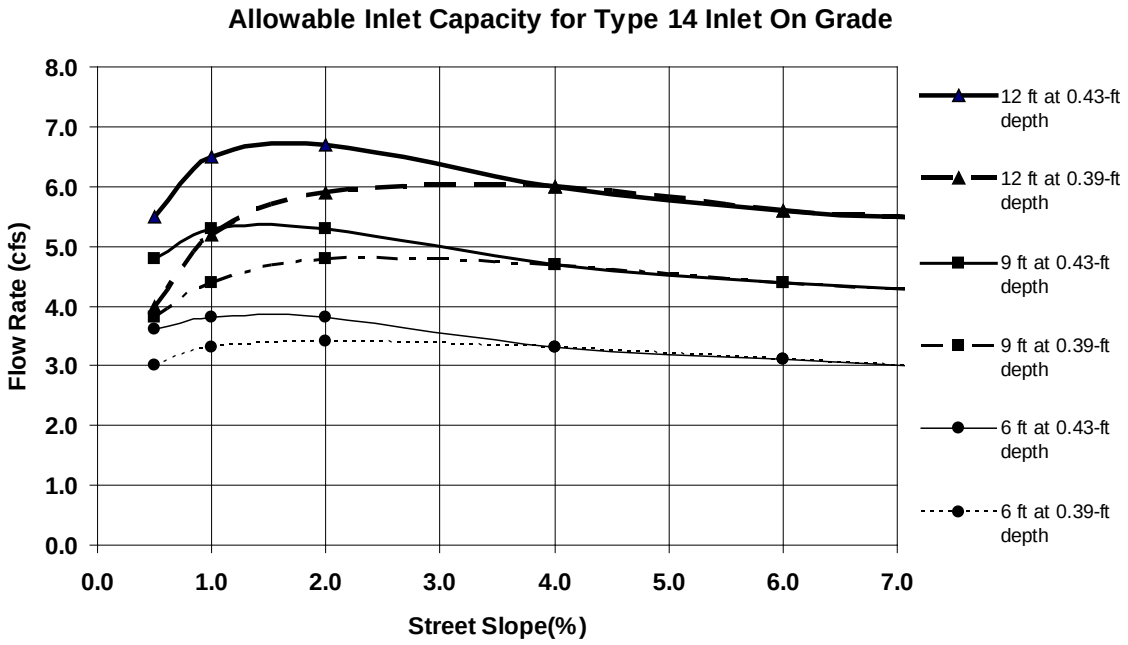
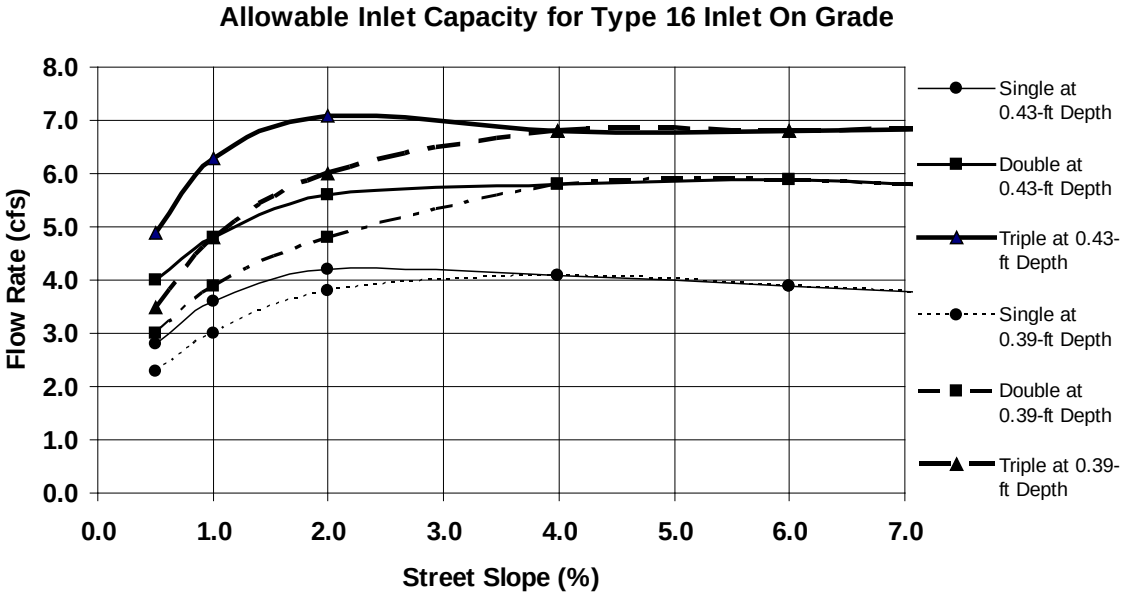
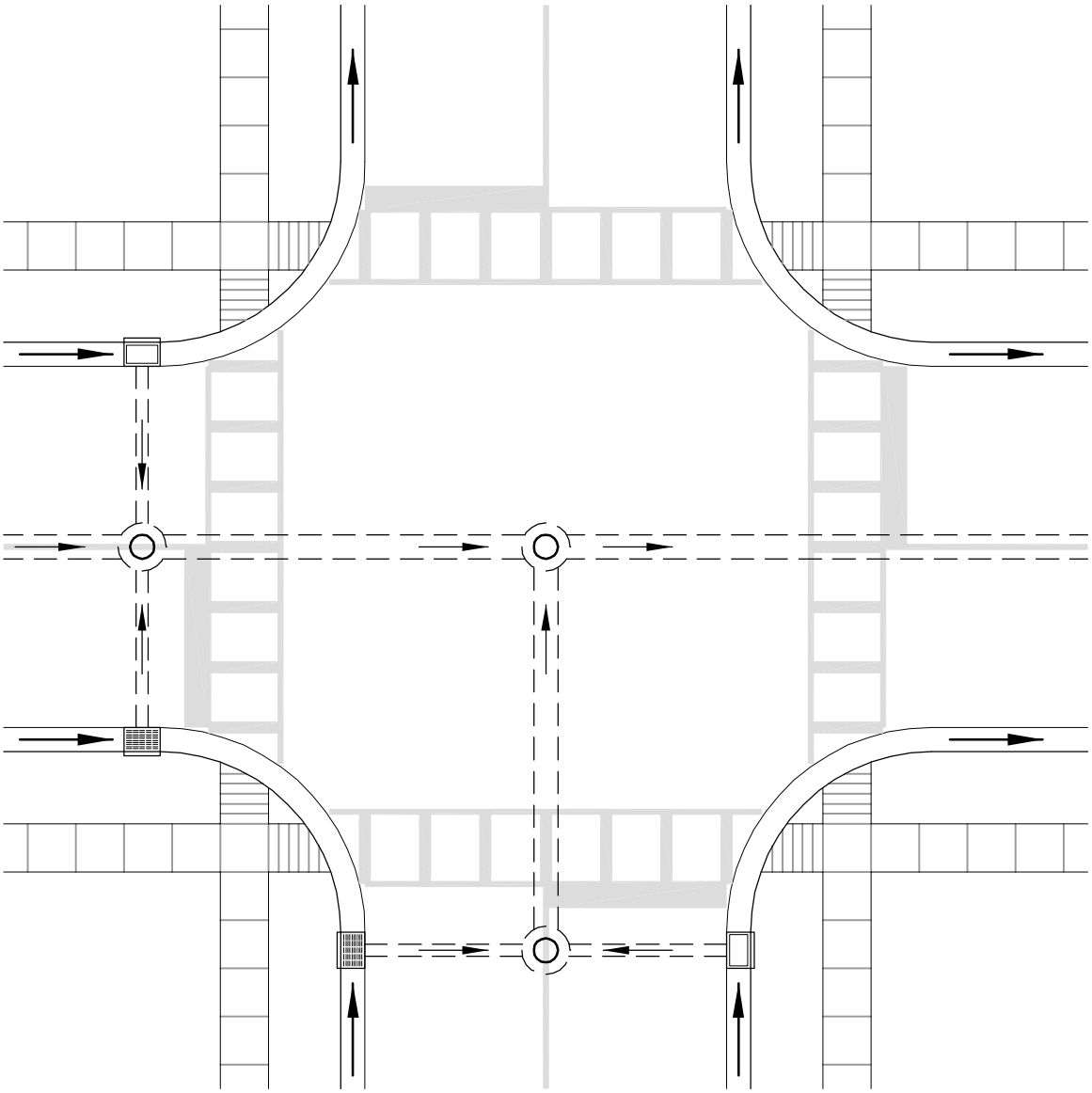


Figure 8.2. Allowable Inlet Capacity—On Grade Conditions

Note: See Section 8.3.2 for assumptions.







ONE OF THESE INLETS IS REQUIRED IF SLOPE AROUND CURB RETURN IS MORE THAN 1%, OTHERWISE BOTH OF THESE TWO INLETS ARE REQUIRED

INLETS REQUIRED TO PREVENT INTERSECTION FLOODING

FLOW DIRECTION

STORM SEWER

CURB RAMP

MANHOLE

NOTE:
INLET SIZE IS SUBJECT TO DRAINAGE ANALYSIS.

SCHEMATIC
NOT TO SCALE

FIGURE 8.3
INLET PLACEMENT AT INTERSECTIONS

REVISED	
BY	DATE

CITY AND COUNTY OF DENVER
DEPARTMENT OF PUBLIC WORKS
WASTEWATER MANAGEMENT DIVISION

INLET PLACEMENT AT INTERSECTION

ISSUE DATE	DRAWN BY: KL
JAN. 2006	CHECKED BY: SF

1/3/06; C:\PROJECT\041-159\DOKAL\INLET PLACE V4.DWG

9.0 STORM SEWERS

9.1 Introduction

Storm sewers are a part of the drainage system and are required when the other parts of the system no longer have capacity for additional runoff. Except as modified herein, the design of storm sewers shall be in accordance with the Storm Sewer section of the STREETS/INLETS/STORM SEWERS chapter of the DISTRICT MANUAL.

9.2 Design Storms for Sizing Storm Sewers

Two design storms shall be considered for sizing storm sewers, the minor (2- or 5-year) storm and the major (100-year) storm. In each case, storm sewers are to be sized to carry whatever portion of the runoff that cannot be conveyed on the surface, as dictated by the available capacity in streets and swales during these two events.

9.2.1 Minor Event Design Storm

At a minimum, storm sewers are to be sized to pick up any minor storm runoff that exceeds the minor event capacity of the street or roadside swales (discussed in Chapter 7, Streets). Inlets are located at these points to intercept excess minor event flow and route it to the storm sewer. Storm sewers shall be designed to convey the minor storm flood peaks while flowing at 80 percent of the full pipe capacity. Section 9.3 provides additional information on hydraulic design methods for the minor storm.

9.2.2 Major Event Design Storm

There are conditions when the storm sewer system will be sized to convey flows greater than the minor storm runoff, including locations where:

1) The street capacity for the major storm is exceeded, especially where the grade slopes down behind the curb and the major storm capacity is limited to the height of the curb.

2) The major storm flows split off in an undesired direction (e.g., flow splits at intersections).

3) The storm sewer system is accepting flow from an upstream storm sewer system or branch that is designed for the major storm.

4) Regional storm sewers are designed for the major storm.

5) The storm sewers must convey undetained flows to a regional detention basin.

If a storm sewer is to be designed to carry major storm flows, the inlets to the storm sewer shall be designed accordingly. In pipes designed to convey up to the major storm, the hydraulic grade line (HGL) is allowed to rise above the top of the storm sewer, but shall be kept at least 1.0 foot below manhole lids, inlet grates and inlet curb openings. Section 9.3 provides additional information on hydraulic design methods for the major storm.

9.3 Hydraulic Design

Storm sewers shall be designed to convey the minor storm flood peaks while flowing at 80 percent of the full pipe capacity. To ensure that this objective is achieved, the hydraulic and energy grade lines shall be calculated by accounting for pipe friction losses and pipe form losses. Total hydraulic losses shall be calculated accounting for friction, expansion, contraction, bend, and junction losses following the methods in the Storm Sewer section of the STREETS/INLETS/STORM SEWERS chapter of the DISTRICT MANUAL. In addition, for convenience, a chart identifying the hydraulic properties of circular pipe is provided in Figure 9.1. This chart assumes that the friction coefficient and Manning's n do not vary throughout depth. The Neo UD Sewer software program (downloadable from www.udfcd.org) may also be used to design storm sewers; if used, electronic and hard copy submittals of the program inputs and outputs are required.

The maximum velocity in all storm sewers shall be 18 ft/sec. The minimum velocity shall be 3 ft/sec at half-full or full-conduit flow conditions.

The final EGL shall be at or below the proposed ground surface for the design event. The HGL shall not exceed the crown of the pipe for the minor storm. In cases where the conduit is designed to convey up to the full 100-year flow, the allowable HGL must be 1 foot below inlet elevations, or 1 foot below ground where no inlets are present.

9.4 Construction Materials

Construction materials must be in accordance with the most current *Denver Storm Drainage and Sanitary Construction Details and Technical Specifications.*

9.5 Pipe Size

The minimum allowable pipe size for storm sewers is dependent upon a practical diameter from the maintenance standpoint. The length of the sewer also affects maintenance and, therefore, the minimum diameter. Table 9.1 presents the minimum pipe size for public storm sewers.

Table 9.1. Public Storm Sewer Size Criteria

Type	Minimum Equivalent Pipe Diameter
Main Trunk	18 inches
Lateral from Inlet	15 inches

9.6 Vertical and Horizontal Alignments

Table 9.2 provides the vertical alignment requirements for storm sewers.

Table 9.2. Vertical Alignment Requirements for Storm Sewers

Vertical Alignment of Storm Sewer Relative to:	Minimum Vertical Clearance (above or below)	Comment
Cover	Minimum cover depends upon the pipe size, type and class, and the soil bedding condition.	The sewer grade shall be such that a minimum cover is maintained to withstand AASHTO HS-20 (or as designated by Denver) loading on the pipe.
Water Main	18 inches	Approval from Denver Water will be required for lesser clearances.
Sanitary	12 inches	In addition, when a sanitary sewer main lies above a storm sewer, or within 18 inches below, the sanitary sewer shall have an impervious encasement or be constructed of approved sewer pipe with the nearest joint 9 feet from the centerline of the crossing.
Other		For vertical drops greater than 8 feet, special designs are required that address potential cavitation and energy dissipation. These situations will require special review. See *Design and Construction of Urban Stormwater Management Systems* (ASCE and WEF 1992) for guidelines for drop shaft structures.

In most cases, storm sewer alignment between drainage structures (inlets or manholes) shall be straight, using manholes to accommodate changes in alignment. Storm sewer horizontal alignment may be curvilinear for pipes with diameters of 48 inches or greater, but only when approved in writing by the Review Engineer. The applicant must demonstrate the need for a curvilinear alignment. The radius limitations for pulled-joint pipe are dependent on the pipe length and diameter and amount of opening permitted in the joint. The maximum allowable joint pull shall be 3/4 inch. The minimum parameters for radius-type pipe shall be in accordance with the manufacturer's specifications.

All storm sewers parallel to the street shall not be placed under the tree lawn or the sidewalk.

9.7 Manholes/Cleanouts

Manholes shall be required whenever there is a change in size, direction, elevation, grade, or where there is a junction of two or more sewers. A manhole may be required at the beginning and/or at the end of the curved section of storm sewer. The maximum spacing between manholes shall be 500 feet. The required manhole size shall be in accordance with the *Denver Storm Drainage and Sanitary Construction Details and Technical Specifications* and as shown in Table 9.3.

Table 9.3. Manhole Sizes for Straight Sewers

Sewer Diameter	Manhole Diameter
≤30 inches	4 feet
33 to 36 inches	5 feet
42 inches and larger	Type “B” or “P” Manhole

Larger manhole diameters or a junction structure may be required when large diameter pipe sewer alignments are not straight through manholes or when more than one sewer line goes through the manhole. A special structure is required for 42-inch or larger pipe when the angle of deflection is more than 45 degrees.

Cleanouts for maintenance access, instead of manholes, are only allowed for private, on-site sewers less than 10 inches in diameter and must be the same size as the pipe to be cleaned. Spacing of cleanouts must conform to the requirements of the International Plumbing Code.

9.8 Outlets

Proper design of storm sewer outlets is necessary to minimize erosion at the outfall location and to protect public safety. Key design criteria on these topics follow.

9.8.1 Erosion Protection at Storm Sewer Outlets

Adequate erosion protection shall be provided at all sewer outlets in the form of riprap or concrete basins in accordance with Table 9.4 and the HYDRAULIC STRUCTURES chapter of the DISTRICT MANUAL.

Table 9.4. Erosion Protection at Conduit Outlets

Erosion Protection Type	DISTRICT MANUAL Chapter	Appropriate Use	Inappropriate Use
Riprap Lining	MAJOR DRAINAGE	· Receiving channel on same line and grade · Storm sewer and culvert outlets · High tailwater · Fish passage	· Wetland channels
Low Tailwater Stilling Basin	HYDRAULIC STRUCTURES	· Storm sewer and culvert outlets · Low tailwater	· Confined receiving area
Concrete Impact Stilling Basin	HYDRAULIC STRUCTURES	· Storm sewer outlets · Low tailwater	· In-line culvert outlets · High visibility areas
Concrete Baffle Chute	HYDRAULIC STRUCTURES	· Storm sewer outlets · Low tailwater · Degrading channel	· In-line culvert outlets · High debris potential · High visibility areas
Drop Structures	HYDRAULIC STRUCTURES	· Wetland channels · Low-rise box culverts or small diameter pipes where plugging is possible	· Confined receiving area · Fish passage

Source: Table adapted after *Draft Douglas County Drainage Criteria Manual* (Muller Engineering 2005).

9.8.2 Safety

Headwalls and wingwalls associated with storm sewer outlets shall be provided with guardrails, handrails, or fencing in conformance with Denver building codes and roadway design safety requirements. Handrails shall be required in all areas where the drop from the headwall or wingwall exceeds 30 inches. The height of the handrail shall be 42 inches for pedestrian walkways or open areas and 54 inches for bicycle traffic (AASHTO 2002).

9.9 Checklist and Design Aids

All of the design criteria in this chapter must be followed. Several key considerations that the designer must take care to address include:

1. Design the EGL below the ground surface for the design event.

2. Design the HGL not to exceed the pipe's crown for the minor storm.

3. Design the HGL not to exceed 1 foot below ground when the conduit is designed to convey the major event.

4. Account for all losses in the EGL and HGL calculations including outlet, form, bend, manhole, and junction losses.

5. Provide adequate erosion protection at the outlet of all sewers.

6. Provide cross sections for rip rap protection.

7. Check for minimum pipe cover and clearance with utilities.

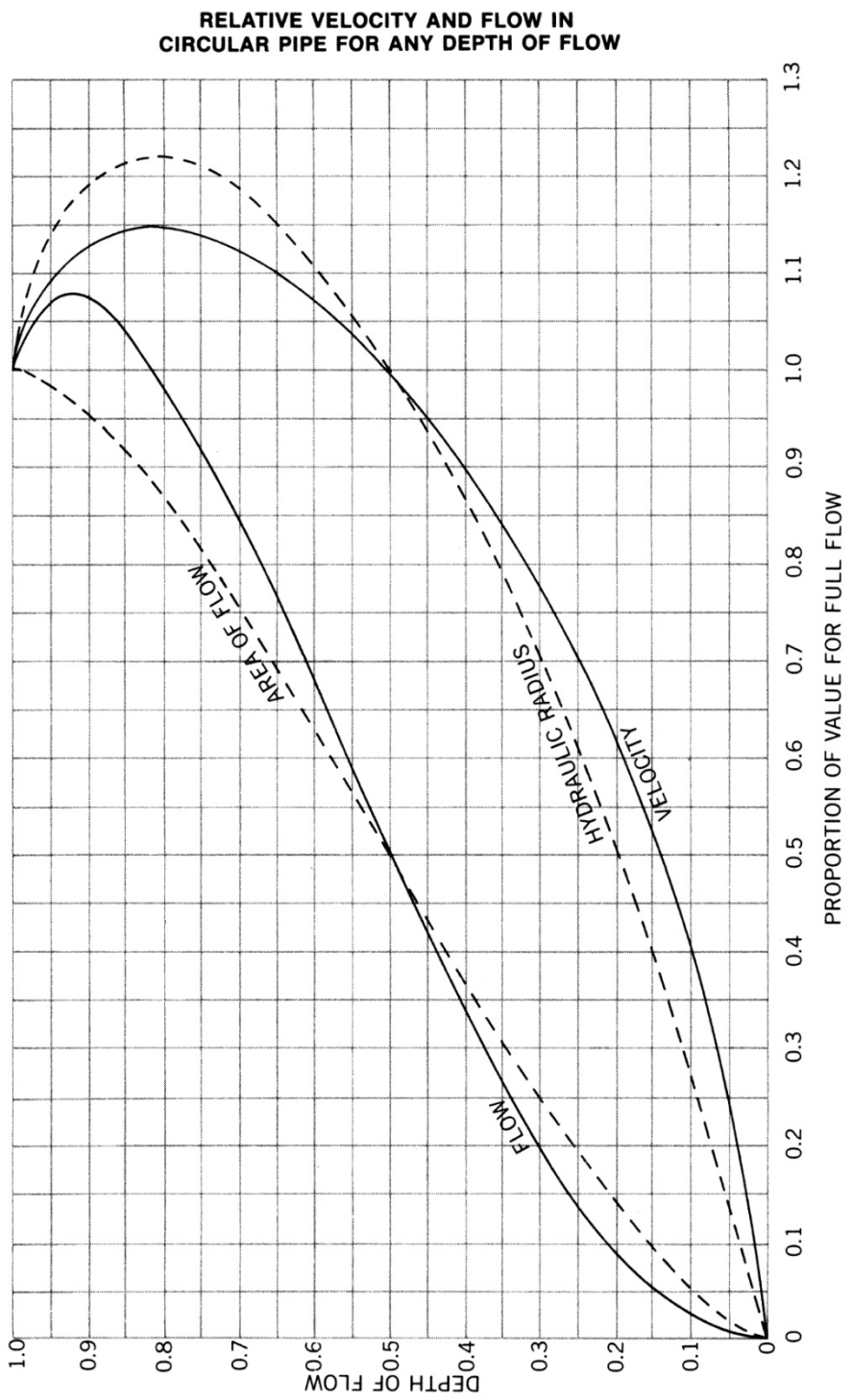
8. Check overflow under sump conditions.

9. Design the invert of the inflow pipe to the detention basin to be higher than the water quality level.

10. Flapgates should only be considered as a last option.

11. Aprons must be provided at outfall structures.

Figure 9.1. Hydraulic Properties of Circular Pipe



Date: Jan 2006	**Reference: "Concrete Pipe Design Manual," ACPA, 2000.**
Revised:	**Diagram Courtesy of American Concrete Pipe Association**

This page intentionally left blank.

