

## Table of Contents

---

### CHAPTER 1. GENERAL PROVISIONS

1.0	Introduction .....	1-1
1.1	Enactment Authority .....	1-1
1.2	Jurisdiction .....	1-1
1.3	Purpose .....	1-1
1.4	Amendments and Revisions.....	1-1
	Table 1-1 Examples of Minor and Major Revisions .....	1-2
1.5	Enforcement Responsibility .....	1-2
1.6	Review and Approval .....	1-2
1.7	Interpretation .....	1-3
1.8	Relationship to Other Standards .....	1-3
1.9	Variances from these Criteria.....	1-3
1.10	Acronyms .....	1-4

### CHAPTER 2. STORMWATER MANAGEMENT POLICY & PRINCIPLES

2.0	Introduction .....	2-1
2.1	Principles.....	2-1
2.2	Planning Policy.....	2-3
2.3	Design Policy .....	2-5
2.4	Operations and Maintenance Policy.....	2-6
2.5	Construction of Public Improvements Policy .....	2-7
2.6	Floodplain Policy .....	2-8
2.7	Regulatory/Legal Policy.....	2-9
2.8	Hazard Minimization & Public Safety Policy.....	2-9
2.9	Miscellaneous Policy.....	2-10

### CHAPTER 3. STORMWATER MANAGEMENT AND DEVELOPMENT

3.0	Introduction .....	3-1
3.1	Planning for Stormwater Management.....	3-1
	3.1.1 Impacts of Development .....	3-1
	3.1.2 Multi-Purpose Resource .....	3-1
	3.1.3 Allocation of Space .....	3-2
	3.1.4 Regional and Local Master Planning .....	3-2
	3.1.5 Site Design and Layout.....	3-2
	3.1.6 Volume Reduction Practices.....	3-3
	3.1.7 Design of Stormwater Quantity Management Improvements .....	3-3
	3.1.8 Water Quality Treatment.....	3-4
	3.1.9 Channel Stabilization .....	3-4
	3.1.10 Maintenance Considerations .....	3-5
	3.1.11 Drainage Law.....	3-5
	3.1.12 County Permits .....	3-5
	3.1.13 Environmental Permitting.....	3-6
3.2	Special Planning Areas and Districts .....	3-6
	3.2.1 Four Square Mile Area.....	3-6
	3.2.2 Cherry Creek Basin Water Quality Authority (CCBWQA).....	3-7
	3.2.3 Denver Highline Canal.....	3-7
	3.2.4 Areas with Existing Drainage Problems.....	3-7
	3.2.5 Local Improvement Districts .....	3-7
3.3	Special Considerations .....	3-7
	3.3.1 Irrigation Ditches.....	3-7

## Table of Contents

---

	3.3.2	Jurisdictional Dams and Reservoirs .....	3-8
	3.3.3	Groundwater Investigations .....	3-9
3.4		Construction of Improvements and Fees .....	3-10
	3.4.1	Local Drainage System, Off-Site Conveyance System and the Major Drainageway System .....	3-10
	3.4.2	Master Planning Fees .....	3-11
	3.4.3	Storm Sewer Cost Recovery Fees .....	3-11
	3.4.4	Major Drainage Basin Fees .....	3-11
	3.4.5	Major Drainageway Stabilization .....	3-12
	3.4.6	Construction of Major Drainageway Improvements .....	3-12
3.5		Stormwater Facility Maintenance .....	3-13
	3.5.1	Maintenance Responsibility .....	3-13
	3.5.2	Easements .....	3-13
	3.5.3	Operation and Maintenance Manual .....	3-14
	3.5.4	Easements on Residential Lots .....	3-14
	3.5.5	UDFCD Maintenance Assistance .....	3-14