10.0 OPEN CHANNELS

10.1 Introduction

This chapter provides the minimum technical criteria for the hydraulic evaluation and design of open channels in Denver. In many instances, special design or evaluation techniques will be required. Design criteria in the Open Channels section of the MAJOR DRAINAGE chapter of the *Urban Storm Drainage Criteria Manual* (DISTRICT MANUAL) are hereby incorporated by reference. Except as modified herein, all open channel designs shall be in accordance with the DISTRICT MANUAL.

10.2 Channel Types

A variety of channel types occur in Denver. These include channels resulting from natural processes and artificial channels. Examples of natural channels include Bear Creek, the South Platte River, Cherry Creek and Sand Creek. Most natural channels within the older parts of Denver have been modified in the past. Artificial channels include large designated floodways, irrigation canals and flumes, roadside ditches, concrete or rock-lined channels, composite channels, bioengineered channels and grass-lined channels. An overview of channel types allowed in Denver under various conditions and associated design considerations is provided below, followed by specific design criteria in Section 10.4 through 10.6.

As previously discussed in Chapter 3, a major drainageway is defined as any drainage flow path with a tributary area of 130 acres or more. Minor drainageways convey flows from tributary areas less than 130 acres.

10.2.1 Natural Channels

If natural channels are to be used for carrying storm runoff from an urbanized area, the altered nature of the runoff peaks and volumes from urban development will inevitably cause erosion, which must be planned for and controlled based on detailed hydraulic analysis. Investigations necessary to assure that the natural channels will be adequate are different for every waterway. At a minimum, the engineer must prepare cross sections of the channel, define the water surface profile for the minor and major design flood, investigate the bed and bank material to determine erosion tendencies, and study the bank slope stability of the channel under future flow conditions. Supercritical flow does not normally occur in natural channels, but calculations must be made to assure that the results do not reflect supercritical flow. Typically, a variety of measures must be implemented to ensure channel stability that may include drop structures along with both hard (e.g., rip-rap, boulders) and soft (e.g., willows, revegetation, slope shaping) streambank stabilization measures. The natural floodplain along these channels should be preserved whenever practicable.

10.2.2 Grass-lined Channels

Denver requires grass-lined channels for major drainageways, except in cases of existing development where right-of-way (ROW) is restricted. Grass-lined channels provide many benefits such as channel

storage, lower velocities, and multiple-use greenbelt benefits. Grass stabilizes the body of the channel, consolidates the soil mass of the bed, checks the erosion on the channel surface, controls the movement of soil particles along the channel bottom, and creates turbulence resulting in loss of energy and increased flow retardance.

Key design considerations for grass-lined channels include erosion, sediment deposition, scour, and hydraulics. Channels in sandy soils require special erosion control techniques and velocity limitations. For the purposes of these DENVER CRITERIA, sandy soils are defined as non-cohesive sands classified as SW, SP, or SM in accordance with the Unified Soil Classification System. The UDFCD publication *Design Guidelines and Criteria for Channels and Hydraulic Structures on Sandy Soil* (Simons Li and Associates 1981) should be used when appropriate. Grass-lined channels in developing areas should be stabilized with grade control structures to prevent downcutting, depression of the water table and degradation of natural vegetation. Low-flow areas may need to be armored or otherwise stabilized to guard against erosion.

10.2.3 Concrete-lined Channels

Concrete-lined channels for major drainageways will be permitted only where ROW restrictions within existing development prohibit grass-lined channels. The lining must be designed to withstand the various forces and actions that cause bank overtopping, deteriorate the lining, erode the soil beneath the lining, and erode unlined areas, especially for the supercritical flow conditions.

If the project constraints suggest the use of a concrete channel for a major drainageway, the applicant shall present the concept with justification to the Department of Public Works for consideration of a waiver from these DENVER CRITERIA. If a waiver is granted, supporting design information will be required for approval of a concrete-lined channel.

10.2.4 Riprap or Rock Lined Channels

Riprap or rock-lined channels are generally discouraged and shall be permitted only in areas of existing development where ROW for major drainageways is limited and such limitation prohibits the use of grass-lined channels. The advantage of rock lining a channel is that a steeper channel grade can be used due to the higher friction of the rock. Also, steeper side slopes are permitted. Rock linings (i.e., revetments) are permitted as a means of controlling erosion for natural channels. The disadvantages are appearance, the large initial cost of construction and the high maintenance costs due to vandalism and loss of rock during high flows.

If the project constraints suggest the use of riprap lining for a major drainageway, then the engineer must present the concept and its justification to the Review Engineer for consideration of a waiver from these DENVER CRITERIA.

10.2.5 Other Channel Types

The MAJOR DRAINAGE chapter of the DISTRICT MANUAL provides criteria for composite channels, which have a distinct low-flow channel vegetated with a mixture of wetland and riparian vegetation, and bioengineered channels, which use vegetative components and other natural materials in combination with structural measures to construct natural-like channels. These channel types are allowed in Denver when designed in accordance with the DISTRICT MANUAL criteria.

Additionally, a variety of commercially available synthetic fabrics and channel lining products intended to reduce erosion are available. The use of synthetic fabrics for lining of channels for major drainageways within Denver is restricted to areas of existing development where the ROW constraints prohibit the use of a grass-lined section and where existing drainage problems are evident. The linings shall be restricted to channels with a Froude number of 0.8 or less. Such use shall be allowed only upon written approval for a waiver from the Review Engineer.

The DISTRICT MANUAL also provides guidance for boatable channels, where special safety considerations must be considered for drop structures and other channel characteristics.

10.3 Flow Computations and Design Approach

Regardless of the type of channel selected, hydraulic analyses must be conducted to evaluate flow characteristics, including flow regime, water surface elevations, velocities, depths and hydraulic transitions for multiple flow conditions. All flow computations shall be in accordance with the MAJOR DRAINAGE chapter of the DISTRICT MANUAL. The UD-Channels spreadsheet (downloadable from www.udfcd.org) may be used to complete some flow calculations; however, water surface profile calculations necessary to determine the energy grade line (EGL), water surface elevation, and hydraulic grade line (HGL) must be completed separately using the methods in the DISTRICT MANUAL. All channels shall be designed considering public safety and maintenance requirements.

If published UDFCD or Denver outfall system or drainage master plans exist, then channel designs should be completed in accordance with the recommendations of these plans.

10.4 Design Criteria for Natural Channels

The design criteria and evaluation techniques for natural channels are:

1. Channel and overbank areas shall have adequate capacity for the 100-year storm runoff.

2. Erosion-control structures, such as drop structures or grade-control checks, shall be provided to control channel erosion as the tributary watershed urbanizes.

3. Water surface profiles shall be defined so that the floodplain can be zoned and protected.

4. Filling of the floodplain shall be avoided because it reduces valuable channel storage capacity and tends to increase downstream runoff peaks.

5. Roughness factors (n values) representative of unmaintained channel conditions shall be used for the analysis of water surface profiles.

6. Roughness factors (n values) representative of maintained channel conditions shall be used to determine velocity limitations.

7. Control structures will typically be required to decrease the thalweg slope, control erosion and sediment deposition for both the major and the minor storm runoff. The appearance of these structures should be compatible with their surroundings. Where possible, structures should be located at principal grade changes to minimize the cost of retaining structures, reduce perceived scale and appearance of mass and bulk, and use existing land forms of the site. All check drops, dams, or structures should, whenever feasible, use natural materials to integrate with natural landscape characteristics and should only be provided where necessary as indicated by hydraulic analyses.

8. Plan and profile drawings of the floodplain shall be prepared. Appropriate allowances for known future bridges or culverts, which can raise the water surface profile and cause the floodplain to be extended, shall be included in the analysis. The applicant shall contact the Public Works Department for information on future bridges and roads in undeveloped areas.

9. Natural waterway channel boundaries and alignments shall be preserved, maintained or enhanced in their natural condition to serve as landscape and visual amenities, to provide focal points for development projects, and to help define “edges” in and around communities. Vegetation groups, rock outcroppings, terrain form, soils, waterways, and bodies of water shall be preserved to the extent practicable.

10. The usual rules of freeboard depth, curvature and other factors, which are applicable to artificial channels, do not apply for natural channels. A minimum of 1 foot of freeboard above the 100-year water surface shall be provided, with 3 feet provided at bridges and 18 inches at structures. Significant benefits may be realized if channel overtopping and localized flooding of adjacent areas are planned for the major runoff peak.

11. If a natural channel is to be used as a major drainageway for a development, then the applicant shall meet with the Department of Public Works to discuss the concept and obtain the requirements for planning and design documentation. Approval of the concept and design will be made in accordance with the requirements of Chapter 2 of these DENVER CRITERIA.

10.5 Design Criteria for Artificial Channels

Design criteria and procedures for open channels provided in the MAJOR DRAINAGE chapter of the DISTRICT MANUAL are incorporated by reference and not repeated below. The primary artificial channel types and design criteria include:

1. Grass-lined Channels: Designs should be compatible with location, environmental and recreational conditions. The criteria in the MAJOR DRAINAGE chapter of the DISTRICT MANUAL shall apply. Additionally, Denver specifies the following criteria:

    a. Freeboard: Freeboard should be calculated relative to the 100-year flow defined by the Flood Hazard Area Delineation, Drainage Master Plan, or other credible study based on fully developed future land use conditions using the following equation:

    $$H_{FB} = 0.5 + v^2/2g \qquad \text{(Equation 10.1)}$$

    where

    H_{FB} = freeboard height (feet)

    v = average channel velocity (ft/sec)

    g = acceleration of gravity = 32.2 ft/sec^2

    The minimum freeboard shall be 1.0 foot, with the following exceptions:

        i. Structures: 18 inches

        ii. Bridge crossings over major drainageways: 3 feet (e.g., the South Platte River, Cherry Creek, Sand Creek, First Creek, Clear Creek and Bear Creek)

        iii. Swales (small drainageways with a 100-yr flow <20 cfs): 6 inches

        iv. Special areas where limited overtopping is desired for specific purposes: Site-specific

    b. Curvature: Center-line curvature shall have a radius twice the top width of the design flow, but not less than:

        i. 100 ft for major drainageways (i.e., areas draining 130 acres or more)

        ii. 50 ft for minor drainageways (i.e., areas draining less than 130 acres)

        iii. 25 ft for swales (i.e., small drainageways with a 100-yr flow <20 cfs)

c. Roughness Coefficient: Use the maximum Manning's n value for determining the channel hydraulic capacity and the minimum value for determining the channel lining stability.

d. Main Channel: A main channel is required for sandy soils, but may also be used with other soil conditions.

e. Trickle Channel: Baseflows shall be carried in a concrete trickle channel that provides a minimum capacity of 2 percent of the 100-year flow, but not less than 1 cfs. Alternatives to concrete will be considered on a case-by-case basis. Composite or wetland-bottom-type channels are allowed and must be designed in accordance with the DISTRICT MANUAL. For swales, trickle channel requirements will be evaluated on a case-by-case basis.

f. Bottom Width: The minimum bottom width shall be consistent with the maximum depth and velocity criteria and shall not be less than 4 feet or the trickle channel width when trickle channel is required.

g. Water Surface Profiles: The energy gradient shall be shown on all drawings. The standard method for determining the water surface profile is the U.S. Army Corps of Engineers HEC-RAS computer model.

h. Other Hydraulic Information: For minor drainageways, submit capacity and velocity calculations and Froude numbers with construction drawings, including electronic submittal of spreadsheets.

2. Riprap-lined Channels: The criteria in the MAJOR DRAINAGE chapter of the DISTRICT MANUAL shall apply.

3. Concrete-lined, Composite and Bioengineered Channels: The criteria in the MAJOR DRAINAGE chapter of the DISTRICT MANUAL shall apply.

4. Manufactured Lining Types: The criteria in the MAJOR DRAINAGE chapter of the DISTRICT MANUAL shall apply, as well as the manufacturer's recommendations for the specific product. The applicant will be required to submit the technical data in support of the proposed material. Additional information or calculations may be requested by the Department of Public Works to verify assumptions or design criteria.

Regardless of the channel type, vegetation and land form, variations are encouraged to enhance the aesthetic quality of channels, provided that channel functional factors are not compromised. Channel capacity must be increased to accommodate increases in plant material types and densities and variation of land form. Overstory canopy trees are allowed and encouraged outside of high hazard areas.

If extensive modification or disruption of existing areas is necessary, rehabilitate the channel corridor to conform to, or improve upon, predevelopment conditions. Channels should be natural-looking and/or be consistent with the surrounding land use. Techniques that can be used to achieve this goal include varying the slope and edge of channel, using river rock for riprap, replanting appropriately sized riparian vegetation, introducing meandering character on flat areas, and providing pools and rocks in steeper areas. A higher concentration of plant materials should be included where drainages intersect arterial streets, when feasible, to maintain and enhance visibility from roadways. The distance (buffer) on each side of any flowing or intermittent stream channel should be large enough to ensure its use for active and passive recreation and as a visual amenity.

To be eligible for UDFCD maintenance, the most current version of UDFCD's maintenance eligibility requirements (downloadable from www.udfcd.org) must be met.

10.6 Design Criteria for Channel Rundowns

A channel rundown is used to convey storm runoff from a higher elevation to a lower elevation (e.g., the bank of a channel to the invert of an open channel or drainageway). The purpose of the structure is to minimize channel bank erosion from concentrated overland flow. Denver's design criteria for channel rundowns are summarized in Table 10.1. See the Rundowns section of the HYDRAULIC STRUCTURES chapter of the DISTRICT MANUAL for rundown details and additional guidance for rundowns into storage facilities and wetland channels, as well as criteria for grouted riprap rundowns. An alternative to rundowns includes the use of storm sewers with drop manholes and low tailwater or impact basin energy dissipators at the outlet.

Table 10.1. Channel Rundown Design Criteria

Feature	Criteria
Cross Sections	Typical cross-sections for channel rundowns are presented in the HYDRAULIC STRUCTURES chapter of the DISTRICT MANUAL.
Design Flow	The channel rundown shall be designed to carry the full design flow or 1 cfs, whichever is greater.
Flow Depth	The maximum depth at the design flow shall be 12 inches. Due to the typical profile of a channel rundown beginning with a flat slope and then dropping steeply into the channel, the design depth shall be the critical depth for the design flow.
Outlet Configuration	The channel rundown outlet shall enter the drainageway at the trickle channel flow line. Erosion protection of the opposite channel bank shall be provided by a layer of B-24 grouted boulders in accordance with the MAJOR DRAINAGE chapter of the DISTRICT MANUAL. The width of this erosion protection shall be at least three times the channel rundown width or pipe diameter. Grouted boulder protection shall extend up the opposite bank to the minor storm flow depth in the drainageway or 2 feet, whichever is greater.
General	All designs must be in accordance with the DISTRICT MANUAL.

10.7 Retrofitting Existing Channels

Many redevelopment projects in Denver provide opportunities for retrofitting and improving existing open channels. Guidance for retrofitting existing channels is provided in the MAJOR DRAINAGE chapter of the DISTRICT MANUAL.

10.8 Environmental Permitting

A variety of federal (e.g., 404 permit), state (e.g., dewatering, stormwater) and local permits are often required when constructing open channels. The engineer shall obtain necessary permits.

10.9 Checklist and Design Aids

All of the design criteria in this chapter must be followed. Several key considerations that the designer must take care to address include:

1. Check flow velocity with low retardance (“n”) factor and capacity with high retardance factor.
2. Check Froude number and critical flow conditions.
3. Grass channel side slopes must be 4:1 or flatter.
4. Show EGL and water surface profile on design drawings.
5. Consider all backwater conditions (i.e., at culverts) when determining channel capacity.
6. Check velocity for conditions without backwater effects.
7. Provide adequate freeboard.
8. Provide adequate ROW for the channel and continuous maintenance access.

11.0 HYDRAULIC STRUCTURES

11.1 Introduction

Hydraulic structures are used to guide and control water flow velocities, directions and depths, elevation and slope of streambed, general configuration of the waterway, and its stability and maintenance characteristics. Hydraulic structures (e.g., riprap, channel grade control structures, bridges) help to control the energy associated with flowing water, thereby reducing erosion-related damage to the stream. Consideration of environmental, ecological, aesthetic and public safety objectives should be integrated with careful and thorough hydraulic engineering design. The proper application of hydraulic structures can reduce initial and future maintenance costs by managing the character of the flow to fit the environmental and project needs. All hydraulic structures should be designed and constructed considering aesthetics and should fit in with their surroundings to the extent practicable. Structures must be designed with long-term maintainability as a key criterion.

The criteria to be used in the design of hydraulic structures shall be in accordance with the HYDRAULIC STRUCTURES and MAJOR DRAINAGE chapters of the DISTRICT MANUAL, unless modified herein.

11.2 Application of Hydraulic Structures and Design Guidance

Table 11.1 summarizes the types of hydraulic structures that may be constructed in Denver and cross-references the reader to the appropriate criteria and guidance for their construction. A checklist for hydraulic structure design is also provided in the HYDRAULIC STRUCTURES chapter of the DISTRICT MANUAL.

Table 11.1. Summary of Hydraulic Structure Types and Criteria

Hydraulic Structure	Application	Location of Criteria
Riprap	Riprap can be placed at culverts, storm sewer outlets, channel bottom and banks, check drops, bridges, gabions or other areas subject to erosion.	MAJOR DRAINAGE chapter in DISTRICT MANUAL and Table 9.4 of these DENVER CRITERIA
Channel Grade Control Structures (Check and Drop Structures)	Grade control structures, such as check structures for low flow channels and drop structures across waterways, dissipate energy and can effectively reduce upstream channel erosion and instability. Grade control structures are also often necessary to meet the maximum permissible velocity for major design storm runoff in grass-lined channels and wetland channels.	"Channel Grade Control Structures" section of HYDRAULIC STRUCTURES in DISTRICT MANUAL "Open Channel Design Criteria" section of MAJOR DRAINAGE in DISTRICT MANUAL
Conduit Outlet Structures	Conduit outlet structures are designed to dissipate flow energy and reduce erosion at culverts and storm sewer outlets. For culverts or storm sewers where the Froude number at the outlet is in excess of 2.5, the U.S. Bureau of Reclamation (USBR) Type VI impact stilling basin shall be used. If this structure is used on a culvert, an upstream trash rack must be provided.	"Conduit Outlet Structures" section of HYDRAULIC STRUCTURES in DISTRICT MANUAL Also see MAJOR DRAINAGE in DISTRICT MANUAL Also see Table 9.4 of these DENVER CRITERIA
Bridges	Bridge structures can cause adverse hydraulic effects and scour that must be evaluated and controlled in the hydraulic design.	"Bridges" section of the HYDRAULIC STRUCTURES chapter in DISTRICT MANUAL
Transitions and Constrictions	Channel transitions are typically used to alter the cross-sectional geometry for specific purposes such as fitting the waterway within a more confined right-of-way. Constrictions such as bridges and culverts must be planned to meet hydraulic design goals.	"Transitions and Constrictions" section of HYDRAULIC STRUCTURES in DISTRICT MANUAL
Bends and Confluences	Confluences should be hydraulically evaluated to determine whether supercritical flow and hydraulic jump conditions are present, resulting in the need for hydraulic structures.	"Bends and Confluences" section of HYDRAULIC STRUCTURES chapter in DISTRICT MANUAL For lined channels and conduits, also see the MAJOR DRAINAGE chapter in DISTRICT MANUAL
Rundowns	A rundown is used to convey storm runoff from high on the bank of an open channel to the low-flow channel of the drainageway or into a detention facility. The purpose is to control erosion and head cutting from concentrated flow. Without such rundowns, the concentrated flow will create erosion.	"Rundown" section of HYDRAULIC STRUCTURES in DISTRICT MANUAL Also see the Open Channels chapter in these DENVER CRITERIA for rundown criteria

12.0 CULVERTS

12.1 Introduction

A culvert is defined as a conduit for the conveyance of water under a roadway, railroad, canal, or other embankment. In addition to serving hydraulic functions, culverts also must carry overhead loads from traffic and other activities, thereby serving a structural function. Proper culvert design is essential because culverts often significantly influence upstream and downstream flood risks, floodplain management and public safety. The criteria presented in this chapter shall be used in the design of culverts. The criteria, techniques, and design examples provided in the CULVERTS chapter of the DISTRICT MANUAL are hereby incorporated by reference and not repeated herein, unless modified by Denver.

12.2 General Design and Hydraulic Evaluation

The hydraulic principles, criteria, roughness coefficients, entrance loss coefficients, culvert capacity charts and other information provided in the CULVERTS chapter of the DISTRICT MANUAL shall be used in the hydraulic evaluation, sizing and design of culverts, except as modified herein. The UD-Culvert spreadsheet (downloadable from www.udfcd.org) may also be used in the hydraulic evaluation of culverts. When used, the software input and output listings should be submitted to Denver in electronic and hard copy formats.

Additional references prepared by the Colorado Department of Transportation and the Federal Highway Administration (e.g., FHWA 1985, Ginsberg 1987) may also be helpful in hydraulic evaluation of culverts, particularly with regard to bridge crossings.

12.3 Culvert Sizing Criteria

For street crossings, the minimum culvert size is based on the allowable street overtopping for the various street classifications as set forth in Table 12.1 and allowable headwater depths as discussed in Section 12.7. In no case shall street overtopping occur for a 10-year frequency or smaller storm. Other conditions may be present that will require a larger culvert size, particularly with regard to public safety concerns and upstream and downstream impacts. In some cases, the minimum criteria may result in some structures remaining in the 100-year floodplain, which may require an increase in culvert size to lower the floodplain elevation. Also, if only a small increase in culvert size is required to prevent overtopping, then the larger culvert is required.

Table 12.1. Allowable Roadway Overtopping at Culvert Crossings

Street Classification	10-Year Storm Maximum Depth	100-Year Storm Maximum Depth
Local	None	12 inches at the gutter flow line.
Arterial and Collector	None	No cross-flow. 12 inches at the gutter flow line. Maximum headwater to culvert diameter ratio (H/D) <1.5.

See the DISTRICT MANUAL for criteria and design procedures for culvert applications in conditions other than street crossings.

12.4 Construction Material and Pipe Size

Within Denver, culverts shall be constructed from reinforced concrete. Other materials for construction shall be subject to written approval by the Review Engineer. The minimum pipe size for culverts within a public ROW shall be 18-inch-diameter culvert. The minimum pipe size for roadside ditch culverts for driveways shall be 15-inch-diameter culvert.

12.5 Inlet and Outlet Configuration

Within Denver, all culverts are to be designed with headwalls, wingwalls and aprons, or with flared end sections at the inlet and outlet. Flared end sections are only allowed on pipes with diameters of 30 inches (or equivalent) or less.

Headwalls, wingwalls, and flared-end sections should be designed and constructed to use the existing land forms of the site and blend with the natural landscape. Naturally occurring stone or river rock used as a cover material is preferred.

Additional protection in the form of riprap will also be required at the inlet and outlet due to the potential scouring velocities. Refer to Table 9.4.

12.6 Velocity Considerations

In design of culverts, both the minimum and maximum velocities must be considered. A minimum velocity of flow is required to assure a self-cleansing condition of the culvert, while maximum velocities are limited to prevent excessive erosion. Table 12.2 summarizes the minimum and maximum allowable velocities under various outlet conditions.

Table 12.2. Allowable Velocities at Culvert Outlets

Velocity at Outlet	Condition
Minimum Velocity: 3 ft/sec	All Conditions
Maximum Velocity: <5 ft/sec 5-12 ft/sec >12 ft/sec (not recommended)	Level of Outlet Protection Required per Maximum Velocity: Minimal erosion protection required Substantial erosion protection required Energy dissipater, shaped riprap basin or other measures required

12.7 Headwater Considerations

The maximum headwater for the 100-year design flows shall be 1.5 times the culvert diameter, or 1.5 times the culvert rise dimension for shapes other than round. Also, the headwater depth may be limited by the street overtopping criteria in Table 12.1.

12.8 Structural Design

As a minimum, all culverts shall be designed to withstand an HS-20 loading (unless designated differently by Denver) in accordance with the design procedures of the American Association of State Highway and Transportation Officials (AASHTO) in *Standard Specifications for Highway Bridges* and with the pipe manufacturer's recommendation.

12.9 Trash Racks

Trash racks may be required at the upstream end of culverts on a case-by-case basis to reduce blockages and facilitate routine cleaning and debris removal. Trash racks shall not be placed at the downstream end of culverts. Public safety is the highest priority when determining whether to include and how to design a trash rack. The DISTRICT MANUAL criteria for trash racks shall be followed.

12.10 Checklist and Design Aids

All of the design criteria in this chapter must be followed. Several key considerations include:

1. No street overtopping for the 10-year storm.
2. Check minimum and maximum outlet velocity.
3. Minimum culvert size crossing the public ROW is 18-inch diameter or equivalent.
4. Minimum culvert size for roadside ditches at driveways is 15-inch diameter or equivalent.
5. Headwalls and wingwalls are provided for all culverts with diameter larger than 30 inches.
6. Check maximum headwater for design conditions.
7. Check structural requirements and emergency overflow route.
8. Check public safety provisions.

This page intentionally left blank.

13.0 DETENTION (STORAGE)

13.1 Introduction

Detention of flood flows for all development and redevelopment projects (as defined in Section 1.3) is required in accordance with the policies presented in Section 3.3.1.12 of these DENVER CRITERIA. The main purpose of a detention facility is to store the excess storm runoff associated with increased basin imperviousness and discharge this excess at a rate similar to the rate experienced from the basin without development.

This chapter provides the criteria that shall be used in the design and evaluation of all detention facilities. The criteria presented in the STORAGE chapter of the DISTRICT MANUAL are hereby incorporated by reference and shall be adhered to unless elaborated upon or modified herein. Any special design conditions that cannot be defined by these DENVER CRITERIA shall be reviewed by the Department of Public Works before proceeding with design. Denver strongly encourages integration of detention and water quality treatment requirements in accordance with the strategies presented in Chapter 6 of the current *Denver Water Quality Management Pla*n, which can be downloaded from http://www.denvergov.org/publicworks/ and Volume 3 of the DISTRICT MANUAL. All detention facilities must have adequate maintenance access and be maintained on a regular basis.

13.2 Design Criteria

13.2.1 Design Storm Event Frequency

All detention facilities shall be designed to control the 10- and 100-year recurrence interval floods and may be combined with the water quality capture volume (WQCV).

13.2.2 Sizing Methodology for Volumes and Release Rates

Table 13.1 summarizes acceptable methodologies for sizing detention facilities. The STORAGE chapter of the DISTRICT MANUAL should be referenced for application of these methods. Input and output listings used with software programs shall be provided to Denver in electronic and hard copy formats.

Table 13.1. Detention Sizing Methodologies

Method	Site Conditions	Comments
Simplified Method Based on Empirical Equations in STORAGE Chapter of DISTRICT MANUAL	Small basins less than 90 acres. Do not use when off-site flows are present. Use with care when multi-stage controls are used.	This method has limited application subject to the site conditions.
Hydrograph Routing Procedures using Colorado Urban Hydrograph Procedure (CUHP)/Stormwater Management Model (SWMM) and/or UD-Pond Wizard or UD-Detention Spreadsheet (downloadable from www.udfcd.org)	Larger basins greater than 90 acres. Required when upstream detention facilities are present in watershed.	A historic imperviousness of 2% or less must be used in this procedure. The Natural Resources Conservation Service (NRCS) soil classification for the land area must also be used. Off-site tributary areas to the facility must be included in sizing volumes. Also see the UD Detention Spreadsheet.

When integrating the WQCV into detention facilities, as discussed in Chapter 14 of these DENVER CRITERIA, the facility shall be sized to control the 10-year volume plus the WQCV. For the 100-year event, one-half of the WQCV may be included in the 100-year volume.

The maximum allowable unit release rates for the 10- and 100-year volumes shall be based on the predominant soil type at a site in accordance with Table 13.2. If NRCS soil surveys are not available for a site, then site-specific soils evaluation shall be completed.

Table 13.2. Maximum Allowable Unit Flow Release Rates (cfs/acre) per Tributary Area

Design Return Period	NRCS Soil Group and Release Rate (cfs/acre)		
	A	B	C&D
10-year	0.13	0.23	0.30
100-year	0.50	0.85	1.00

13.2.3 Relationship to Adjacent Properties and Structures

Impacts to upstream and downstream properties relative to proposed detention facilities shall be considered and minimized through appropriate facility design. If an adequate outfall does not exist or if some portions of the proposed development drain directly off-site, then it may be necessary for the new development to over-detain, thereby incorporating more restrictive release rates and larger detention volumes.

Designs shall take into account the location of structures near detention facilities and plan accordingly to prevent seepage into basements and structural damage.

13.2.4 Maintenance

All detention facilities shall be designed with adequate maintenance access provisions and in a manner that facilitates ease of maintenance. For larger regional facilities to be eligible for UDFCD maintenance, the most current version of UDFCD's maintenance eligibility requirements (downloadable from www.udfcd.org) must be met.

13.3 Detention Methods

There are two basic approaches to designing storage facilities. When runoff storage facilities are planned on an individual site basis, they are referred to as "on-site." Larger facilities that have been identified and sized as a part of some overall regional plan are categorized as "regional" facilities. In addition, the regional definition can also be applied to storage facilities that address moderately sized watersheds to encompass multiple land development projects. This chapter focuses primarily on on-site detention facilities. In order for Denver to consider regional facilities, the following criteria must be met:

1. A Denver-approved master plan recommends the regional detention facility.
2. The regional detention facility is designed to accommodate the fully developed flows from the upstream watershed.
3. The regional detention facility is constructed, or will be constructed in phases with the development; otherwise, temporary detention must be provided.
4. Legally-binding ownership and maintenance responsibilities by a public entity are clearly defined to ensure the proper function of the facility in perpetuity.
5. There is adequate conveyance of the fully developed flows from the site to the regional detention basin.
6. Design is completed in accordance with the DISTRICT MANUAL, considering these criteria:
    a. Multi-use (e.g., recreation) shall be considered in the design of detention basins.
    b. The creation of jurisdictional dams shall be strongly discouraged.
    c. Basins shall be located on existing publicly-owned lands whenever possible.
    d. If regional flood control detention facilities incorporate regional extended detention basins for stormwater quality, developments upstream of the regional facility shall provide the minimum level of onsite stormwater quality enhancement identified in Chapter 14, Stormwater Quality.

Criteria for several approaches to on-site detention are provided in the remainder of this chapter based on the facility being located in open space, parking lots or underground. Underground detention is only

allowed in ultra-urban settings where redevelopment is taking place and when no other on-surface methods are practicable. In these cases, underground detention must meet strict criteria to be approved for use by Denver. Retention ponds to capture 100-year runoff are strongly discouraged and shall only be considered when there is no formal drainageway available within a reasonable distance of the site or one that is grossly inadequate.

13.4 Design Standards for Above-ground Detention Basins

13.4.1 State Engineer's Office

Any dam constructed for the purpose of storing water, with a surface area, volume, or dam height as specified in Colorado Revised Statutes 37-87-105 as amended, shall require the approval of the plans by the State Engineer's Office. Those facilities subject to state statutes shall be designed and constructed in accordance with the criteria of the state, in addition to these DENVER CRITERIA.

13.4.2 Grading Requirements

Grading requirements for embankments shall be in accordance with Table 13.3. All earthen embankments shall be covered with topsoil and revegetated with grass.

Table 13.3. Grading Criteria for Embankments

Embankment Height	Criteria
5 feet in height or less	No steeper than 4 (horizontal) to 1 (vertical).
Higher than 5 feet	Slopes shall not be steeper than 3 (horizontal) to 1 (vertical), but 4 (horizontal) to 1 (vertical) is preferred.
Riprapped embankments	No steeper than 3 (horizontal) to 1 (vertical).
Grassed detention facilities	Minimum bottom slope shall be 1.0 percent measured perpendicular to the trickle channel.

13.4.3 Use of Retaining Walls

The use of retaining walls within detention basins is generally discouraged; however, if walls are unavoidable, low-height walls less than 30 inches that are constructed of natural rock or landscape block are preferred. Long-term maintenance access, safety and aesthetics are important design considerations. Maintenance equipment must be able to safely reach the bottom of the facility and have adequate space to operate and turn. If several retaining walls are used, a separation of at least 4 feet shall be provided. Any future outfalls to the basin shall be designed and constructed concurrently with the detention basin. This eliminates future disturbance of the retaining walls, which may jeopardize the wall's structural integrity, in order to construct the future outfall. Foundation walls of buildings shall not be used as detention basin retaining walls.

If accepted by Denver, any retaining walls exceeding a height of 30 inches (as measured from the ground line to the top of the wall) shall be provided with handrails and shall require a Building Permit. All handrails/guardrails shall be designed to meet International Building Code (IBC) requirements.

Appropriate measures (typically an all-weather access road to the basin bottom) shall be included to allow for access by maintenance equipment.

Walled-in or steep-sided basins should be located away from major pedestrian routes and emergency egress routes should be provided. Site lighting may also be required to discourage illicit activity in walled-in basins.

A licensed professional engineer shall perform a structural analysis of the retaining wall for the various loading conditions the wall may encounter. The wall design and calculations shall be stamped by the professional engineer and submitted to Denver for review. The structural design details and requirements for the retaining wall(s) shall be included in the construction drawings.

13.4.4 Freeboard Requirements

For sites greater than or equal to 5 acres, the elevation of the top of the embankment shall be a minimum of 1 foot above the water surface elevation when the emergency spillway is conveying the maximum design or emergency flow. For sites less than 5 acres, the minimum required freeboard is 1.0 foot above the computed 100-year water surface elevation in the detention facility.

13.4.5 Inlet Configuration

Inlets shall be designed in accordance with the DISTRICT MANUAL. Forebays shall be provided, as shown in Figure 13.1, to reduce sediment loading to the facility. Such forebays shall be regularly maintained.

13.4.6 Trickle Channel (Low Flow) Control

All grassed bottom detention basins shall include a concrete trickle channel designed according to DISTRICT MANUAL and as illustrated in Figure 13.2.

13.4.7 Outlet Configuration

The DISTRICT MANUAL and UDFCD website (www.udfcd.org) provide design guidance, design details and examples for several detention basin outlet configurations. Figure 13.3 provides design details with Denver's criteria incorporated. The minimum allowable size of the outlet pipe is 8 inches, provided that it can convey 120 percent of the 100-year outflow, and a control orifice plate at the entrance of the pipe is required to control the discharge of the design flow. The trash rack must be designed in accordance with the DISTRICT MANUAL. Clogging is a particularly important concern on small sites. Figure 13.4 illustrates how outlet designs and trash racks may be used to minimize clogging. The UDFCD website (www.udfcd.org) should be referenced for design details illustrating the integration of the WQCV into detention facilities.

All outlets shall be designed to minimize unauthorized modifications that affect proper function. A sign with a minimum area of 1.0 square foot shall be attached to the outlet or posted nearby (if unable to be posted to the outlet) with the following message:

WARNING

Keep screen and grate clean.

Unauthorized modification of this outlet is a code violation.

13.4.8 Embankment Protection/Emergency Spillway Requirements

Whenever a detention basin uses an embankment to contain water, the embankment shall be protected from catastrophic failure due to overtopping. Overtopping can occur when the basin outlets become obstructed or when a larger than 100-year storm occurs. The emergency spillway of a storage facility should be designed to pass flows in excess of the design flow of the outlet works. When the storage facility falls under the jurisdiction of the Colorado State Engineer's Office (SEO), the spillway's design storm is prescribed by the SEO (SEO 1988). If the storage facility is not a jurisdictional structure, the size of the spillway design storm should be based upon the risk and consequences of a facility failure. Generally, embankments should have spillways that, at a minimum, are capable of conveying the total peak 100-year storm discharge from a fully developed total tributary catchment, including all off-site areas, if any. Frequently, however, analysis of downstream hazards will indicate that the spillway design storm will need to be larger than the 100-year event.

Failure protection for the embankment may be provided in the form of a buried heavy soil riprap layer on the entire downstream face of the embankment or a separate emergency spillway. Structures shall not be located in the path of the emergency spillway or overflow. The invert of the emergency spillway should be set equal to or above the 100-year water surface elevation.

13.4.9 Landscaping Requirements

Water diversion/detention areas and embankments should be designed and constructed to blend with their surroundings, creating site amenities rather than eyesores. The *Denver Water Quality Management Plan* should be referenced for more guidance on designing aesthetically pleasing facilities. In open space or natural areas, techniques to be considered include creation of topographic changes that mimic natural conditions (including a variety of slope changes), using natural materials such as stone, blending with the textures and patterns of the surrounding landscape, and using materials that match the local environment. Existing drainage patterns should be preserved whenever possible.

All above-ground detention basins shall be revegetated in accordance with the criteria described in the REVEGETATION Chapter of the DISTRICT MANUAL. Additionally, landscaping improvements may be provided in the basin to enhance the aesthetics of the basin. When determining landscaping, long-term maintainability of the facility should be a high priority. The following is a list of guidelines (adapted from *Draft Douglas County Storm Drainage Criteria Manual*, Muller Engineering, 2005) for basin landscaping:

- Detention areas should have attractive natural-looking features, fit into the surrounding landscape and add to the overall character of an area, as opposed to having boxy and geometric features. The shape of the detention basin should be as natural looking as practical, with terracing of the slopes

and bottom. The tops and the toes of slopes should vary, and there should be an undulation in the shape and grading of the sides of the detention area.

- Slopes should vary and be well vegetated to prevent erosion. The use of appropriate groundcovers and grasses at the top of the slope help to soften the appearance of the detention area and can incorporate the detention area into the landscape design. Appropriate plant material, such as wetland species or drought tolerant species, should be planted in the detention area and on the slopes. Shrubs and trees should be planted back from the top of the slope. Native and perennial species should be used to the extent practical.

- Use of rock or wood mulch in and adjacent to detention facilities is discouraged because of its potential to be displaced and clog outlet structures. Mulch placed over filter fabric is particularly susceptible to displacement and should not be used on slopes greater than 6 (horizontal) to 1 (vertical) or below the 100-year water surface elevation.

- Rundowns, which convey runoff from streets and parking lots into channels or storage facilities, should be incorporated into the overall design and be attractively designed.

13.4.10 Multiple Use Considerations

Multiple uses of detention facilities are encouraged; however, it is critical that the uses of these areas be taken into account to ensure that usage conflicts are minimized. For example, areas used as soccer fields or golf courses need to drain within a reasonable timeframe to prevent soggy fields that are incompatible with recreational use. Other park and detention facility conflicts may relate to safety in areas used for child play, West Nile virus concerns, and/or protection and enhancement of wildlife. Specific factors that shall be considered for multiple use facilities include:

- Compatibility with design, historic designation or other protective constraints including wildlife habitat and protection.

- Compatibility with recreational uses. The level of organized and informal activity in a park must be considered.

- Technical constraints and opportunities including soil characteristics, turf management, or terrain.

- Potential for new natural areas and wildlife corridors.

- Size and configuration of the park. For example, a small neighborhood park under five acres would probably not be appropriate for a detention facility.

- Maintenance and operations, funding resources, successful techniques for dealing with silt, debris, etc.

- The configuration and easements for underground utilities and their impact on the existing park land.

- Potential for total rehabilitation of existing sites to accommodate multi-purpose uses.
- Impacts on all aspects of the open space system: Highline Canal and trails, South Platte River Greenway, natural areas including potential areas such as along gulches, traditional parks, and other publicly owned lands.

13.5 Design Standards for Parking Lot Detention

13.5.1 Depth Limitation

The maximum allowable design depth of ponding in parking lots for the 100-year flood is 12 inches.

13.5.2 Outlet Configuration

Where a drop inlet is used to discharge to a storm sewer or drainageway, the minimum pipe size for the outlet is 8-inch diameter, provided that it can convey 120 percent of the 100-year outflow. Where a weir and a small diameter outlet through a curb are used, the size and shape are dependent on the discharge/storage requirements. A minimum 4-inch-diameter pipe size is recommended. See Figure 13.5 for a representative outlet structure for use with small structures in parking lots.

13.5.3 Performance

To assure that the detention facility performs as designed, maintenance access shall be provided in accordance with Section 3.3.3. The outlet shall be designed to minimize unauthorized modifications, which affect function. Any repaving of the parking lot shall be evaluated for impact on volume and release rates and is subject to approval by the Department of Public Works. A sign shall be attached or posted in accordance with Section 13.5.4.

13.5.4 Flood Hazard Warning

All parking lot detention areas shall have multiple signs posted identifying the detention basin area. The signs shall have a minimum area of 1.5 square feet and containing the following message:

WARNING
This area is a detention basin and is subject
to periodic flooding to a depth of (provide design depth).

Any suitable materials and geometry of the sign are permissible, subject to approval by the Department of Public Works.

13.6 Design Standards for Underground Detention

Underground detention is strongly discouraged in Denver for the following reasons:

- Underground detention is not visible; therefore, it tends to be “out-of-sight, out-of-mind.” As a result, these devices do not typically receive regular maintenance, nor is their performance periodically monitored.

- Maintenance access is often poor, which can be a deterrent to maintenance.
- Anaerobic (absence of dissolved oxygen) conditions in bottom sediments are more likely to develop in underground devices. This condition can release pollutants that were bound to the sediment and cause bad odors.

Nevertheless, Denver recognizes that there are some cases where the use of such facilities is necessary due to extreme space constraints in smaller, ultra-urban redevelopment sites. Denver will consider the use of underground detention under these circumstances; however, the applicant must comply with the following restrictions prior to receiving authorization for its use:

- Clear evidence must be provided documenting why detention cannot be provided on the ground surface and why the use of an underground facility is the best choice for the site, considering factors such as initial installation, maintenance, and ability to assure long-term function.
- The WQCV must still be provided above-ground, even if detention is provided below ground.

When no other alternative is practicable, the requirements for underground detention are provided below.

13.6.1 Materials

Underground detention shall be constructed using corrugated aluminum pipe (CAP), reinforced concrete pipe (RCP), concrete vaults or approved equivalents. Galvanized or aluminumized pipes are not acceptable. The pipe thickness, cover, bedding, and backfill shall be designed to withstand HS-20 loading, or as otherwise required by Denver.

13.6.2 Configuration

Pipe or vault segments shall be sufficient in number, height, and length to provide the required minimum storage volume. The minimum headroom height of the pipe or vault segments shall be 48 inches to permit maintenance.

If parallel pipes are used, the pipe segments shall be placed side by side and connected at both ends by elbow and tee fittings (see Figure 13.6). The pipe segments shall be continuously sloped at a minimum of 0.25 percent to the outlet. Manholes for maintenance access shall be placed in the tee fittings, bends and in the straight segments of the pipe, when required.

Permanent buildings or structures shall not be placed directly above the underground detention.

13.6.3 Inlet and Outlet Design

Inlets to detention facilities can be surface inlets, pipes and/or a local private storm sewer system.

Outlets from underground detention shall consist of a short (maximum 50 foot) length(s) of pipe with an 8-inch minimum diameter that can convey 120 percent of the 100-year outflow. A two-pipe outlet may be required to control both design return periods. The invert of the lowest outlet pipe shall be set at the

lowest point in the detention vault. The outlet pipe(s) shall discharge into a standard manhole or standard inlet or into an open drainageway with erosion protection. If an orifice plate is required to control the release rates, the plate(s) shall have a hinge on one side to open into the detention pipes to facilitate back flushing of the outlet pipe(s) and be firmly bolted or secured to the wall to prevent leakage around the edges.

13.6.4 Maintenance Access

Access easements to the detention facility shall be provided in accordance with Figure 13.6. Maintenance access designs shall take into consideration Occupational Safety and Health Administration (OSHA) requirements for confined space entry.

13.7 Design Standards for 100-year Runoff Retention Ponds

13.7.1 Allowable Use

A retention facility (a pond with a zero release rate or a very slow release rate when a trickle outflow can be tolerated) is used when there is no available formal downstream drainageway, or one that is grossly inadequate. When designing a retention facility, the hydrologic basis of design is difficult to describe because of the stochastic nature of rainfall events. Thus, sizing for a given set of assumptions does not ensure that another scenario produced by nature (e.g., a series of small storms that add up to large volumes over a week or two) will not overwhelm the intended design. For this reason, retention ponds are strongly discouraged as a permanent solution for drainage problems. They have been used in some instances as temporary measures until a formal system is developed downstream.

When a retention pond is proposed as a temporary solution to an evolving drainage problem, the pond shall be sized to capture, as a minimum, the runoff equal to 1.5 times the 24-hour, 100-year storm plus 1-foot freeboard. The facility also shall be situated and designed so that when it overtops, no human-occupied or critical structures (e.g., electrical vaults) will be flooded, and no catastrophic failure at the facility (e.g., loss of dam embankment) will occur. Retention facilities shall be as shallow as feasible to encourage infiltration and other losses of the captured urban runoff. A minimum infiltration drawdown of the volume in 72 hours will be required for all retention ponds. If this volume cannot be infiltrated within this time frame, a secondary outlet must be designed to provide additional releases from the pond.