### CHAPTER 4. DRAINAGE REPORT AND CONSTRUCTION DRAWING SUBMITTAL REQUIREMENTS

4.0		Introduction .....	4-1
4.1		Review Process .....	4-1
	4.1.1	Drainage Report Requirements .....	4-1
	4.1.2	Stand Alone Document .....	4-1
	4.1.3	Submittal Adequacy .....	4-1
	4.1.4	Pre-application Meeting .....	4-1
	4.1.5	Review by Referral Agencies .....	4-1
	Table 4-1	Drainage Report Submittal Requirements .....	4-2
4.2		Acceptance .....	4-2
	4.2.1	Phase III Drainage Report Acceptance Required for Construction ..	4-2
	4.2.2	Two Year Acceptance for Phase III Drainage Reports .....	4-2
4.3		Phase I Drainage Report and Plan .....	4-3
	4.3.1	Requirement for Phase I Drainage Report and Plan Submittal .....	4-3
	4.3.2	Report Contents .....	4-3
	4.3.3	Phase I Drainage Plan Requirements .....	4-6
4.4		Phase II Drainage Report and Plan .....	4-6
	4.4.1	Requirement for Phase II Drainage Report and Plan Submittal .....	4-6
	4.4.2	Report Contents .....	4-7
	4.4.3	Certification Statement .....	4-12
	4.4.4	Standard Forms .....	4-13
	4.4.5	Checklists .....	4-13
	4.4.6	Phase II Drainage Plan Requirements .....	4-13
4.5		Phase III Drainage Report and Plan .....	4-14
	4.5.1	Requirement for Phase III Drainage Report and Plan Submittal ....	4-14
	4.5.2	Report Contents .....	4-14
	4.5.3	Certification Statement .....	4-14
	4.5.4	Phase III Drainage Plan Requirements .....	4-15
	4.5.5	Electronic Submittal Requirements .....	4-15
4.6		Special Drainage Reports .....	4-15
	4.6.1	Transitional Phase II Drainage Report .....	4-15
	4.6.2	Floodplain Modification Study .....	4-16

## Table of Contents

---

4.6.3	Cherry Creek Basin Permanent Best Management Practice (BMP) Plan Required Prior to Land Disturbance .....	4-17
4.7	Stormwater Facilities Maintenance Agreement.....	4-17
4.8	Operation and Maintenance Manual for Stormwater Management Facilities.....	4-17
4.8.1	Operation and Maintenance Manual Requirement .....	4-17
4.8.2	Development of the O & M Manual.....	4-17
4.9	Construction Drawings .....	4-18
4.9.1	Stormwater Management Improvements.....	4-18
4.9.2	Construction Plan Submittal .....	4-18
4.9.3	Certification.....	4-20
4.10	Record Drawings and Acceptance of Improvements .....	4-21
4.10.1	Record Drawing Requirements.....	4-21
4.10.2	Acceptance .....	4-21
4.11	Summary Table of Required Certifications and County Action .....	4-22
Table 4-2	Summary of Required Certifications and County Action.....	4-22

### CHAPTER 5. FLOODPLAIN

5.0	Introduction .....	5-1
5.0.1	Floodplain Philosophy.....	5-1
5.1	Applicability .....	5-1
5.2	Floodplain Management and Regulation.....	5-1
5.2.1	Floodplain Management .....	5-2
5.2.2	National Flood Insurance Program (NFIP) .....	5-2
5.2.3	Colorado Water Conservation Board.....	5-2
5.2.4	Floodplain Development Standards.....	5-3
5.3	Standard Level of Protection .....	5-3
5.3.1	Standard Level of Protection .....	5-3
5.3.2	Higher Level of Protection .....	5-3
5.4	Sources of and Use of Existing Floodplain Information.....	5-3
5.4.1	FEMA Flood Insurance Rate Maps (FIRMs) and Flood Insurance Study (FIS).....	5-3
5.4.2	UDFCD Flood Hazard Area Delineation (FHAD) Studies.....	5-5
5.4.3	Other Floodplain Information .....	5-6
5.4.4	Confirmation of Floodplain Data .....	5-6
5.5	Floodplain Information Unavailable .....	5-6
5.6	Floodplain Development Permit .....	5-7
5.6.1	Required for all Activities Within the Floodplain.....	5-7
5.6.2	Floodplain Development Permit Application .....	5-7
5.6.3	Floodplain Development Permit Requirements .....	5-8
5.6.4	Floodplain Permit Inspections.....	5-9
5.7	Floodplain Uses and Restrictions.....	5-9
5.7.1	Use Factors .....	5-9
5.7.2	Prohibited Uses .....	5-10
5.7.3	Storage of Materials.....	5-10
5.7.4	Uses Not Specifically Prohibited.....	5-10
5.7.5	Variances.....	5-10
5.7.6	Allowable Uses and Improvements to be Considered .....	5-11
5.8	Existing Structures in the Floodplain .....	5-11
5.8.1	Improvements .....	5-11
5.8.2	Floodproofing.....	5-11