13.7.2 Calculation of Retention Volume

The standard methodology described below in Equation 13.1 and Table 13.4 shall be used for calculating the required volume for retention. The intent of this methodology is to provide a simple, reasonable calculation without compromising Denver's policies for public safety and welfare.

$$V_r = 1.5 \times [(r_{eff} / 12) \times A] \quad \text{(Equation 13.1)}$$

where:

V_r = Volume of retention pond in acre-feet

r_{eff} = Effective rainfall (from Table 13.4) in inches

A = Area of development in acres

Table 13.4. Required Retention Rainfall

% Impervious	Effective Rainfall (r_{eff})	% Impervious	Effective Rainfall (r_{eff})
35	2.56	70	3.54
40	2.70	75	3.68
45	2.84	80	3.82
50	2.98	85	3.96
55	3.12	90	4.10
60	3.26	95	4.24
65	3.40	99	4.35

The proposed site development plan shall be used to determine the percent imperviousness value for use in Table 13.4.

The effective rainfall for retention is based on the 100-year, 24-hour rainfall obtained from the NOAA Atlas. The average value for Denver is considered to be 4.8 inches. The effective rainfall was extrapolated using CUHP to obtain an effective value based on site development characteristics. No reduction in volume will be allowed for pond infiltration during the storm event.

13.7.3 Design Standards for Retention Ponds

Design standards for retention ponds must comply with specific site development, floodproofing, site investigation and physical design considerations, as described below.

1. Site Development: The total development site area must be accounted for when planning for the retention of stormwater runoff. Provide grading for the entire site development to drain to the retention pond. Any off-site basins that historically flow through the site must be provided flow routes around the site and returned to the natural drainageway. Colorado state law maintains that “a property within a natural drainageway is subservient to the historic drainage from upper lands.” Off-site drainage cannot be excluded if there is no other discharge location to be used; therefore, in volume calculations, include all off-site drainage basin areas that cannot otherwise be rerouted around the development and returned to the natural drainage path.

2. Floodproofing: The construction of a retention pond is essentially creating an isolated floodplain on the property. Delineate the limits of the 100-year flood area on the design drawing. Provide 1 foot of freeboard from the 100-year maximum water surface elevation of retention pond volume. Provide a 100-year emergency release overflow route from the site, which returns the flow back to its natural drainage path. Ensure finished floor elevations are 1.5 feet above the water surface elevation when the emergency spillway is conveying the maximum design flow or emergency flow.

3. Site Investigation: Site selection for infiltration retention ponds is critical. Factors for evaluating site suitability include:

    - Location of groundwater table
    - Location of bedrock
    - Seasonal fluctuation of water table
    - Soil permeability and porosity
    - Soil profile
    - Environmental conditions (e.g., contaminated soils)
    - Proximity to structures (e.g., basements)

    The following factors would preclude the site's use as a retention infiltration pond:

    - A seasonal high groundwater of less than 4 feet below the pond bottom
    - Bedrock within 4 feet of the pond bottom
    - Pond location over fill
    - Surface and underlying soils classified as NRCS Hydrologic Group D
    - Saturated infiltration rate less than 0.3 inch per hour

    A thorough geotechnical and geohydrological investigation shall be performed to determine site suitability. The following shall be included in the investigation:

    - Soil borings to a depth of 10 feet or to bedrock
    - Percolation tests
    - Soil classification

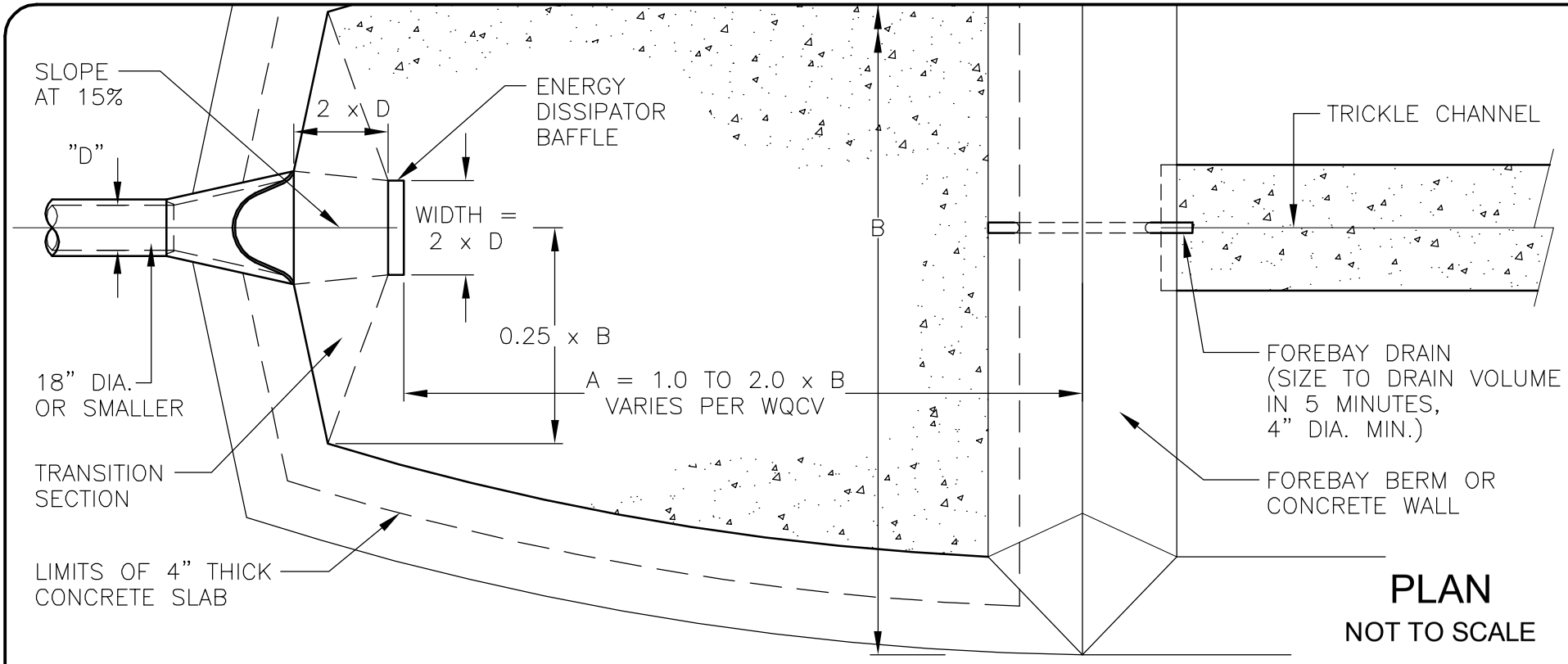
4. Physical Design Characteristics: The pond construction shall conform to the criteria as explained in Section 13.4 for above-ground detention basins. Section 13.4.2 shall be adhered to for grading

requirements. Section 13.4.8 shall be consulted for embankment protection as required. Section 13.4.9 shall be referred to for landscaping requirements.

13.8 Checklist and Design Aids

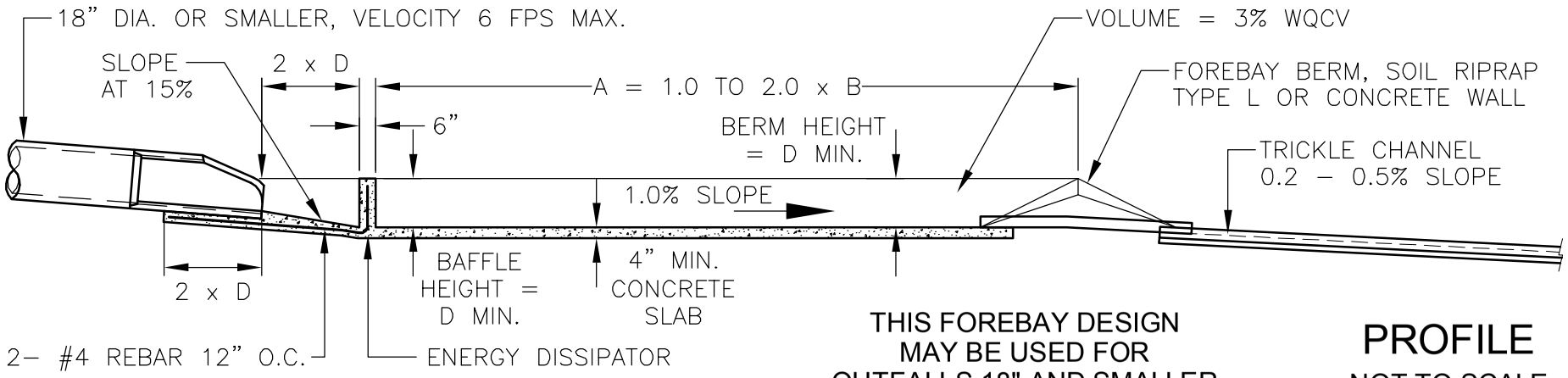
All of the design criteria in this chapter must be followed. Several key considerations that the designer must take care to address include:

1) Grade earth slopes 4:1 or flatter.
2) Provide minimum freeboard of 1 foot.
3) Provide trickle channels in above-ground detention areas.
4) Protect embankment from overtopping conditions.
5) Provide proper trash racks at all outlet structures.
6) Provide signs as required.
7) Provide maintenance access.
8) Provide emergency spillway and check emergency overflow path.
9) Check finished floor elevation of any structure near the detention basin.
10) Ensure that failure of underground detention is clearly evident from above ground.
11) Design the invert of the inflow pipe to the detention basin to be higher than the water quality level.



PLAN

NOT TO SCALE



THIS FOREBAY DESIGN
MAY BE USED FOR
OUTFALLS 18" AND SMALLER

PROFILE

NOT TO SCALE

FIGURE 13.1
POND FOREBAY WITH DISSIPATOR

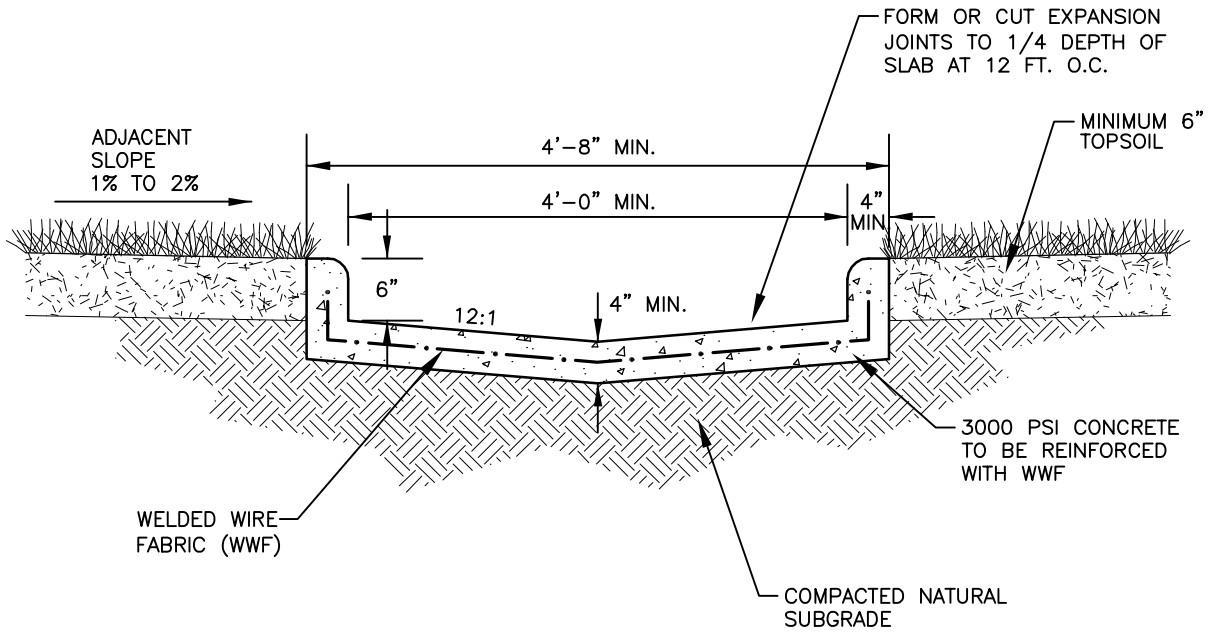
REVISED	
BY	DATE

CITY AND COUNTY OF DENVER
DEPARTMENT OF PUBLIC WORKS
WASTEWATER MANAGEMENT DIVISION

POND FOREBAY
WITH DISSIPATOR

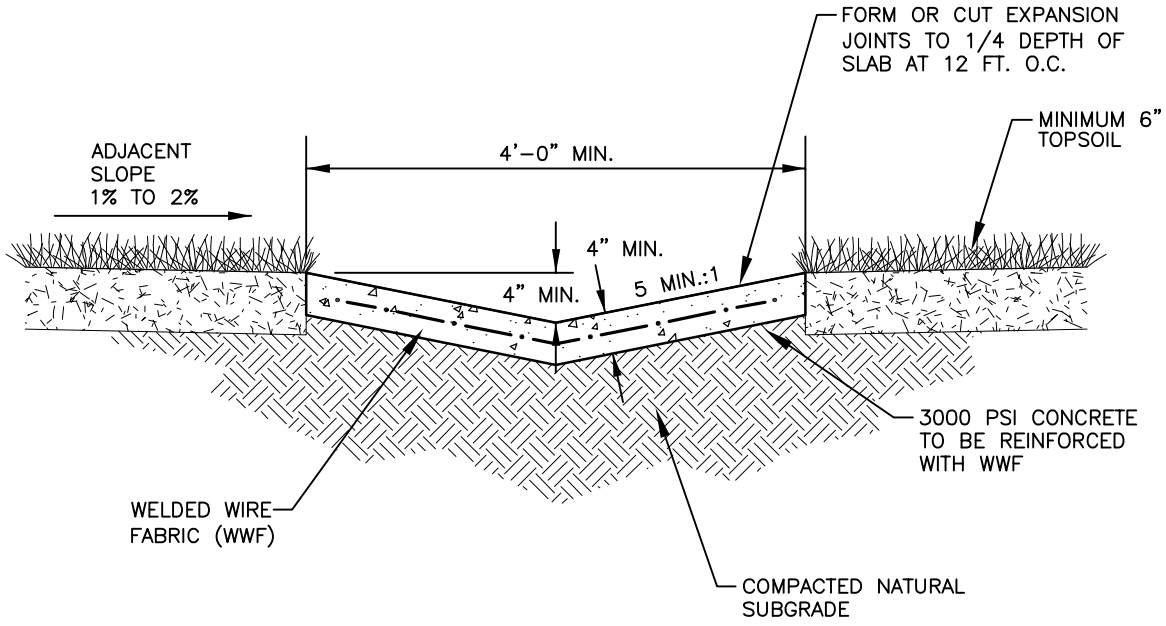
ISSUE DATE	DRAWN BY: KL
JAN. 2006	CHECKED BY: SF,BU

1/10/06; C:\PROJECT\041-159\DOCKAL\FOREBAY DISSIPATOR V6.DWG



DETENTION BASIN TRICKLE CHANNEL FOR DRAINAGE CATCHMENTS ≥5 ACRES

NOT TO SCALE



DETENTION BASIN TRICKLE CHANNEL FOR DRAINAGE CATCHMENTS <5 ACRES

NOT TO SCALE

FIGURE 13.2
CONCRETE TRICKLE CHANNEL SECTIONS FOR DETENTION BASINS

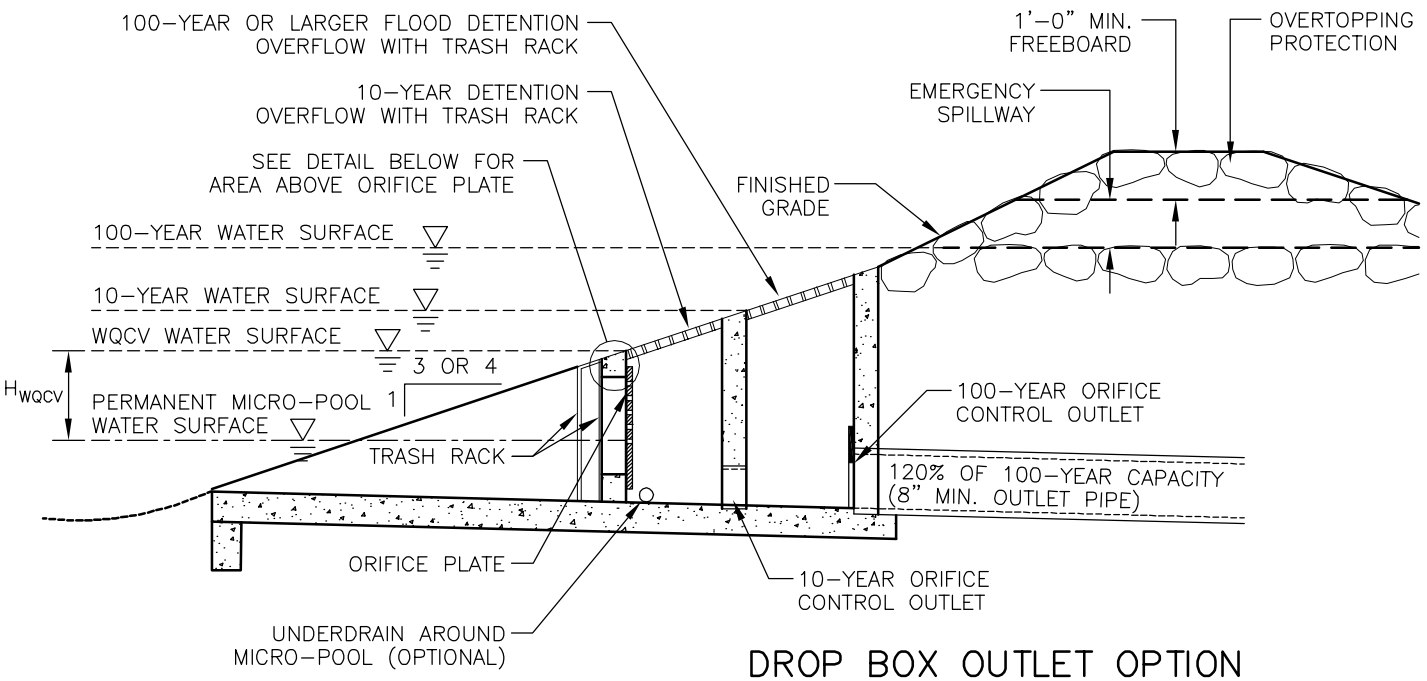
REVISED	
BY	DATE

CITY AND COUNTY OF DENVER
DEPARTMENT OF PUBLIC WORKS
WASTEWATER MANAGEMENT DIVISION

CONCRETE
TRICKLE CHANNEL SECTIONS
FOR DETENTION BASINS

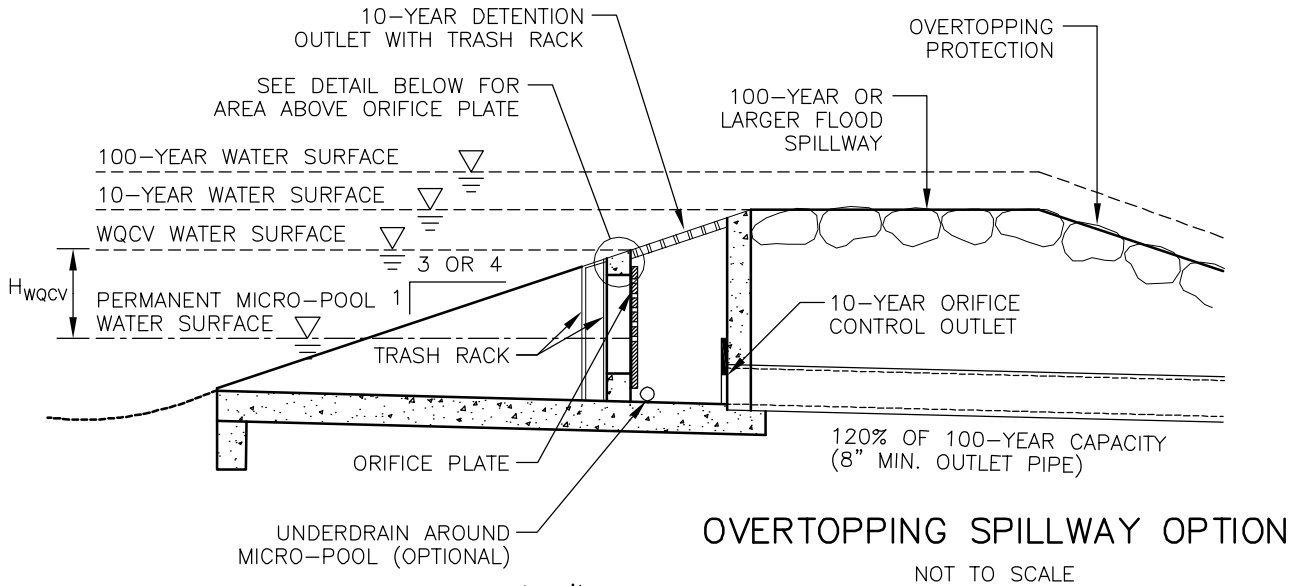
ISSUE DATE	DRAWN BY: KL
JAN. 2006	CHECKED BY: SF

1/3/06; C:\PROJECT\041-159\DOOKAL\TRICKLE CHANNELS V5.DWG



DROP BOX OUTLET OPTION

NOT TO SCALE

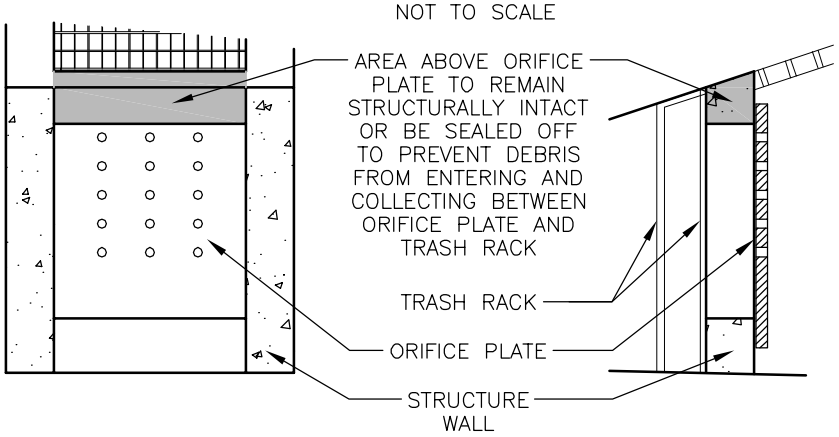


OVERTOPPING SPILLWAY OPTION

NOT TO SCALE

DETAIL

NOT TO SCALE



NOTE:

SIZE 10– TROUGH 100–YEAR OVERFLOW TRASH RACKS PER STORAGE CHAPTER IN DISTRICT MANUAL.

FIGURE 13.3
TYPICAL DETENTION OUTLET STRUCTURE

REVISED	
BY	DATE

CITY AND COUNTY OF DENVER
DEPARTMENT OF PUBLIC WORKS
WASTEWATER MANAGEMENT DIVISION

TYPICAL WQCV OUTLET STRUCTURE

ISSUE DATE	DRAWN BY: KL
JAN. 2006	CHECKED BY SF

1/10/06; C:\PROJECT\041-159\000KAL\UDFCD USDCM V6 SD4.DWG

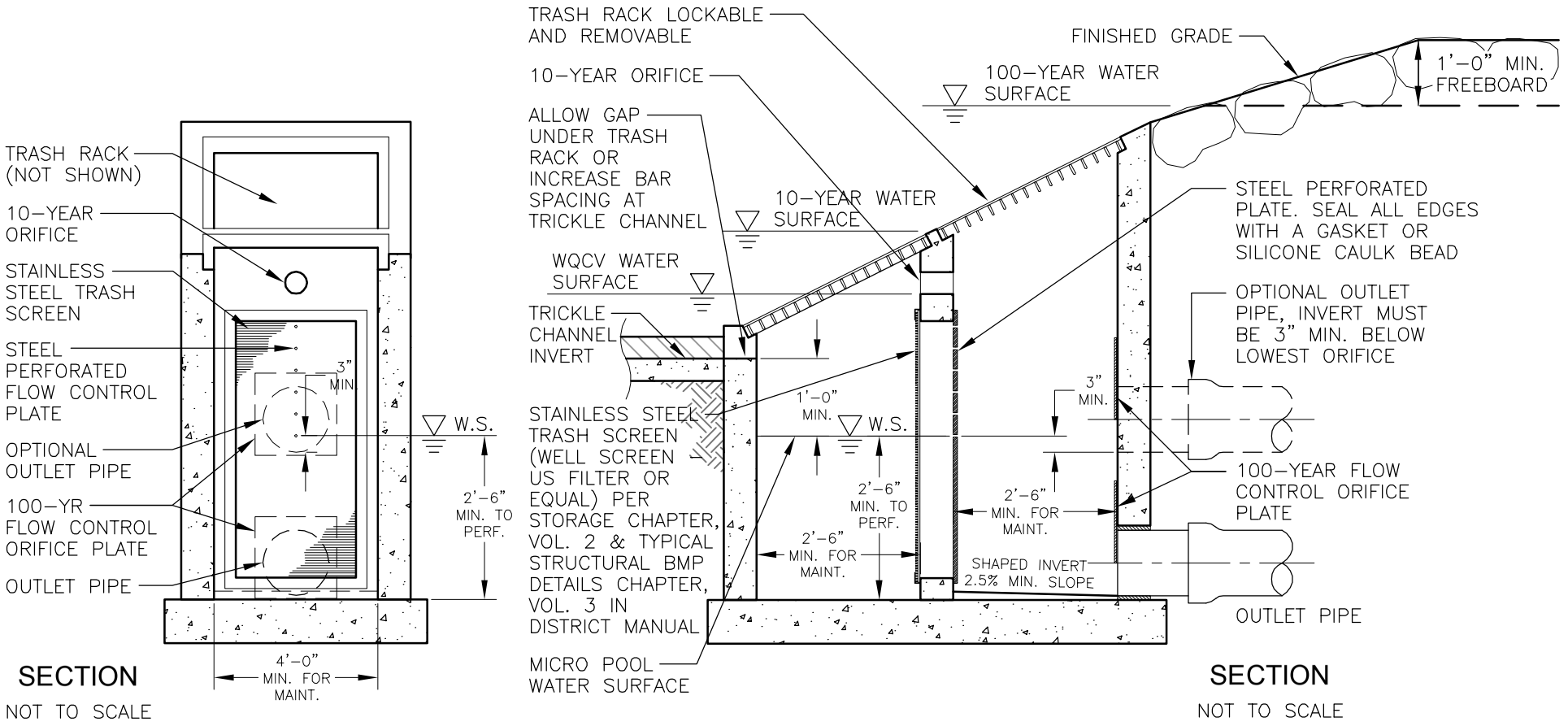


FIGURE 13.4
DETENTION OUTLET STRUCTURE FOR SMALL SITES <5 ACRES

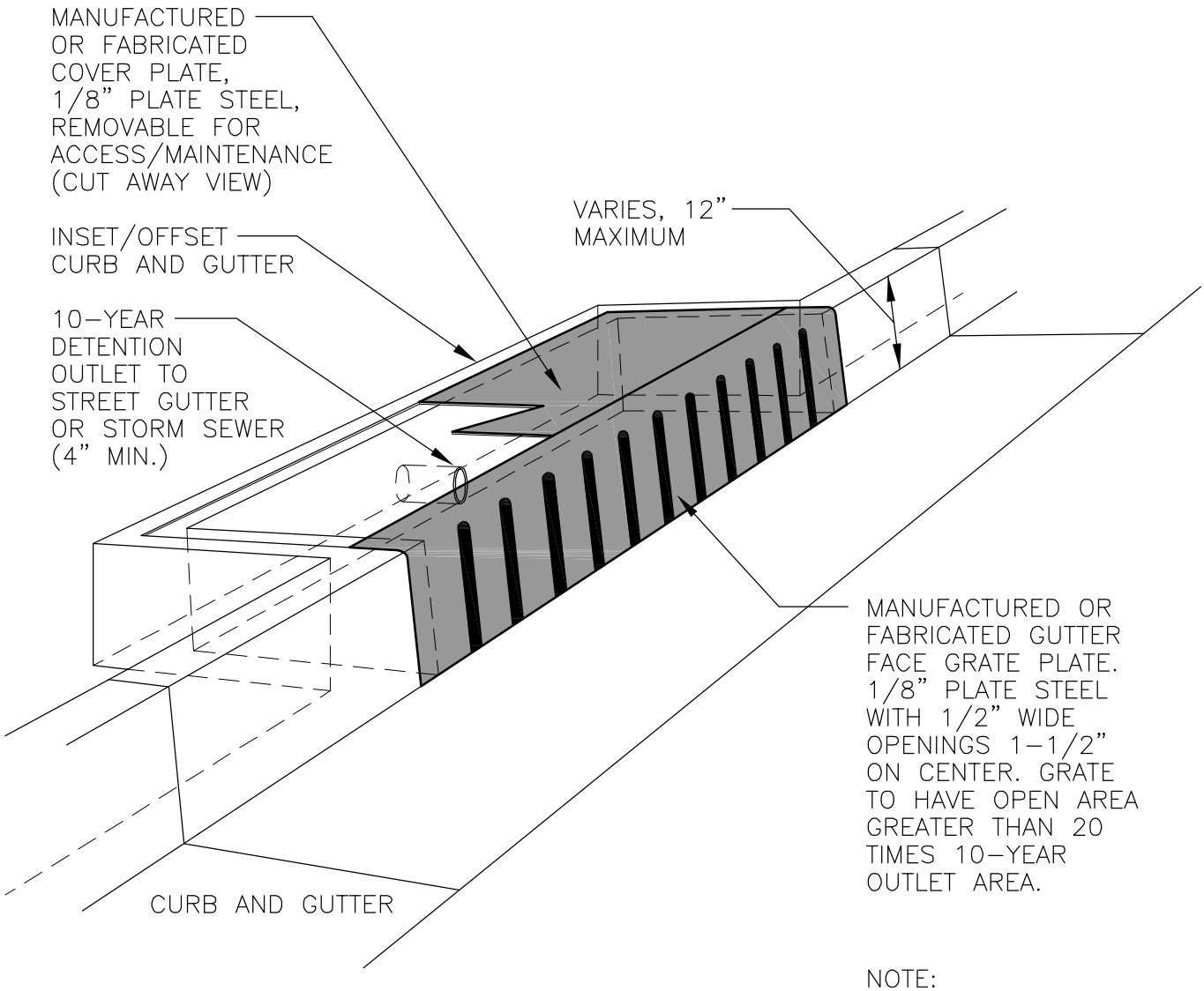
REVISED	
BY	DATE

CITY AND COUNTY OF DENVER
DEPARTMENT OF PUBLIC WORKS
WASTEWATER MANAGEMENT DIVISION

WQCV OUTLET FOR DRAINAGE CATCHMENTS < 5 ACRES

ISSUE DATE	DRAWN BY: KL		
JAN. 2006	CHECKED BY: SF		

1/9/06; C:\PROJECT\041-159\DOUKAL\WQCV OUTLET V11.DWG



NOTE:
TYPICALLY APPLIED TO SITES <1 ACRE OR AS FOREBAY TO WQCV POND.

NOT TO SCALE

FIGURE 13.5
PARKING LOT DETENTION OUTLET GRATE FOR SMALL SITES

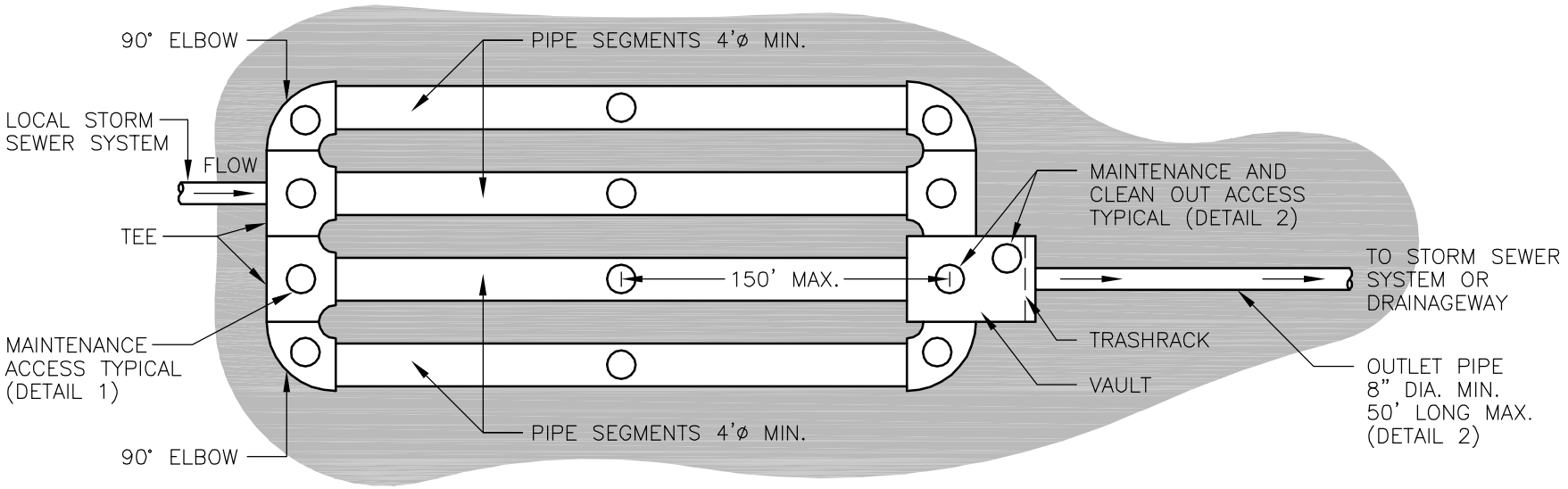
REVISED	
BY	DATE

CITY AND COUNTY OF DENVER
DEPARTMENT OF PUBLIC WORKS
WASTEWATER MANAGEMENT DIVISION

CURB AND GUTTER PARKING LOT DETENTION OUTLET GRATE FOR TRIBUTARY SITES

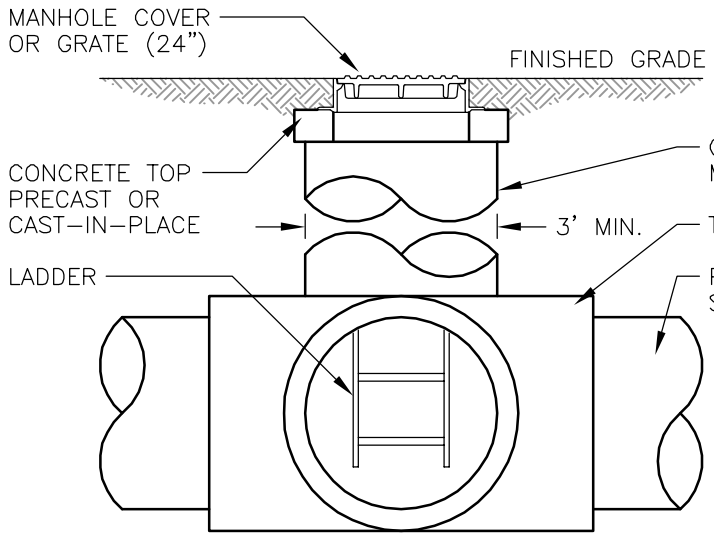
ISSUE DATE	DRAWN BY: KL
JAN. 2006	CHECKED BY: SF

1/3/06; C:\041-159\000KAL\GUTTER GRATE V7.DWG



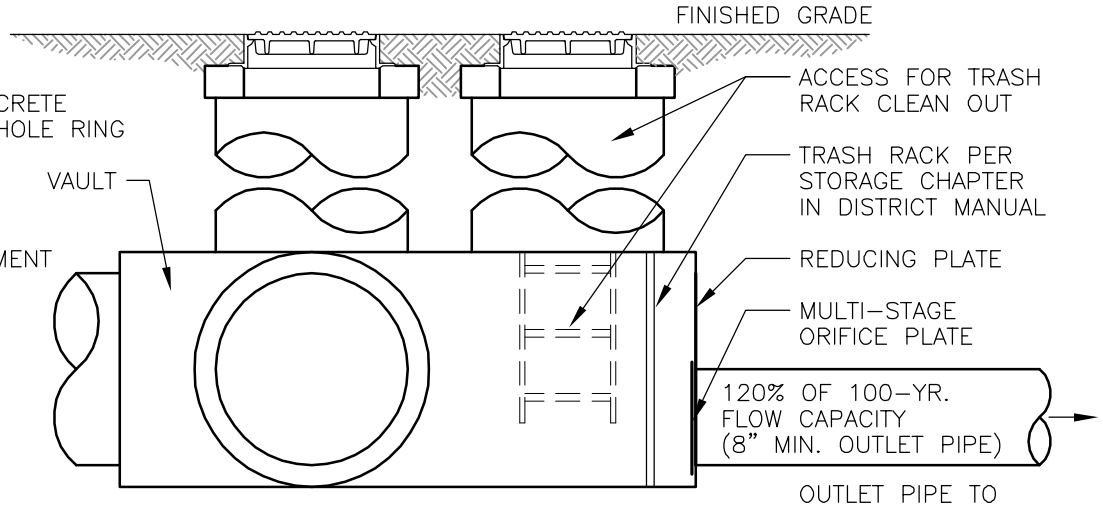
GENERAL PLAN

NOT TO SCALE



DETAIL 1 – MAINTENANCE ACCESS

NOT TO SCALE



DETAIL 2 – OUTLET

NOT TO SCALE

FIGURE 13.6
UNDERGROUND DETENTION LAYOUT
(NOT TO BE USED FOR WQCV)

REVISED	
BY	DATE

CITY AND COUNTY OF DENVER
DEPARTMENT OF PUBLIC WORKS
WASTEWATER MANAGEMENT DIVISION

UNDERGROUND DETENTION

ISSUE DATE	DRAWN BY: KL
JAN. 2006	CHECKED BY: SF,BU

1/10/06; C:\PROJECT\041-159\DOGKAL\UG DETENTION V6.DWG

This page intentionally left blank.

14.0 WATER QUALITY

14.1 Introduction

Urban stormwater runoff from rainfall and snowmelt typically carries a variety of pollutants that can adversely affect streams, rivers and lakes unless specific measures are taken to reduce these impacts. Adverse physical impacts to streams can also result from urban runoff, even from small, frequently occurring storms. All public and private Projects (as defined in Section 14.2) in Denver must implement measures designed to enhance the quality of stormwater runoff. These measures are commonly referred to as stormwater quality Best Management Practices (BMPs). Denver requires that Projects provide functional, maintainable, and attractive stormwater quality BMPs that are integrated into the overall site design, compatible with the surrounding land use and community goals, and remain maintainable and function as intended.

This chapter hereby incorporates by reference specified portions of Volume 3 of the DISTRICT MANUAL for purposes of design and implementation of BMPs. Furthermore, application of the criteria contained herein shall be in accordance with the guidelines stated in the *Denver Water Quality Management Plan*.

14.2 Definitions

The terms 'project' and 'new development or redevelopment project' are used more broadly in other chapters of these DENVER CRITERIA and other reference documents. (See footnote 1, chapter 1.) For purposes of this chapter alone, the following words and phrases have the meaning given below:

1. *Projects:* All public and private construction, earth disturbance, demolition, linear, and other projects disturbing any existing ground surface.

2. *New Development or Redevelopment Project* (also called "Chapter 14 Development or Redevelopment Projects"): A Project of development or redevelopment that disturbs greater than or equal to one acre, including Projects less than one acre that are part of a larger common plan of development or redevelopment, which discharge into the Denver MS4.

3. *Linear Project:* A transportation corridor Project which is not a part of a New Development or Redevelopment Project, having as its primary purpose the construction, replacement, or rehabilitation of streets, railways, and/or utilities including but not limited to roadways, utilities, railways, curb and gutter, alleys, sidewalks, trails, bridges, and related appurtenances .

4. *Linear Construction Project*: A Linear Project where new and/or additional pavement or concrete (or other alteration to the footprint of the transportation corridor) is installed, which new/additional paving disturbs one (1) acre or more outside of the original footprint, including Projects less than one (1) acre that are part of a larger common plan of development or redevelopment.

5. *Linear Rehabilitation Project*: A Linear Project where pavement is removed and replaced with essentially the same footprint of the area, which removal/replacement does not disturb one (1) acre or more outside of the original footprint, including Linear Rehabilitation Projects less than one (1) acre that are part of a larger common plan of rehabilitation.

6. *Linear Maintenance Project:* A Linear Project that does not alter the footprint of the street or the curb and gutter, maintains original line and grade and original purpose of the existing facility including but not limited to 'rotomill and overlay', 'chipseal', or similar Projects as well as the installation, maintenance or replacement of utilities.

7. *Regional/Subregional:* For purposes of this chapter, regional facilities may provide water quality treatment for the area encompassed by any of the Collection System Basins (also known as Major Basins) identified in *The City and County of Denver Storm Drainage Master Plan (2009 and June 2010 Errata* and as it may be revised from time to time) on the basis of geology, existing drainage conditions, complaint records, split flow characteristics, and detailed hydrologic modeling using the Colorado Urban Hydrograph Procedure. See Table 14.1. Collection System Basins. *S*ubregional facilities may provide water quality treatment for a portion of any of the Collection System Basins.

Table 14.1. Collection System Basins

Major Drainageways	Collection System Basins[2] (eligible for Regional or Subregional Treatment Facilities)	
	ID	Name
South Platte River (Basin 0000)	0058-01	Prairie Gateway
	0059-01	Globeville – Utah Junction
	0060—01	I-70 & Colorado Boulevard
	0060-02	I-70 & York
	0061-01	27th & Federal
	0061-02	Highland
	0062-01	Lower Platte Valley
	0063-01	Central Platte Valley
	0064-01	1st & Federal
	0064-02	Valverde
	0065-01	Ruby Hill
	0065-02	Dartmouth
	0067-01	College View
	0067-02	West Belleview
	0067-03	Marston Lake
Second Creek (Basin 3500)	3501-01	West Fork Second Creek
First Creek (Basin 3700)	3700-01	Pena Corridor
	3700-02	Green Valley Ranch
	3700-03	Dogwood & Blue Gamma Tribs.
	3702-01	Tributary "T"
Irondale Gulch (Basin 3900)	3900-01	Stapleton East Section 10
	3900-02	Montbello
	3900-03	Parkfield
	3900-04	Majestic Commerce Center
	3901-01	West Montbello
	3901-02	Gateway
	4000-01	Stapleton West Section 10
Rocky Mountain Arsenal (Basin 4000)	4000-01	Stapleton West Section 10
Clear Creek (Basin 4300)	4300-03	North of I-70
	4309-01	Berkeley Lake
Sand Creek (Basin 4400)	4400-01	North Stapleton
	4400-02	Quebec Corridor
	4400-03	Stapleton
	4400-04	East Stapleton
Westerly Creek (Basin 4401)	4401-01	South Stapleton
	4401-02	11th Avenue to Montview
	4401-03	Lowry
	4401-04	South of Alameda
Montclair (Basin 4500)	4500-01	City Park
	4500-02	36th & Downing
	4500-03	Park Hill – Colfax Avenue
	4500-04	Park Hill – 6th Avenue

[2] Collection System Basins are also termed Major Basins in the City and County of Denver Storm Drainage Master Plan (2009 with June 2010 Errata and as it may be amended from time to time).

Major Drainageways	Collection System Basins[2] (eligible for Regional or Subregional Treatment Facilities)	
	ID	Name
Cherry Creek (Basin 4600)	4600-01	Central Business District
	4600-01 0062-01	Central Business District
	4600-02	Cherry Creek Mall
	4600-03	Upper Cherry Creek
	4600-04	Cherry Creek Reservoir
Goldsmith Gulch (Basin 4601)	4601-01	Lower Goldsmith Gulch
	4601-02	Middle Goldsmith Gulch
Sloan's Lake (Basin 4700)	4700-01	West Colfax Avenue
Lakewood Gulch (Basin 4800)	4800-01	12th & Federal
Dry Gulch (Basin 4801)	4801-01	12th & Sheridan
Weir Gulch (Basin 4900)	4900-01	West 6th Avenue
I-25 & South Platte (Basin 5000)	5000-01	West Washington Park
	5000-02	University & Mexico North
	5000-03	University & Mexico South
Sanderson Gulch (Basin 5100)	5100-01	West Florida Avenue
Harvard Gulch (Basin 5200)	5200-01	Harvard Gulch Lower Basin
	5200-02	Harvard Gulch Middle Basin
	5200-03	Harvard Gulch Upper Basin
West Harvard Gulch (Basin 5300)	5300-01	West Yale Avenue
Greenwood Gulch (Basin 5400)	5401-01	South Monaco Parkway
Bear Creek (Basin 5500)	5500-01	Fort Logan
	5500-02	Upper Bear Creek
	5500-03	Academy Park Tributary
	5500-04	Marston Lake North
	5500-05	Pinehurst Tributary
Marston Lake North (Basin 5501)	5501-01	Henry's Lake
Dutch Creek	5901-01	Coon Creek

14.3 Basic Design Principles and Procedure

The *Denver Water Quality Management Plan* identifies guiding principles for integrating stormwater quality measures into the overall design of Projects. This information is summarized below for the reader's convenience.