## Table of Contents

---

5.8.3	Floodproofing Certification.....	5-11
5.8.4	Elevation Certificate.....	5-11
5.9	Floodplain Zoning, Ownership and Easements.....	5-12
5.9.1	Floodplain Zoning.....	5-12
5.9.2	Floodplain Ownership.....	5-12
5.9.3	Floodplain Easements.....	5-13
5.10	Subdivision Platting Considerations.....	5-14
5.10.1	Actual Floodplain Limits.....	5-14
5.10.2	FEMA Special Flood Hazard Areas.....	5-14
5.10.3	Freeboard Requirements.....	5-15
5.11	Floodway and Floodplain Fringe Encroachments.....	5-15
5.11.1	General.....	5-15
5.11.2	Floodway.....	5-15
5.11.3	Floodplain Fringe.....	5-15
5.11.4	Floodplain Fringe Encroachment (Filling).....	5-16
5.12	FEMA Map Revisions and Amendments.....	5-16
5.12.1	General.....	5-16
5.12.2	Conditional Letter of Map Revision (CLOMR).....	5-17
5.12.3	Conditional Letter of Map Revision Based on Fill (CLOMR-F).....	5-17
5.12.4	Letter of Map Revision (LOMR).....	5-17
5.12.5	Letter of Map Revision Based on Fill (LOMR-F).....	5-17
5.12.6	Conditional Letter of Map Amendment (CLOMA).....	5-17
5.12.7	Letter of Map Amendment (LOMA).....	5-17
5.13	Floodplain Modification Study.....	5-18
5.13.1	Requirement.....	5-18
5.13.2	Incorporation into Other Submittals.....	5-18
5.13.3	Floodplain Modification Study Outline.....	5-18
5.13.4	Schedule for Submittal of Floodplain Modification Studies.....	5-19
5.13.5	Agency Review Requirements.....	5-20
5.13.6	Conceptual Approval.....	5-21

## CHAPTER 6. HYDROLOGY

6.0	Introduction.....	6-1
6.0.1	Stormwater Quality Considerations.....	6-1
6.1	Design Rainfall.....	6-1
6.1.1	One-hour Rainfall.....	6-1
Table 6-1	1-Hour Point Rainfall Values for Arapahoe County (Inches).....	6-2
6.1.2	Intensity-Duration Curves.....	6-2
6.1.3	Six-hour Rainfall.....	6-2
Table 6-2	6-Hour Point Rainfall Values for Arapahoe County (Inches).....	6-2
6.2	Selecting a Method to Estimate Runoff.....	6-3
Table 6-3	Comparison of Hydrological Methods.....	6-3
6.3	Rational Method.....	6-4
6.3.1	Rational Method Equation.....	6-4
6.3.2	Time of Concentration ( $t_c$ ).....	6-4
6.3.3	Rainfall Intensity (I).....	6-6
6.3.4	Runoff Coefficient (C).....	6-6
6.3.5	Basin Area (A).....	6-7
6.4	CUHP/UDSWMM.....	6-7
6.4.1	CUHP.....	6-7

## Table of Contents

---

6.4.2	UDSWMM.....	6-7
6.5	Other Hydrologic Methods.....	6-7
6.5.1	Published Hydrologic Information.....	6-7
6.5.2	Statistical Methods.....	6-8
6.5.3	Retention Volume.....	6-8
6.6	Runoff Reduction Associated with Minimizing Directly Connected Impervious Area.....	6-8
6.7	Design Hydrology Based on Future Development Conditions.....	6-8
6.7.1	On-site Flow Analysis.....	6-8
6.7.2	Off-site Flow Analysis.....	6-9
6.8	Consideration of Detention Benefits in Off-Site Flow Analysis.....	6-9
6.8.1	Major Drainageway Basin Distinction.....	6-9
6.8.2	Analysis when System is Part of a Major Drainageway Basin.....	6-9
6.8.3	Analysis when a System is not a Part of a Major Drainageway Basin.....	6-10
6.8.4	Analysis when System is a Part of a Master-Planned Regional Detention Drainageway Basin.....	6-10
Figure 6-1	Rainfall Intensity-Duration Curve, Arapahoe County, Colorado.....	6-11
Figure 6-2	Standard SF-2 Form.....	6-12
Figure 6-3	Standard SF-3 Form.....	6-13