1. **Consider stormwater quality needs early in the design process.** Left to the end of site development, stormwater quality facilities will often be "shoe-horned" into the site, resulting in forced, constrained approaches. When included in the initial planning for a project, opportunities to integrate stormwater quality facilities into a site can be fully realized.

2. **Take advantage of the entire site when planning for stormwater quality treatment.** Spreading runoff over a larger portion of the site can help to reduce undesirable treatment strategies that rely on proprietary underground treatment devices or deep, walled-in basins that detract from a site and are difficult to maintain.

3. **Reduce runoff rates and volumes to the maximum extent practicable to more closely match natural conditions**. To achieve this, place stormwater in contact with the landscape, minimize directly connected impervious areas, reduce the amount of impervious area (e.g., replace low-use or emergency access paved areas with porous pavement) and select treatment techniques that promote infiltration.

4. **Integrate stormwater quality management and flood control, when practical.** For example, in cases where an extended detention basin, retention pond, wetland basin, or sand filter basin is used to address stormwater quality, any of these basins can be modified to include flood control detention in addition to the WQCV if space constraints allow.

5. **Design attractive stormwater quality facilities that enhance the site, the community, and the environment.** Designers should consider surrounding land use type, immediate context, the prominence of the stormwater quality facility's location on the site, and the proximity of the site to important civic spaces.

6. **Design sustainable facilities that can be safely maintained.** Facility design should provide adequate maintenance access with a minimum disturbance, disruption, and cost. Designers need to fully consider how these facilities will be maintained, and what equipment will be necessary.

7. **Design and maintain facilities with public safety in mind**. Designers need to consider minimizing perimeter wall heights, providing railing adjacent to vertical drops of 30" or more, and ensuring basin edges are designed with gradually sloping banks. They should also avoid walled-in or steeply sloped, remote basins that could provide haven for illicit activities. Lighting should be considered an option, where necessary.

The following design process provides guidance for implementing these seven principles into the requirements presented in this Chapter.

1. **Develop an initial site design.** This should include a rough layout of lots, buildings, streets, parking, and landscape areas with a general idea of proposed site grades and an estimate of approximate areas associated with roofs, streets, walks, parking lots, and landscaping or open space.

2. **Consider the full range of BMP alternatives.** Determine which of the seven Development Types in Table 14.2 most closely match the site and then consider the full range of alternative approaches for addressing drainage and stormwater quality for the site, including techniques to reduce runoff and distribute BMPs throughout the site. Reduce runoff volume to the maximum extent practicable by implementing practices that minimize directly connected impervious area and promote infiltration. Test the influence of several alternatives on the overall character and

layout of the site, weigh pros and cons of each, and progress towards an optimum approach. Consider long-term or life-cycle costs in the selection of alternative BMPs. When selecting and designing BMPs that rely on infiltration (such as porous pavement detention or bioretention), the designer needs to carefully consider geotechnical and foundation issues and the ability of the property owner to understand and properly maintain these facilities.

3. **Pursue a functional distribution of landscape areas.** Consider these principles:

    - Keep detention basins shallow and consider providing some space for tree and shrub plantings around their perimeter in areas that do not restrict maintenance access.
    - Reserve an initial area about 5 to 15 percent of the size of the impervious area for stormwater quality treatment. This area may be reduced in later stages of design.
    - Minimize exclusive reliance on extended detention basins (primarily for aesthetic and land use reasons). When included, locate them near a low-lying area of the site away from pedestrian corridors and gathering places.
    - Landscaped areas/grass buffers, porous landscape and porous pavement areas should be distributed throughout the site. See the Implementation Details section of Chapter 6 of the *Denver Water Quality Management Plan* for several examples of how bioretention facilities can be configured adjacent to buildings, in parking lots, and in other landscape areas. In general, it is prudent to locate bioretention facilities in close proximity to the impervious area being served.

4. **Consider surface conveyance as an alternative to pipes.** Conveying flows on the surface is the best method for getting runoff to porous landscape and porous pavement detention because it allows the facilities to be shallow. If flow can be conveyed on the surface in grass swales or in strips of modular block porous pavement, additional stormwater quality benefits will accrue and the required WQCV will be reduced. If runoff must be conveyed under the surface in a pipe, area inlets within a landscaped area are preferred over street or curb inlets, since this gives runoff a chance to sheet flow through vegetation and infiltrate prior to entering the storm sewer. The basin or channel receiving these flows must be deep enough to allow the opposite end of the pipe to empty.

5. **Integrate stormwater quality and flood control detention.** Identify flood control detention requirements, water quality treatment requirements and opportunities to integrate these functions into multi-purpose facilities.

6. **Tailor approach to the specific pollutants of concern.** If downstream receiving waters are threatened by specific stormwater constituents, such as lakes threatened by excessive

phosphorus loading leading to eutrophication, provide BMPs that are particularly effective at addressing that pollutant.

Table 14.2. Development Type Summary

Development Type	Percentage Landscape	Percentage Parking/Paving	Building Footprint	Parking	Blueprint Denver* Building Block	Examples
Ultra Urban	0-5%*	0-5%	90-100%	structure	Downtown	LODO
					Employment	Portions of Stapleton and Lowry
					Urban Residential	Capitol Hill
High Density Mixed Use	0-10%**	0-15%	80-90%	structure/ surface	Pedestrian Shopping Corridor	East Colfax Grant-York
					Mixed Use Residential	Golden Triangle
					Transportation Oriented Development (TOD)	Colorado Station (at I-25)
					Neighborhood Centers	Old South Gaylord
Campus	15-30%	10-25%	45-75%	surface/ structure	Campus/Institutional	Auraria, Denver Tech Center
Industrial	10-15%	40-60%	25-50%	surface	Industrial	I-70 Corridor
Low Density Mixed Use	10-25%	30-50%	25-60%	surface	Town Centers	14th and Krameria
					Commercial Corridor	South Colorado Blvd., Colfax
					Regional Centers	University Hills Shopping Center
					Entertainment/Cultural/ Exhibition	Natl. Western, Pepsi Center
Residential	40-70%	5-20%	10-45%	surface	Single Family/Duplex Residential	City Park West Neighborhood
					Single Family Residential	Sloan's Lake Neighborhood, Regis Neighborhood
Parks and Natural Areas Open Space	80-95%	5-15%	0-10%	surface	Parks and Natural Areas Open Space	City Park

*Blueprint Denver (Denver 2000) is the city's integrated land use and transportation plan that defines a variety of land use types for existing and proposed development in Denver.

** The low percentage of landscape does not preclude the use of porous pavement detention or "planter box" porous landscape detention to provide treatment for the WQCV on Ultra Urban or High Density Mixed Use sites.

14.4 Requirements

All Projects shall comply with the following criteria:

1. All Projects located within Denver shall provide specific measures to enhance the water quality of storm-generated runoff from the fully developed project site in accordance with Table 14.3 and as follows:

   Except as provided in subparagraph 2, below, Denver requires implementation of a four-step process for all Development and Redevelopment Projects including Linear Construction Projects:

   Step 1. Employ runoff reduction practices:

   Reduce post-development site runoff volume to the maximum extent practicable. This includes implementation of onsite structural controls, and/or Minimizing Directly Connected Impervious Area (MDCIA), Low Impact Development (LID) practices, and appropriate non-structural controls (also collectively referenced herein as “BMPs”).

   Step 2. Implement BMPs providing a water quality capture volume (WQCV) with slow release:

   Control the remaining (residual) runoff through structural controls that treat the necessary WQCV, with appropriate reduction “credits” for steps taken to reduce runoff volume, in accordance with the procedures in the DISTRICT MANUAL. Alternative structural control proposals may be accepted if it is demonstrated that the water quality benefit of the proposed permanent BMP meets or exceeds treatment of the WQCV. The Manager will make the final decision on whether an alternative to treatment of the WQCV can be implemented for any particular site.

   Determination of the WQCV and design requirements for timed release outlet structures shall conform to the methods and procedures outlined in Volume 3 of the DISTRICT MANUAL.

   Step 3. Stabilize drainageways:

   Implement stream channel stabilization techniques for drainageways on, or adjacent to, the site as needed to minimize channel impacts from site runoff.

Step 4. Implement site specific and other source control BMPs:

If a site includes substantial potential pollutant sources (e.g., gas stations, loading facilities, industrial sites), provide additional treatment, including covering of storage/handling areas, spill containment and control, and other best available technologies.

2. Regional and subregional treatment facilities. It is recognized that the physical characteristics of some Projects, including Linear Construction Projects, may constrain the selection of onsite treatment facilities. Underground facilities are disfavored because of concerns for worker safety, public safety and maintenance. At such time as the Manager receives program approval from the Water Quality Control Division of the Colorado Department of Public Health and Environment, and if MDCIA, LID practices, or other onsite structural controls are employed to reduce post-construction site runoff to the maximum extent practicable, regional or subregional treatment of the remaining WQCV may be allowed[3].

3. Design criteria and design details of treatment and source control BMPs, and design aid tools are provided in Volume 3 of the DISTRICT MANUAL, which provisions are adopted and incorporated by reference herein as Denver's minimum technical requirements. Volume 3 of the DISTRICT MANUAL also provides guidance about the BMPs which Denver may, in its discretion, follow.

4. All facilities designed to provide detention of storm-generated runoff for drainage and flood control purposes shall provide water quality enhancement through the use of a timed release water quality outlet structure or an approved alternative.

5. Sites that are not required to provide detention of storm runoff for drainage and flood control purposes may still be required to detain for water quality purposes in accordance with Table 14.3.

6. The landowner or owner's representative shall maintain the post-construction BMPs in accordance with the approved structural BMP operation and maintenance plan so that they function as intended. Maintenance guidance is provided in Volume 3 of the DISTRICT MANUAL.

[3] Denver intends to develop criteria for implementation of regional and subregional water quality facilities during a pilot project to evaluate a regional water quality approach(es). This paragraph 2 shall not take broad effect until completion of the pilot project, and approval by the Colorado Department of Public Health and Environment of a modified New Development Program under the City's MS4 permit.

Table 14.3. Permanent Stormwater BMP Requirements

Project Size	Permanent (i.e., Structural) Stormwater Quality BMPs Required?
1 acre or larger Development or Redevelopment* Project	Required
< 1 acre with flood control detention at-grade	Required
< 1 acre without flood detention at-grade	Denver May Require
Linear Construction Project*	Required
Linear Rehabilitation Project	Not Required
Linear Maintenance Project	Not Required

*Regional or subregional WQCV treatment may be allowed; see section 14.4(2).

14.5 Selection of BMPs[4]

Although a variety of BMPs may improve water quality at a given Project site, Denver requires installation, operation and maintenance of BMPs that meet the criteria expressed in Section 14.4 and that are appropriate for the community. Accordingly, additional factors related to the development type, aesthetics, surrounding land use, long-term sustainability and maintenance shall be taken into account in the selection, approval, and implementation of stormwater quality BMPs.

Table 14.2 summarizes typical land uses present in Denver. Table 14.4 identifies BMPs appropriate for use in these settings. Those BMPs marked "highly appropriate" generally will be required for that development type. Those BMPs marked "somewhat appropriate" *may* be acceptable for that development type. Those BMPs that are marked "not recommended" will generally be rejected. The developer may request approval of alternative BMPs and, in that case, should submit information to support its preference for "somewhat appropriate," "not recommended," or other BMP to demonstrate equivalence with the "highly appropriate" BMPs.

The *Denver Water Quality Management Plan* and the *BMP Selection Tool* in Volume 3 of the DISTRICT MANUAL provide guidance and supplemental information for BMP design. Additional guidance and design details for the structural BMPs in Table 14.4 can be obtained from Volume 3 of the DISTRICT MANUAL.

Underground vault-type devices are discouraged due to concerns that regular maintenance will not be provided, as well as the worker safety and public safety risks presented during maintenance activities.

[4] The requirements for Development or Redevelopment Projects and Linear Construction Projects are provided in section 14.4.

Supplemental design requirements for bioretention and sand filters are provided in Figures 14.1 and 14.2, respectively.

Table 14.4. Recommended Selection of Structural BMPs

	Runoff Reduction		Stormwater Quality Detention				Possible Flood Control Detention	
Development Type	Porous Pavement[1]	Grass Buffers and Swales & other MDCIA/ LID	Bioretention[2]	Porous Pavement Detention[1]	Dry Ponds: Extended Detention and Sand Filter Basins[3]	Wet Ponds: Constructed Wetland Basin and Retention Ponds [4]	Landscape Areas	Parking Lots
Ultra Urban			✓	✓				
High Density Mixed Use			✓	✓				
Campus	✓	✓	✓	✓	✓		✓	✓
Industrial					✓		✓	✓
Low Density Mixed Use	✓	✓	✓	✓	✓		✓	✓
Residential	✓	✓	✓	✓	✓		✓	
Parks and Natural Areas Open Space	✓	✓	✓	✓		✓	✓	✓

KEY	
✓	Highly appropriate
	Somewhat appropriate
	Not recommended

Notes:

1. Porous pavement and porous pavement detention may be used in parking areas and other low-use areas where there is no likelihood of groundwater contamination.
2. Bioretention may be applied in the vicinity of buildings, in parking lot islands, and in other landscape areas where there is no likelihood of groundwater contamination or geotechnical concerns. Wherever bioretention is used, geotechnical issues related to building foundation drainage and expansive soils must be addressed.
3. To avoid constrained configurations of forebays, low-flow channels, and outlet structures, extended detention basins are generally recommended only for drainage areas exceeding 1.0 acre, although sand-filter detention basins may be used for areas less than 1.0 acre. Sand-filter detention basins may be considered for use in Ultra Urban and High Density Mixed Use land uses.
4. Constructed wetland basins and retention ponds may generally be used only for drainage areas exceeding 1.0 acre that have sufficient base flow to support wetlands and permanent pools; water rights considerations need to be addressed.

14.6 Maintenance

Denver requires the following:

1) Facilities shall be designed to be readily maintainable with clearly specified long-term maintenance requirements.

2) Long-term maintenance of structural BMPs must be provided by the facility owner.

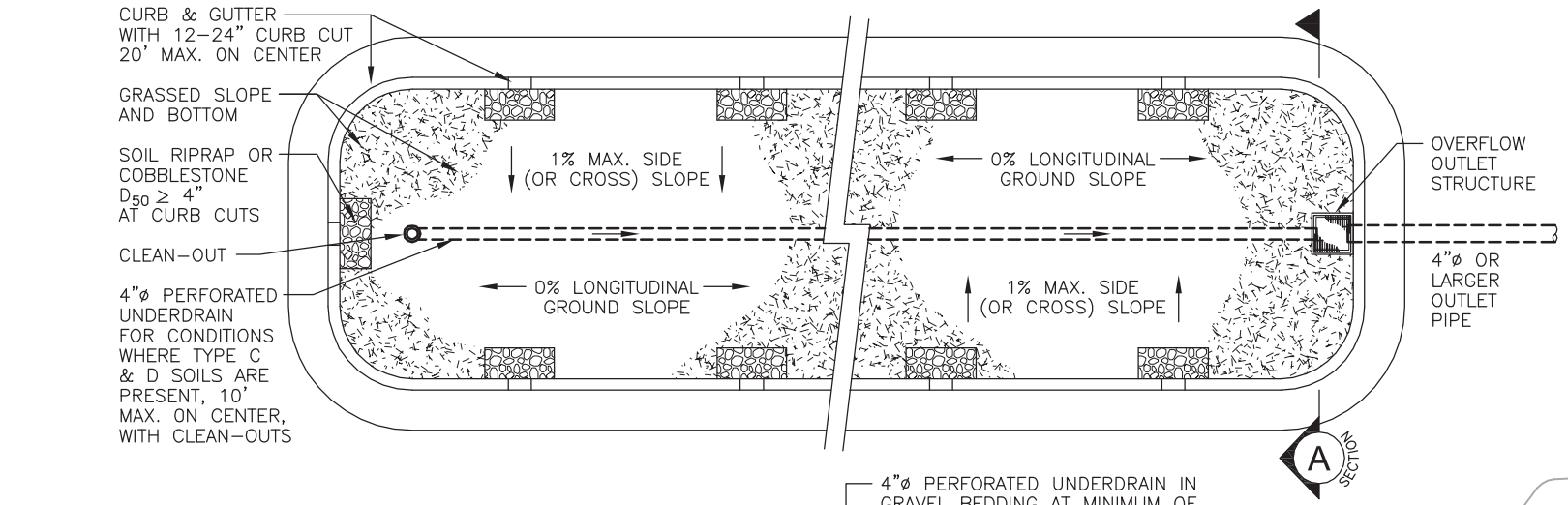
3) The facility owner, or owner's representative, shall submit to the city at the time it seeks plan approval an operations and maintenance plan to assure that all structural BMPs function as intended.

Maintenance guidelines are provided in the *Denver Water Quality Management Plan* and Volume 3 of the DISTRICT MANUAL which Denver may, in its discretion, follow.

14.7 Checklist and Design Aids

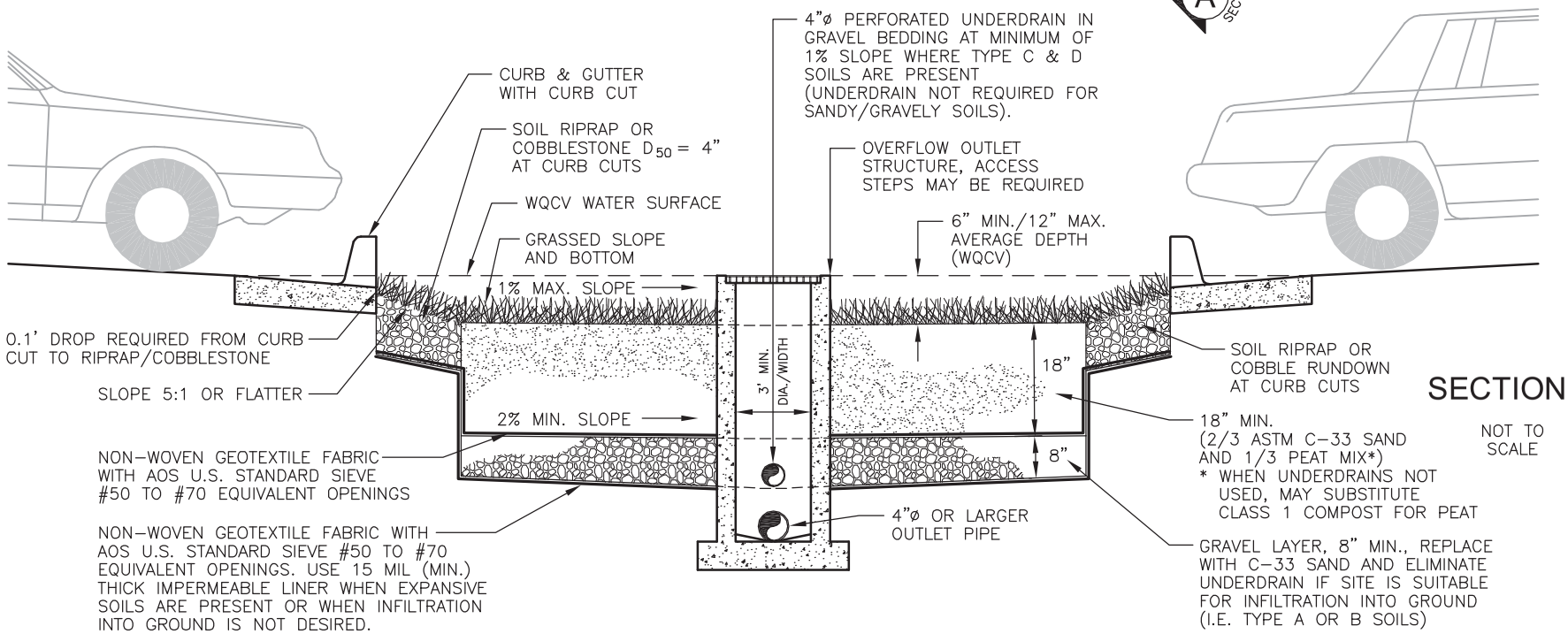
All of the design criteria in this chapter must be followed. Several key considerations that the designer must take care to address include:

1. Provide stormwater quality treatment in accordance with the requirements of this Chapter.
2. When treatment of the WQCV is required, calculate WQCV in accordance with the DISTRICT MANUAL.
3. Provide completed design forms from the DISTRICT MANUAL for selected structural BMPs.
4. Provide schematic details of selected structural BMPs.
5. Design the invert of the inflow pipe to the detention basin to be higher than the water quality level in detention basins.
6. Provide water quality outlet structure designs that minimize the number of perforation columns.
7. Design forebays to effectively capture sediment and keep the outlet structure from clogging.
8. Select BMPs with ease of maintenance as a top priority.
9. Provide an operations and maintenance plan for all structural BMPs. The components of this operations and maintenance plan shall be in accordance with Section 3.0 (Developing a Maintenance Plan) of Chapter 6 (BMP Maintenance) of Volume 3 of the DISTRICT MANUAL.
10. If proposed BMP(s) are not selected from Volume 3 of the DISTRICT MANUAL, then provide documented evidence that the BMP can satisfy the minimum technical requirements by meeting or exceeding similarly applicable BMP(s) in Volume 3 of the DISTRICT MANUAL.
11. Provide convenient access (such as a bench to easily reach a water quality plate) for maintenance.



PLAN

NOT TO SCALE



SECTION A

NOT TO SCALE

FIGURE 14.1

BIORETENTION

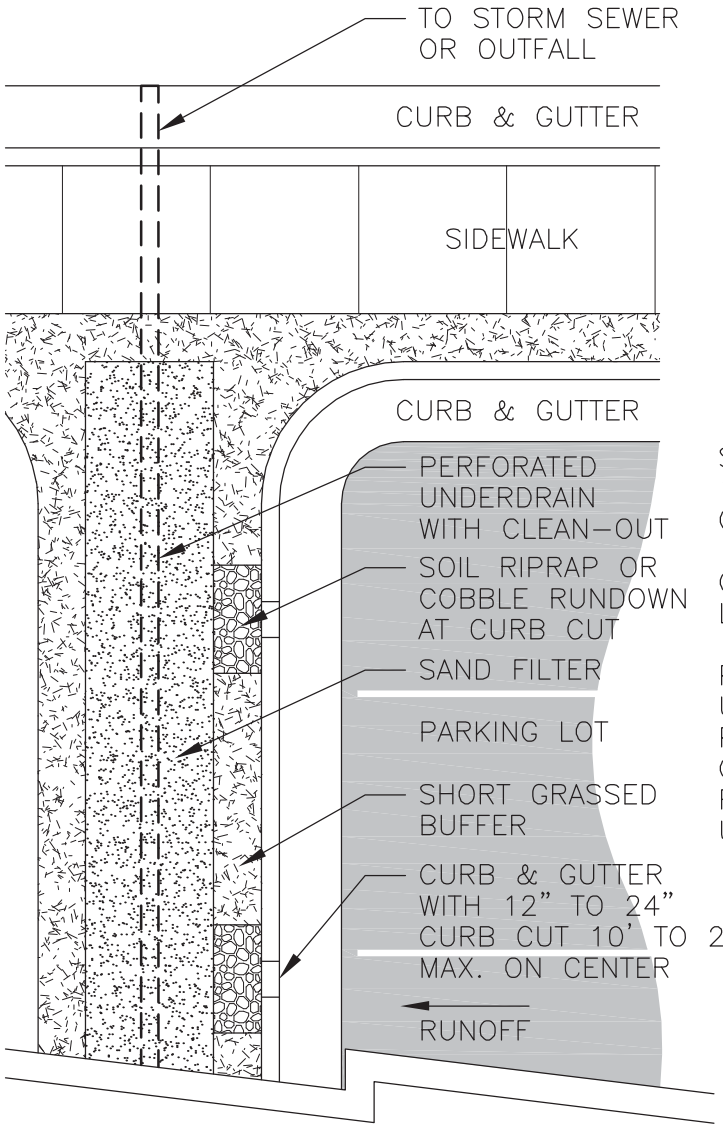
REVISED	
BY	DATE

CITY AND COUNTY OF DENVER
DEPARTMENT OF PUBLIC WORKS
WASTEWATER MANAGEMENT DIVISION

BIORETENTION

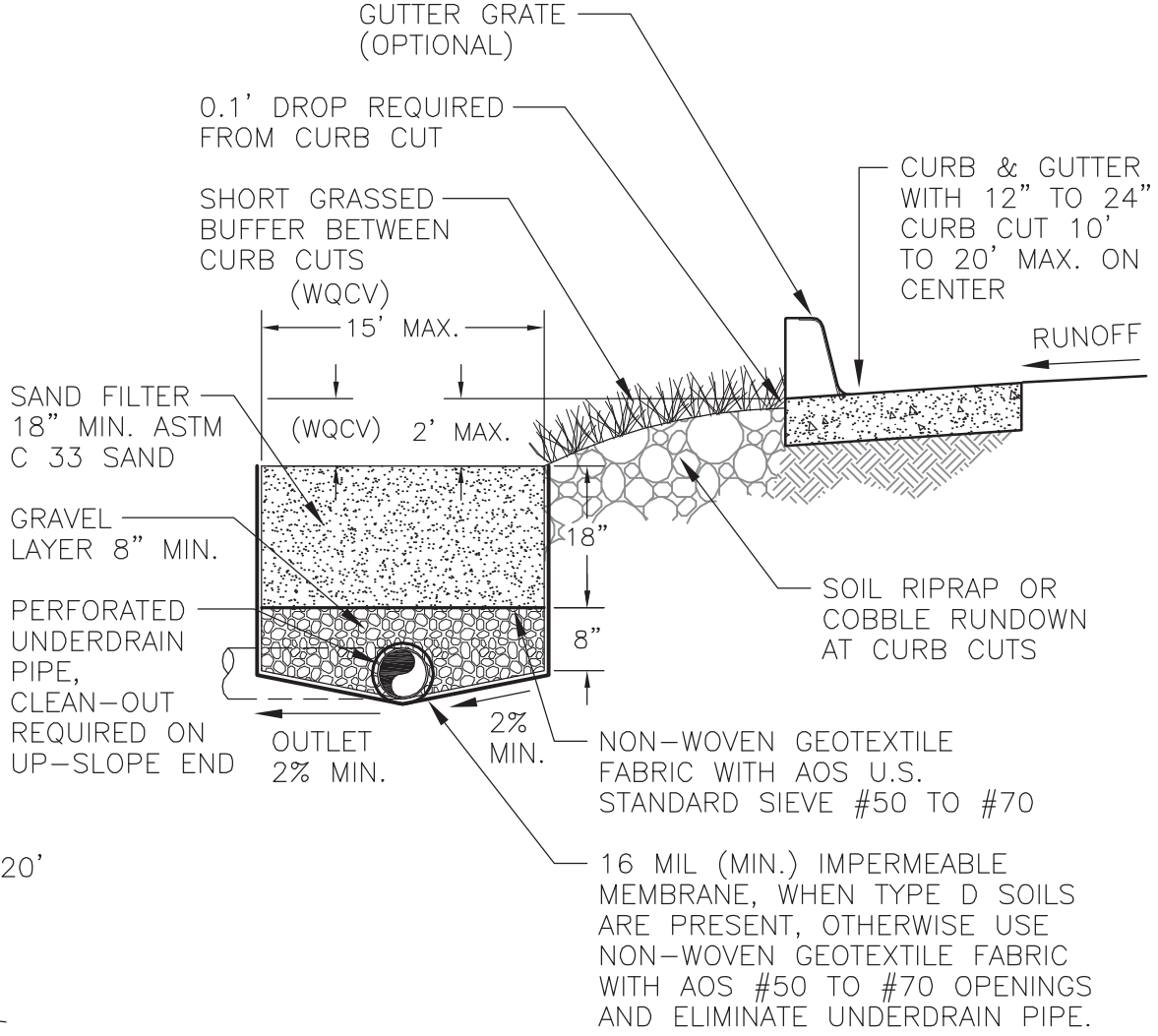
ISSUE DATE: APRIL 2013 | DRAWN BY: KL | CHECKED BY: SF,BE

2/10/06; C:\PROJECT\041-159\000KAL\LS DETENTION V11.DWG



ISLAND/INTERIOR APPLICATION

NOT TO SCALE



SAND FILTER SECTION

NOT TO SCALE

FIGURE 14.2
SAND FILTER DETAILS FOR USE ON SMALL SITES ≤1 ACRE

REVISED	
BY	DATE

CITY AND COUNTY OF DENVER
DEPARTMENT OF PUBLIC WORKS
WASTEWATER MANAGEMENT DIVISION

SMALL DRAINAGE CATCHMENT (≤1 ACRE) SAND FILTER

ISSUE DATE	DRAWN BY: KL
JAN. 2006	CHECKED BY: SF,BU

2/10/06; C:\PROJECT\041-159\000KAL\SAND FILTER OPTS V9.DWG

15.0 CONSTRUCTION SITE STORMWATER MANAGEMENT AND EROSION CONTROL

15.1 Introduction

Chapter 10 of the *Rules and Regulations Governing Sewerage Charges and Fees and Management of Wastewater* (April 2013) establishes that all development or redevelopment projects located within Denver are required to implement Best Management Practices (BMPs) to control erosion, sedimentation, and pollutant laden stormwater discharges during construction activities. This requirement applies to all public and private new development or redevelopment projects (as defined in Section 1.3[5]) and includes grading, demolition and other projects where there is to be any excavation, trenching or other disturbance of the existing ground surface.

Consistent with and pursuant to Chapter 10 of the Sewerage Regulation, this chapter identifies the triggers and requirements for a Construction Activities Stormwater Discharge Permit (CASDP), general principles of erosion and sediment control, the requirements for Stormwater Management Plans (SWMP), formerly known as Construction Activities Stormwater Management Plans and the minimum technical criteria for erosion control at construction sites. This chapter hereby incorporates by reference specified portions of Volume 3 of the DISTRICT MANUAL pertaining to the design and implementation of construction-related BMPs.

Persons and entities, whose project does not require a CASDP as set forth herein, must nevertheless comply with the requirements of the Code, the Manager's regulations, and permits, including a Sewer Use and Drainage Permit (SUDP), that are otherwise applicable to the project.

15.2 Construction Activities Stormwater Discharge Permits

15.2.1 Permit Triggers

Earth disturbance activities shall not be undertaken at a development or redevelopment project unless a CASDP has been issued by the Manager if any of the following criteria are present.

1. The project site development is one acre or more; or
2. The project site development is under one acre in area, but meets one of the following:
    a. The project site is part of a larger overall development sale or plan, and the overall development plan will ultimately disturb one or more acres at full build-out;

[5] Section 1.3 states: "All new development or redevelopment projects, construction or grading projects, demolition, or any disturbance of existing ground surface shall comply with these DENVER CRITERIA. Hereinafter, such projects are referred to as "development and redevelopment projects," except as the terms are used differently in Chapter 14 pertaining to post-construction water quality."

b. If two or more adjacent project sites are under construction, but not by the same developer or contractor, and the total area for these sites exceeds one acre,
c. The project site has been identified by the Department of Public Works as having a significant potential for erosion, based on site characteristics including topography;
d. The project site is known to contain contaminated soils on site or have a pre-existing condition warranting special care during construction; or,
e. The project site may discharge runoff directly into "Waters of the State."

In addition to permits from Denver, construction projects that exceed one acre of disturbance area, or are part of a one acre or larger development or sale plan, may also need a "Stormwater Discharge Permit Associated with Construction Activities" from the Colorado Department of Public Health and Environment (CDPHE). Information on the State issued permit may be obtained from the Permits and Enforcement Section of the Water Quality Control Division, CDPHE. It is important to note that conditions triggering a Denver permit are more stringent than CDPHE requirements. Denver's CASDPs are triggered based on project site size (see Section 15.2.2.) rather than disturbed area. For a development or redevelopment project that meets both CDPHE's and Denver's permit triggers, separate permits from each jurisdiction are required.

15.2.2 Basis of Project Site Size Determination

The acreage used to determine whether a CASDP is required is the total area of the project site. The project site is the total area at the site where any construction activity will occur including but not limited to clearing, grading, excavation, and demolition activities, as well as haul roads and areas used for staging or support activities which may be located at a different part of the property from where the primary construction activity will take place or on a different piece of property all together.

15.2.3 Co-Permittees

A landowner and developer or contractor, or their duly authorized representative, shall apply to the Manager for a CASDP for development and redevelopment projects meeting the criteria established in Section 15.2.1, above. The landowner, and developer or contractor, shall be co-permittees and each shall comply with the terms and conditions of the Permit, including implementation of the SWMP approved by the Manager. Only natural persons and legal entities may apply for and hold the Permit. At least one of the co-permittees must be designated as having day-to-day control over demolition and construction activities at the site.

15.2.4 Transfer of Permit

When all or a portion of a permitted site is sold or otherwise transferred to a different landowner or the responsibility for development or construction of a permitted site is transferred to another person or entity, the new person or entity must apply to the Manager for amendment and/or transfer of the existing CASDP or apply for a new Permit. Landowner(s), developer, contractor and their agents shall not proceed with construction activities until the appropriate parties have been permitted.

15.2.5 Term, Expiration or Suspension of Permit

1. CASDPs remain active and in effect until the project is completed and final stabilization has been confirmed by the Manager. Final Stabilization methods include: installation of sod or other landscaping measures, hard surfacing (such as paving or concrete), or seeding that has achieved 70% uniform coverage. In addition, all BMPs (except permanent water quality BMPs provided in compliance with Chapter 14) must be removed, an inactivation request submitted to the Manager, and the site must pass a final inspection.
2. CASDPs expire if construction has not commenced within twelve (12) months of the approval of the SWMP or if a period of twelve (12) months expires without any construction related activities occurring on-site. The obligation to provide maintenance, site stabilization, or removal of existing BMPs continues after expiration of the permit until final stabilization has been confirmed by the Manager.
3. Failure to pay any required CASDP fees shall result in the immediate suspension of the Permit.

15.3 Principles and Performance Standards

15.3.1 Principles

Implementation of the following principles is required at development and redevelopment sites for which a CASDP is required and these practices are encouraged at all other construction sites:

1. Reduce soil loss from all construction sites to the maximum extent practicable.
2. Improve the water quality of storm runoff from construction sites to the maximum extent practicable.
3. Prevent accumulation of soil and debris originating from construction activity in Denver's MS4.
4. Prevent discharges of chemicals, chemical wastes and other pollutants from construction sites.
5. Prevent migration of construction debris off site.
6. Prevent damage to properties adjacent to construction sites arising from sediment, debris, chemical wastes or other pollutants.
7. Protect Waters of the State[6] and wetlands from damage caused by erosion, sedimentation, chemical wastes, or other pollutants arising from construction activity.

These principles shall be achieved by implementation of structural and non-structural BMPs in accordance with the technical criteria in Volume 3 of the DISTRICT MANUAL. Factors such as project

[6] Section 10.02 of the Sewerage Regulation defines Waters of the State: "Any and all surface and subsurface waters which are contained in or flow in or through this State, but does not include waters in sewage systems, waters in treatment works of disposal systems, waters in potable water distribution systems, and all water withdrawn for use until use and treatment have been completed."

type, size, duration, soil type, site slope and proximity to Waters of the State shall be considered when selecting BMPs. Guidance for selection of BMPs for construction sites can be obtained from Volume 3 of the DISTRICT MANUAL and the Stormwater Quality Control Plan Information Guide (downloadable from www.denvergov.org/publicworks).

15.3.2 Performance Standards

Denver has established the following performance standards for erosion and sediment control and requires they be met at development and redevelopment sites for which a CASDP is required and encourages these practices at all other construction sites:

1. All earth disturbance activities shall be conducted in a manner that effectively reduces accelerated soil erosion and reduces the movement or deposition of sediment off site.
2. All earth disturbance activities shall be designed, constructed and completed in a manner that minimizes the duration of earth disturbance.
3. Soil stabilization measures shall be implemented within 14 days following completion of grading activities.
4. Sediment resulting from accelerated soil erosion shall be removed from storm or surface runoff to the maximum extent practicable prior to leaving the site.
5. All temporary facilities for conveying water around, through or from earth disturbed by construction activity shall be designed and constructed to limit flows to non-erosive velocities.
6. When earth disturbing activities are completed, all temporary erosion and sediment control facilities shall be removed, and the site shall be permanently stabilized.
7. Final stabilization of disturbed earth shall take place immediately upon completion of construction activity in that part of the development or as approved in the SWMP.
8. All construction wastes, fuel, lubricants, chemical wastes, trash, or debris shall be contained on site and protected from contact with rainfall or surface runoff.
9. All chemical wastes, trash, debris, or contaminated soil shall be periodically removed from the construction site and disposed of properly.

15.4 Construction Stormwater Planning[7]

15.4.1 Stormwater Management Plan Requirements

All development and redevelopment sites for which a CASDP is required shall submit for approval a proposed SWMP to address sediment and erosion control and to minimize stormwater pollution to the

[7] Most requirements of this section are not new but are based on guidance previously contained in Denver's Construction Activities Stormwater Manual (CASM).

maximum extent practicable. An approved SWMP shall be incorporated as a part of the Permit issued by the City.

The SWMP shall include the following components:

1. Narrative Report providing an identification of the applicant, local contact/project manager, consultant, project location, and nature of the project; and a description of the project site. A Narrative Report Information Worksheet can be downloaded from Denver's website (www.denvergov.org/publicworks/).
2. Identification and description of all potential pollutant sources for each phase of the construction project. This information is to be used for selection of BMPs.
3. Best Management Practices (BMPs), including installation, operation, and maintenance details. For any proposed BMPs that are not currently identified in Volume 3 of the DISTRICT MANUAL or published by the City, documentation describing the BMP in terms of its design, capacity, projected effectiveness, installation, operation, and maintenance requirements. (See Section 15.4.3 for additional detail.)
4. Site drawings and maps (See Section 15.4.7 for additional detail.)
5. Phased construction plans, with an indication of BMPs proposed for each phase.
6. Certification by each co-permittee as follows: "I am duly authorized to submit, on my own behalf as (insert name of co-permittee applicant) or as a duly authorized representative of (insert name of co-permittee applicant), this Stormwater Management Plan in connection with an application to the Wastewater Management Division of the City and County of Denver for a Construction Activities Stormwater Discharge Permit for the Project named above as described herein. I understand that erosion control, sediment control and water quality enhancing measures beyond those described herein may be required in accordance with a finally approved Stormwater Management Plan that is adopted and incorporated into a Construction Activities Stormwater Discharge Permit for the Project named above as described herein. Further, I understand that, once approved by Denver's issuance of the requested Permit, my obligations to implement the approved Plan shall continue until such time as the Plan is properly completed, modified or terminated."

The SWMP should fully address the methods to be used to prevent sediment, debris, and other pollutants from entering the Municipal Separate Storm Sewer System (MS4). Proposed structural and non-structural BMPs shall be described with sufficient implementation detail to insure that the logical phases of the proposed construction project meet the principles and performance standards listed in Section 15.3, above.

15.4.2 Professional Engineer Requirements

SWMPs shall be prepared by or under the responsible charge of a Professional Engineer registered in the State of Colorado. If the Professional Engineer determines that any requirements, as applied to the specific project, pose a safety hazard, it is the Engineer's responsibility to notify the permit reviewer of these issues, as well as to recommend an approach to alleviate the concern.

15.4.3 Structural and Non-Structural Best Management Practices (BMPs)

The SWMP shall clearly describe the installation and implementation specifications for each structural BMP. Nonstructural BMPs such as treatment, operating procedures, and practices to control site runoff, spillage or leaks, waste disposal, or drainage from material storage shall also be described.

1. Structural BMPs for Erosion and Sediment Control. The SWMP shall clearly describe and locate all structural BMPs implemented at the site to minimize erosion and sediment transport. BMPs may include, but are not limited to: wattles/sediment control logs, silt fences, rock socks, compacted earthen dikes, drainage swales, sediment traps, subsurface drains, pipe slope drains, inlet protection, outlet protection, gabions, and temporary or permanent sediment basins.
2. Non-Structural BMPs for Erosion and Sediment Control. The SWMP shall clearly describe and locate, as appropriate, all non-structural BMPs implemented at the site to minimize erosion and sediment transport. Description must include interim and permanent stabilization BMPs, and site-specific scheduling for implementation of the BMPs. The SWMP should include practices to ensure that existing vegetation is preserved where possible. Non-structural BMPs may include, but are not limited to: project phasing, administrative controls, training procedures, designated haul routes, sweeping procedures, utilization of temporary vegetation, permanent vegetation, vegetative buffer strips, protection of trees, and preservation of mature vegetation.

15.4.4 Minimum BMPs

The following are the minimum BMP requirements for project sites for which a CASDP is required. Additional BMPs may be required by the Manager, on a site by site basis:

1. Vehicle Tracking Control: Tracking control measures shall be implemented at all access points to a construction site that are used by vehicular traffic or construction equipment.
2. Inlet Protection: Inlet Protection shall be implemented on all existing or proposed storm sewer inlets in the vicinity of the project site that may receive site runoff. The BMP must be appropriate to the type of storm inlet and appropriate for the ground surface at the inlet.
3. Site Stabilization: Measures for preventing the discharge of sediment from construction sites must be implemented where over-lot grading of the site has occurred. This BMP is particularly necessary on sites where construction activities will be limited to small areas of the graded site. Acceptable BMPs include but are not limited to:
    a. Preserving existing vegetation

b. Seeding and planting
c. Mulching
d. Mulching and seeding
e. Temporary/Permanent re-vegetation operations
f. Chemical soil stabilizer application (requires WMD approval)

4. Spill Prevention/Containment: Measures shall be implemented for preventing, controlling, or containing spills of fuel, lubricants, temporary sanitary toilets, or other pollutants and protecting potential pollutants from contact with precipitation or runoff.
5. Chute Washout Containment: A containment area shall be designated for the washout of cement truck delivery chutes. This containment area shall be designed so that all wash water is totally contained. Water discharged into the containment area is allowed to infiltrate, evaporate, or be removed from site to an appropriate facility. Dried cement waste shall be removed and properly disposed.
6. Street Sweeping: Paved surfaces which are adjacent to construction sites shall be swept by the close of each business day (and during the day as needed) when sediment and other materials are tracked or discharged onto them. Sweeping by hand or mechanical street sweepers is acceptable. Mechanical street sweepers using water while sweeping may be required in order to minimize dust. Flushing off paved surfaces with water is prohibited.
7. Perimeter Control: Construction sites shall install a perimeter control measure along the edge of the construction site to prevent, or filter surface runoff leaving the construction site. The type of perimeter control used shall be determined based on site and location. Maintenance and repair of the control measure shall occur as needed and as soon as practicable following discovery of the need.
8. Structural controls: Post-construction water quality structural BMPs, above or below ground, for facilities subject to the requirements of Chapter 14 are encouraged and may be required as construction BMPs when site conditions allow. A description of the procedures to be employed to convert an active construction BMP to a permanent water quality feature may also be required to ensure final design standards are met without any reduction in capacity or function resulting from the use of the BMP during construction.
9. Control Discharges from Stockpiled Sediment or Soil: The following BMPs are required for stockpiles composed of sediment, soil, land clearing debris, or construction materials containing soil or sediment:

    a. Locate the piles outside of any natural buffers and physically separated from other stormwater controls,
    b. Stockpiles located within 100’ of perimeter controls, inlets, or stormwater conveyances shall be protected with additional controls. Acceptable controls include but are not limited

to: utilization of the existing grade, compressed dirt berms, silt fence, and straw wattle.

c. Where practicable, provide cover or appropriate temporary stabilization to avoid the stockpile's direct contact with precipitation or to minimize sediment discharge.

15.4.5 Site Specific BMP Requirements

Individual development and redevelopment sites may have site characteristics that require the application of specific BMPs for erosion and sediment control. These site-specific BMP requirements are in addition to those listed above.

1. Potential for High Flow Conditions. Development and redevelopment sites that are located directly adjacent to Waters of the State, or have areas tributary to the site which may generate large volumes of runoff, need to be protected by BMPs that provide flow control and diversion. Acceptable BMPs include: slope drains, temporary swales and channels, diversion dikes, coffer dams, sand bag barriers, etc.
2. Steep Slopes. Development and redevelopment sites that have slopes 3:1 or steeper must implement BMPs to prevent or minimize slope erosion. The use of one or more of the following BMPs or approved BMPs providing equivalent protection is required:

    a. Geotextiles and Matting: Fabric, jute matting and other materials that provide a surface cover on slopes to minimize erosion from raindrop impact or sheet flow runoff. Geotextiles and matting typically require measures to attach the material to the slope.
    b. Slope Roughening/Terracing: Slope roughening is similar to the agricultural erosion measure known as contour plowing where furrows are plowed along elevation contours. Care must be taken to prevent foot or vehicular traffic across areas where this BMP is used as even minimal traffic can destroy the BMP's effectiveness.
    c. Chemical Soil Stabilizer Application: Polyacrylamide and other chemical soil stabilizers may be used providing data has been submitted to verify that the product is effective for the intended use, and is environmentally safe with low toxicity.