### CHAPTER 7. STREET DRAINAGE

7.0	Introduction.....	7-1
7.0.1	Stormwater Quality Considerations.....	7-1
7.1	Function of Streets in the Drainage System.....	7-1
7.1.1	Primary Function of Streets.....	7-1
7.1.2	Design Criteria Based on Frequency and Magnitude.....	7-1
7.1.3	Street Function in Minor (5-year) Storm Event.....	7-1
7.1.4	Street Function in Major (100-year) Storm Event.....	7-1
7.2	Street Classification.....	7-1
7.2.1	Arapahoe County Standard Roadway Sections.....	7-1
7.2.2	Drainage Classification.....	7-2
Table 7-1	Drainage Classification for Current Roadway Sections.....	7-2
Table 7-2	Drainage Classification for Former (1986) Roadway Sections.....	7-2
7.3	Minor (5-year) Storm Allowable Street Flow.....	7-3
7.3.1	Allowable Flow Depth and Roadway Encroachment for Streets with Curb and Gutter.....	7-3
Table 7-3	Minor Storm Allowable Flow Depth and Roadway Encroachment for Streets with Curb and Gutter.....	7-3
7.4	Major (100-year) Storm Allowable Street Flow.....	7-3
7.4.1	Allowable Flow Depth for a Street with Curb and Gutter.....	7-3
Table 7-4	Major Storm Allowable Depth and Containment of Flow for Streets with Curb and Gutter.....	7-4
7.5	Hydraulic Evaluation of Street Capacity.....	7-4
7.5.1	Minor (5-year) Storm Street Capacity Worksheet.....	7-4
7.5.2	Minor Storm Street Capacity Charts.....	7-4
7.5.3	Major (100-year) Storm Street Capacity Worksheet.....	7-5
7.5.4	Major Storm Street Capacity Charts.....	7-5

## Table of Contents

---

7.5.5	Major Storm Street Capacity with Flow Depth Between Curb Full and 12-inches .....	7-6
7.5.6	Non-Standard Street Sections .....	7-6
7.6	Cross-Street Flow .....	7-6
7.6.1	Cross-Street Flow Conditions .....	7-6
7.6.2	Influence on Traffic .....	7-6
7.6.3	Allowable Cross-Street Flow Due to Spread Over the Street Crown .....	7-7
Table 7-5	Allowable Cross-Street Flow Due to Spread Over the Street Crown for Streets with Curb and Gutter .....	7-7
7.6.4	Cross Street Flow Analysis .....	7-7
7.6.5	Crosspans .....	7-7
7.7	Curbless Streets with Roadside Swales for Enhanced Water Quality .....	7-7
7.7.1	Urban Roadside Swales .....	7-7
7.7.2	Allowable Capacity .....	7-8
7.7.3	Driveways and Street Cross-Flow .....	7-8
7.7.4	Downstream Facilities .....	7-8
7.8	Rural Roadside Ditches .....	7-9
7.8.1	Roadside Ditches .....	7-9
7.8.2	Roadside Ditch Design Criteria .....	7-9
Figure 7-1	Arapahoe County Street Capacity Chart <i>Urban Private - Parking One Side (4" Curb)</i> .....	7-10
Figure 7-2	Arapahoe County Street Capacity Chart <i>Urban Private - Parking One Side (6" Curb)</i> .....	7-11
Figure 7-3	Arapahoe County Street Capacity Chart <i>Urban Private - Parking Both Sides (4" Curb)</i> .....	7-12
Figure 7-4	Arapahoe County Street Capacity Chart <i>Urban Private - Parking Both Sides (6" Curb)</i> .....	7-13
Figure 7-5	Arapahoe County Street Capacity Chart <i>Urban Local (4" Curb)</i> .....	7-14
Figure 7-6	Arapahoe County Street Capacity Chart <i>Urban Local (6" Curb)</i> .....	7-15
Figure 7-7	Arapahoe County Street Capacity Chart <i>Two-Lane Collector</i> .....	7-16
Figure 7-8	Arapahoe County Street Capacity Chart <i>Four-Lane Collector</i> .....	7-17
Figure 7-9	Arapahoe County Street Capacity Chart <i>Four-Lane Arterial with Painted Median</i> .....	7-18
Figure 7-10	Arapahoe County Street Capacity Chart <i>Four-Lane Arterial with Raised Median</i> .....	7-19
Figure 7-11	Arapahoe County Street Capacity Chart <i>Six-Lane Principle Arterial/Urban Expressway</i> .....	7-20
Figure 7-12	Arapahoe County Street Capacity Chart <i>Eight-Lane Urban Expressway</i> .....	7-21
Figure 7-13	Arapahoe County Street Capacity Chart <i>Urban Local (4" Curb) (1986 Manual)</i> .....	7-22
Figure 7-14	Arapahoe County Street Capacity Chart <i>Urban Local (6" Curb) (1986 Manual)</i> .....	7-23