3. On-site Drainageway. Development and redevelopment sites that are adjacent to drainageways, have a drainageway within the site, or are constructing a drainageway within the site shall provide BMPs for the following:

    a. Instream Velocity Reduction/Sediment Entrapment: The use of Check Dams, Sediment Traps or similar measures to reduce the velocity of flow and entrap sediment is required. Drainageways, waterways, flood plains, streams, waters of the State, etc. should not be used as sediment collection facilities. BMPs should be used to control sediment from entering these areas.
    b. Temporary Stream Crossing: A temporary stream crossing is required where repeated crossing of a drainageway by construction equipment may be necessary. (This BMP

may require a permit from the Army Corps of Engineers.)

c. Flow characteristics of the drainageway: When evaluating BMPs, crossings, and diversions for onsite drainageways, the SWMP developer is required to determine the flow characteristic for both the 2 and 10 year rainfall events. The results of these calculations shall be used when designing the above elements for projects.

4. Contaminated Site. The SWMP for sites where there is known contamination by solid waste or toxic, radioactive, or other hazardous material shall include appropriate BMPs, including but not limited to:

   a. Construction Management Plan;
   b. Stockpile Protection and Site Stabilization;
   c. Groundwater Dewatering, Management, Remediation Plan(s);
   d. Remediation Plan;
   e. Contaminated Materials Management Plan; and
   f. As and to the extent required by the Colorado Solid Waste Regulations, an informational copy of an Asbestos-Containing Materials/Asbestos-Contaminated Soils Management Plan approved by the Colorado Department of Public Health and Environment

15.4.6 BMP Selection Criteria:

Proposed structural and non-structural BMPs must be sufficient to meet the principles and performance standards for sediment removal/reduction for each construction project phase. Selection of BMPs shall take into consideration implementation, installation, and maintenance issues to insure their ongoing effectiveness. Additional BMPs beyond those specified above may be approved if deemed acceptable by the City.

15.4.7 Site Drawings and Installation Details

The information listed below shall be included on one or multiple site maps. The map(s) shall use one of the following scales; 1”=20’, 1”=30’, 1”=40’, 1”=50’ or 1”=100’. The scale selected must be suitable for practical use and readability. The contour interval for these plans shall be two (2) foot.

1. Existing and Proposed Topography
2. Topographic sections across the site showing both existing and proposed grades
3. Clearly marked existing and proposed grading contours (legible with elevations)
4. Two (2) foot contour intervals
5. Contours 100 feet beyond the project boundaries
6. Location of existing structures on-site
7. Structures subject to demolition are to be clearly located in SWMP drawings
8. Location of structures and natural features within 100' of site boundary

9. Proximity of nearby floodplains and receiving water
10. Locations of proposed structures
11. Denote proposed phased limits of grading and clearing
12. Locations of storage areas including:
    a. Equipment
    b. Fuel/lubricants
    c. Construction materials
    d. Chemicals and waste storage
    e. Sanitary facilities
    f. Equipment maintenance and fueling locations
    g. Soil stockpiles
    h. Borrow pits
13. Locations of contaminated areas
14. Locations of construction entrances
15. Locations for all storm runoff discharge points at site boundaries or internal to site if a drainage way is located on-site.
16. Locations for all proposed BMPs
17. Locations for all containment areas for chute washout
18. All applicable NPDES Standard Notes
19. Installation Details of all proposed BMPs
20. Details for all proposed structural permanent water quality BMPs
21. Professional Engineer's stamp and signature

15.4.8 Supporting Technical Information and Documents

Copies of the plans or technical materials listed below must be available for review upon request at the time of CASDP application. Issuance of the Permit may be delayed until these plans have been reviewed. At the latest, applicant shall submit the requested documents at the time approval of the SWMP is requested.

1. Drainage Report
2. Soils/Geotechnical Studies
3. Environmental Audits (for sites under environmental remediation)
4. Copies of applications for related Colorado Discharge Permit System (CDPS) Permits, including:
    a. Stormwater Discharge Associated with Construction Activity
    b. Minimal Discharge Industrial Wastewater Permit
    c. Construction Dewatering Permits
5. Air Pollution Emission Notification - Fugitive Dust or other Air Pollution Permits
6. Copies of correspondence with other governmental jurisdictions related to:

a. Wetlands
b. Floodplains
c. Waterways
d. Discharges to or from other jurisdictions

7. Copies of temporary access agreements with adjacent land owners
    a. Use of land for material storage or lay down
    b. Stabilization and restoration of disturbed areas
    c. Acceptance of flow to or from adjacent sites

15.5 Responsibilities of Permittees

15.5.1 Copy onsite

Permittees shall keep an electronic or hard-copy of the CASDP including the approved SWMP, as it may be modified from time to time, onsite at all times.

15.5.2 SWMP Modifications, Permit Amendments

Permittees are required to amend, adapt, and adjust their SWMP to accurately reflect phased construction changes and current conditions at site. Plan modifications are broken into major and minor modifications which have differing requirements.

1. Major Modifications. Major modifications are changes to the SWMP that remove or add area to the project, modify the final hydrology or drainage of the final design, replace approved SWMP, or otherwise expand or contract the scope of the approved project. A revised SWMP and any revised supporting documents required by Section 15.3.4 shall be submitted to Denver for review. Major modifications are not effective until approved by Denver. Payment of additional review and acreage fees is also required.
2. Minor Modifications. Minor modifications are changes to the SWMP that do not increase the scope or change hydrology of the project but: modify or improve specific BMPs in use at the site, indicate progression in phasing of the project, or specify relocation of previously approved BMPs within the project. Minor modifications can be made in the field by the permittee if the permittee can demonstrate that the modified soil erosion controls are equivalent to, or better than, the originally approved BMPs. Minor modifications must be thoroughly documented in the permittee's SWMP narrative, drawings and specifications. Should the Manager's representative deem the minor field modification inadequate, permittee shall make specific modifications as directed. Minor modifications are expected and encouraged as part of standard practice for ongoing compliance with requirements for maintenance and operation of BMPs and SWMP implementation corresponding with evolving site conditions.
3. Permit Amendment. Major and minor modifications to the SWMP shall be and are incorporated into the CASDP upon Denver's approval of the modifications as described above.

15.5.3 Operation and Maintenance.

Permittees shall operate and maintain all temporary and permanent soil erosion and sediment control BMPs, retaining walls, structures, plantings, and other protective devices required by a CASDP, including the requirements of the SWMP.

15.5.4 Inspections.

1. Permittees shall conduct inspections of the erosion and sediment control BMPs at least once every 7 days and after every significant precipitation event or significant snow melt until such time as permanent non-erosive conditions are established or active disturbance at site is mitigated to the extent that Denver approves a modified / extended inspection schedule.
2. Permittees shall maintain on site a current log of inspections.
3. Permittees shall contact the appropriate Denver authority, as noted on their permit, no less than 24 hours in advance of any site demolition, clearing, grubbing, grading, or excavation activity. The permittee shall not commence any such activity until the site passes the initial inspection.

15.6 Commonly Observed Problems at Construction Sites

Proper implementation and maintenance of erosion and sediment control measures is critical for the protection of water quality downstream of construction sites. Failure to properly implement and maintain these measures can also result in costly fines and other severe penalties. For these reasons, it is important to plan for and avoid these common problems at construction sites. See Appendix B for commonly observed problems at construction sites.

15.7 Submittal Requirements

An application for a CASDP must be submitted to the Department of Public Works in accordance with this Chapter. The CASDP entrance requirements can be downloaded from Denver's website (www.denvergov.org/publicworks/).

Approval and issuance of a CASDP shall require the submittal and approval of a SWMP. A Narrative Report Information Worksheet can be downloaded from Denver's website (www.denvergov.org/publicworks/). The narrative report and drawings submitted for the SWMP must bear the stamp, signature and certification of a professional engineer (P.E.) and co-permittees' certification signed by the owner and contractor or site developer, or their authorized agents.

The narrative report, P.E.-stamped set of drawings, and miscellaneous technical information, together with additional documentation and correspondence requested by the Manager shall be submitted electronically, or 1 hard copy of each may be provided, for review and approval. Upon approval, three hard copies of the narrative report and three P.E.-stamped sets of drawings shall be submitted.

Guidance concerning the content of plans and reports, standard notes and other permit-related items is provided in Denver's Construction Activities Stormwater Manual (CASM), which can be downloaded from Denver's website (www.denvergov.org/publicworks/).

This page intentionally left blank.

16.0 REFERENCES

16.1 Primary References

Urban Drainage and Flood Control District. 1999. *Urban Storm Drainage Criteria Manual, Volume 3*. Denver, CO: Urban Drainage and Flood Control District. Website: www.udfcd.org.

Urban Drainage and Flood Control District. 2001. *Urban Storm Drainage Criteria Manual, Volumes 1-2*. Denver, CO: Urban Drainage and Flood Control District. Website: www.udfcd.org.

Wright Water Engineers, Inc., Muller Engineering, Wenk Associates, Matrix Design Group and Smith Environmental, 2004. *Denver Water Quality Management Plan*. Denver, CO: City and County of Denver Wastewater Management Division. Website: www.denvergov.org/publicworks/.

16.2 Supplemental References

American Association of State Highway and Transportation Officials (AASHTO). 2002. *Standard Specifications for Highway Bridges*, 17th Edition.

American Concrete Pipe Association. 2000. *Concrete Pipe Design Manual*. Arlington, Virginia: American Concrete Pipe Association.

American Society of Civil Engineers and Water Environment Federation (ASCE and WEF). 1992. *Design and Construction of Urban Stormwater Management Systems. ASCE Manual and Reports of Engineering Practice No. 77 and WEF Manual of Practice FD-20*. New York, NY: ASCE and Alexandria, VA: WEF.

City and County of Denver Office of Emergency Management and Urban Drainage and Flood Control District. 2003. City *and County of Denver Flood Protection Handbook*. Denver, CO: City and County of Denver.

City and County of Denver, Department of Public Works, Engineering Division. 2003. *Storm Drainage and Sanitary Construction Details and Technical Specifications*. Denver, CO: City and County of Denver.

City and County of Denver, Department of Public Works, Wastewater Management Division. 2003. "Rules and Regulations Governing Sewerage Charges and Fees and Management of Wastewater" and Chapter 56, Articles 91 through 107, *Revised Municipal Code*.

City and County of Denver, Department of Public Works, Wastewater Management Division. 2000. *Stormwater Quality Control Plans: An Information Guide*. Denver, CO: City and County of Denver. Website: www.denvergov.org/publicworks/.

City and County of Denver. 2000. *Blueprint Denver, An Integrated Land Use and Transportation Plan.* Denver, CO: City and County of Denver.

City and County of Denver. 2005. Article V. Floodplain Management, Chapter 56, *Revised Municipal Code*, City and County of Denver, codified through October 17, 2005. (Incorporates Ordinances No. 158-86, § 1, 3-17-86; Ord. No. 711-94, § 1, 9-6-94; Ord. No. 464-98, § 11, 7-6-98)

Colorado Department of Public Health and Environment (CDPHE). 2003. *Authorization to Discharge Under the Colorado Discharge Permit System, City and County of Denver, Permit No. COS-000001*. Denver, CO: Colorado Department of Public Health and Environment.

Colorado Department of Transportation. 2000. *2000 M-Standard (Miscellaneous Standard) Plans.* www.dot.state.co.us/DesignSupport/.

Colorado Water Conservation Board (CWCB). 1983. *Colorado Flood Proofing District Manual*.

Division of Water Resources, Office of the State Engineer (SEO). 1988. *Rules and Regulations for Dam Safety and Dam Construction*, 2 CCR 402-1.

Ginsberg, A. 1987. *HY8 Culvert Analysis Microcomputer Program Applications Guide*. Washington, DC: U.S. Department of Transportation, Federal Highway Administration.

International Code Council. 2003. *International Building Code*.

Muller Engineering. 2005. *Arapahoe County Storm Drainage Criteria Manual*. Draft.

Muller Engineering. 2005. *Douglas County Storm Drainage Criteria Manual*. Draft.

National Oceanic and Atmospheric Administration (NOAA). 1973. *Precipitation-Frequency Atlas of the Western United States, Volume III-Colorado*. Washington, D.C.: U.S. Department of Commerce, National Weather Service.

Simons Li and Associates. 1981. *Design Guidelines and Criteria for Channels and Hydraulic Structures on Sandy Soil.*

U.S. Federal Highway Administration (FHWA). 1985. *Hydraulic Design of Highway Culverts*. Hydraulic Design Series No. 5. Washington, DC: U.S. Department of Transportation, Federal Highway Administration.

Urban Drainage and Flood Control District. 2005. District Maintenance Eligibility Guidelines. Downloadable from www.udfcd.org.

Water Environment Federation and American Society of Civil Engineers. 1998. *Urban Runoff Quality Management. WEF Manual of Practice No. 23 and ASCE Manual and Report on Engineering Practice No. 87.* Alexandria, VA: Water Environment Federation.

Appendix A. Standard Forms

Standard Form SF-1. Time of Concentration

PROJECT _____

PREPARED BY _____ DATE _____

Sub-Basin Data			Initial/Overland Time (t_i)			Travel Time (t_t)				t_c Check (Urbanized Basins)		Final t_c	Remarks
DESIGN	C_5	AREA (A) acres	LENGTH (L) feet	SLOPE (S) %	t_i minutes	LENGTH (L) feet	SLOPE (S) %	Velocity (V) ft/sec	t_t minutes	TOTAL LENGTH (L) feet	t_c=(L/180)+10 minutes	$t_c = t_i + t_t$ minutes	

Standard Form SF-2. Storm Drainage System Design (Rational Method Procedure)

CALCULATED BY:	JOB NO.:
DATE:	PROJECT:
CHECKED BY:	DESIGN STORM:

STREET	DESIGN POINT	DIRECT RUNOFF							TOTAL RUNOFF				STREET		PIPE			TRAVEL TIME			REMARKS
		AREA DESIGN	AREA (A)	RUNOFF COEFF. (C)	t_C	CA	I	Q	t_C	Σ(CA)	I	Q	SLOPE	STREET FLOW	DESIGN FLOW	SLOPE	PIPE SIZE	LENGTH	VELOCITY	t_t	
		ac			min		in/hr	cfs	min		in/hr	cfs	%	cfs	cfs	%	in	ft	ft/sec	min	

This page intentionally left blank.

APPENDIX B. COMMONLY OBSERVED PROBLEMS IN DENVER DRAINAGE PROJECTS

Planning

There is a continued tendency to view drainage as an "afterthought," which results in drainage facilities being "shoe horned" into the site plan at the last minute. Thus, instead of drainage facilities adding to the character and appearance of a site (Photo 1), they often stick out like a sore thumb. With some creativity, designers and engineers can design and implement drainage facilities that can serve as community assets rather than liabilities.

Photo 1. Well designed drainage facilities can serve as site amenities when properly and creatively planned.

General Drainage and Flooding

Developers must ensure that an adequate outfall exists downstream and take downstream impacts into consideration with drainage designs. An example of this problem is shown in Photos 2 and 3.

Photos 2 and 3 show a large box culvert to accommodate upstream development relative to a small downstream CMP, which may exacerbate flooding problems on the property downstream.

Other commonly observed problems include:

- Individual lot grading is poor and positive slopes away from buildings are not attained.
- Hydrologic results are not checked for "reasonableness," resulting in either oversized or undersized facilities.
- High groundwater can often be foreseen as a constraint and problem, but is ignored or discounted.

In some cases, developers will assume that unless there is an official 100-year floodplain map, there is no flood hazard on their property. Localized drainage issues are not viewed as flood threats, even though they are. It is important to remember that just because FEMA does not typically issue FIRMs for areas less than one square mile, it does not mean that a floodplain does not exist. A house with two acres of drainage area can have more problems than a house in the regulatory Mississippi River floodplain. To avoid these problems, engineers need to be diligent about determining maximum depths in streets and corresponding first floor elevations for buildings.

Public Safety

Public safety should receive far more attention than it does. This is a wide-ranging problem. A few representative examples include:

- Lack of protection at detention and other outlet structures.
- Side slopes that are overly steep or eroding.
- Hydraulic structures such as concrete drops that create reverse rollers which can keep a person trapped in the flow.

Streets, Inlets and Storm Sewers

Sufficient inlet capacity is often not provided, resulting in pipe capacity being larger than inlet capacity. Inlet and pipe designs need to be in balance. Insufficient overflow conveyance at sump inlets can lead to street flooding and property damage. In some cases (Photo 4), fencing and landscaping block overflow areas resulting in flooding.

Photo 4. Overflow area at sump was blocked with landscaping and fencing, resulting in flooding.

Other concerns include improper allowance for debris blockage when designing inlets, culverts, bridges, and other conduits (Photos 5 & 6).

Photo 5. Debris blocking street inlet.

Photo 6. Debris blocking trash rack at culvert.

Inadequate gutter capacity or modifications to gutters during construction can result in drainage problems (Photo 7). Other drainage problems can be caused by designs that include trash racks at outlet structures, resulting in clogged pipes (Photo 8).

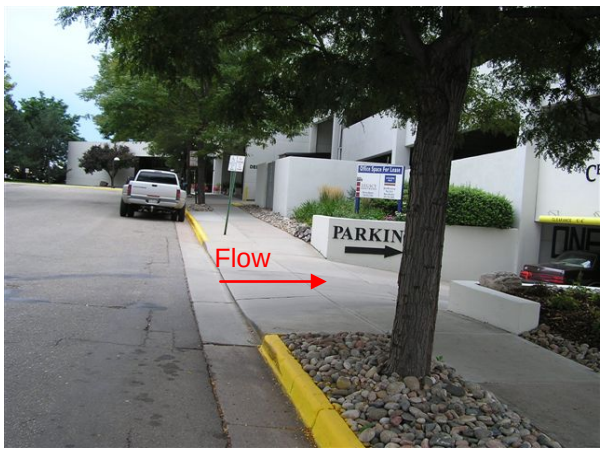


Photo 7. Drainage flows into parking garage due to low curb and sidewalk.

Photo 8. Trash rack on downstream end of pipe results in clogging and causes drainage and maintenance problems.

Detention and Water Quality

There are many commonly observed problems related to design, installation and maintenance of detention facilities. Prior to design of water quality facilities, runoff reduction techniques and measures to minimize directly connected impervious area are not consistently implemented as the critical first step in stormwater quality management.

Unique hazards posed by detention facilities in urban settings are poorly recognized. Examples include dimly lit, secluded areas and lack of guardrails and other measures to promote public safety. Detention/infiltration facilities next to buildings with basements can be problematic for foundations (Photo 9).

Photo 9. Detention basin near home.

Due to regrading, resurfacing, improper design or improper curb installation (Photos 10 and 11), areas planned to drain into detention basins often do not, resulting in lack of detention (Photo 12) and water quality treatment (Photo 13). Other problems include designs where the invert of the inflow pipe to the detention basin is lower than the water quality capture volume (WQCV) surface, resulting in standing water, sediment deposition in the pipe, mosquito breeding habitat, and in general, an unsightly appearance that detracts from the character of the area and property values.

Photo 10. Flow from this parking lot bypasses water quality treatment. The inflow pipe is also too close to the outflow. Lack of micro-pool also caused outlet clogging and standing shallow water.

Photo 11. Curb and rundown provided to correct problem in Photo 10. However, wood chips should not have been placed in the basin, resulting in clogging of the outlet's trash rack.

Photo 12. Parking lot detention does not function as intended: runoff leaves the site undetained.

Photo 13. Flow from this parking lot bypasses water quality treatment basin's outlet and drains directly into the downstream vault.

Maintenance access to facilities is frequently a problem. Even when access is provided, it is often not wide enough, or the designer has not anticipated equipment turning space requirements. When BMP outlets are poorly maintained, they plug and pond water (Photo 14) creating eyesores and nuisance conditions. In other cases, to satisfy water quality requirements, designers sometimes utilize proprietary devices that may be unproven scientifically. These facilities are typically placed below ground, and are not properly maintained because they are "out-of-sight, out-of-mind."

Photo 14. Clogged outlet structure. This structure needs a plate over the top to keep trash away from the orifices. A micro pool would also help to reduce this problem.

Knowledge concerning West Nile virus and conditions that are conducive to mosquito propagation is typically inadequate. Many designers fail to understand that mosquitoes require a stagnant water surface for 72 hours to successfully reproduce. In the course of normal BMP design, operation, and maintenance, it is feasible to assure that stagnant water will not be present for 72 hours, yet this continues to be a problem due to improperly maintained outlets.

Aesthetics should be taken into account when designing drainage facilities. Small, onsite detention basins tend to have a host of problems related to appearance, function, maintenance, safety, etc. (Photos 15 and 16).

Photo 15. This unattractive forebay is an eyesore and a nuisance to the owner.

Photo 16. This detention facility is unattractive, difficult to maintain and, as a result, not maintained well.

Well designed, maintainable and well-maintained facilities as shown in Photos 17 through 20.

Photos 17 and 18 show a properly designed inlet, forebay, trickle channel and outlet in an urban setting that are easy to maintain and are well maintained.

Photos 19 and 20. Attractive and maintainable forebay and detention facility in park setting.

Construction Sites

Frequent inspection and maintenance of erosion and sediment control measures at construction sites is necessary for these measures to function properly.

Removal of temporary erosion and sediment control measures when construction is complete and the site is adequately revegetated is important to prevent clogging of drainage facilities (Photos 21 and 22).

Photos 21 and 22 show before and after construction photos show how straw bales left on site can clog outlet structures later.

Other construction-related erosion and sediment control problems are shown in Photos 23 through 27.

Photo 23. Inlet protection, a secondary line of defense commonly used on construction sites, must allow inlets to operate during larger runoff events. When inlet protection measures block inlets completely, street flooding and potential for flood damage is worsened, and nearby residents are more likely to attempt to remove the inlet protection to alleviate flooding, leading to uncontrolled sediment discharges to the storm sewer.

Photo 24. Silt fence must be properly installed and maintained to serve as an effective construction site BMP. Silt fence should be removed when final stabilization is achieved; otherwise it becomes construction trash left on a completed site.

Photo 25. Improper waste disposal, especially with trash bin sitting in the gutter, is a source of construction site pollution. Oil, paints, concrete washout water, spill cleanup material and other potentially hazardous materials should be properly disposed of in designated receptacles and away from drainage facilities.

Photo 26. Construction site stormwater management involves many pollutants in addition to sediment, including chemicals and materials used on construction sites, trash and lesser-known pollutants such as biocide (pictured in gutter from portable toilet). Portable toilets and other potential sources of pollutants should be distanced from gutters, inlets and other elements of the site drainage system.

Photo 27. Containers should be labeled and stored in designated locations where potential spills can be controlled. Containers should not be stored near the flow lines or gutters, inlets or other watercourses on the site.