## Table of Contents

---

Figure 7-15	Arapahoe County Street Capacity Chart <i>60' Minor Collector (1986 Manual)</i> .....	7-24
Figure 7-16	Arapahoe County Street Capacity Chart <i>80' Major Collector (1986 Manual)</i> .....	7-25
Figure 7-17	Arapahoe County Street Capacity Chart <i>100' Minor Arterial (1986 Manual)</i> .....	7-26
Figure 7-18	Arapahoe County Street Capacity Chart <i>120' (4 Lane) Major Arterial (1986 Manual)</i> .....	7-27
Figure 7-19	Arapahoe County Street Capacity Chart <i>140' (6 Lane) Major Arterial (1986 Manual)</i> .....	7-28

### CHAPTER 8. INLETS

8.0	Introduction .....	8-1
8.1	General .....	8-1
	8.1.1 Function of Inlets .....	8-1
	8.1.2 Types of Inlets .....	8-1
	8.1.3 General Design Guidelines.....	8-1
	8.1.4 Inlet Capacity .....	8-2
8.2	Standard County Inlets.....	8-2
	8.2.1 Selection of Inlet Type .....	8-2
	8.2.2 Standard Inlets Accepted for Use in the County .....	8-2
	Table 8-1 Standard County Inlets .....	8-2
8.3	Inlets on Continuous Grade.....	8-3
	8.3.1 Inlet Capacity Factors .....	8-3
	8.3.2 Curb Opening Inlet (Type R).....	8-3
8.4	Hydraulic Evaluation - Inlets on Continuous Grade.....	8-3
	8.4.1 Preliminary Versus Final Design of Inlets on Continuous Grade .....	8-3
	8.4.2 Inlet Analysis Spreadsheets .....	8-3
	8.4.3 Minor Event Curb Opening Inlet Capacity Charts for Standard Street Sections at Maximum Capacity .....	8-3
	8.4.4 Major Event Curb Opening Inlet Capacity Charts for Standard Street Sections at Maximum Capacity .....	8-4
	8.4.5 Procedure for Street Flows Less than Maximum Allowable .....	8-4
	8.4.6 Non-Standard Street Sections and Other Types of Inlets.....	8-4
8.5	Inlets in Sump Conditions.....	8-5
	8.5.1 Capacity Calculation Factors and Inlets Selection.....	8-5
	8.5.2 Hydraulic Capacity Calculations .....	8-5
	8.5.3 Emergency Overflow Path with Drainage Tract or Easement .....	8-5
	8.5.4 Type C and D Inlets .....	8-5
8.6	Inlet Location and Spacing .....	8-5
	8.6.1 Inlet Location and Spacing .....	8-5
	8.6.2 Inlet Placement on a Continuous Grade Based on Flow Spread .....	8-6
8.7	Other Design Considerations .....	8-6
	8.7.1 Curb Chase Drain (Sidewalk Chase).....	8-6
	8.7.2 Median Inlets .....	8-6
	8.7.3 Maximum Inlet Length .....	8-6
	Figure 8-1 Special Median Inlet Details .....	8-7
	Figure 8-2 Inlet Capacity Chart Curb Opening (Type R) Inlet <i>Urban Private - Parking One Side (4" Curb)</i> .....	8-8

## Table of Contents

---

Figure 8-3	Inlet Capacity Chart Curb Opening (Type R) Inlet <i>Urban Private - Parking One Side (6" Curb)</i> .....	8-9
Figure 8-4	Inlet Capacity Chart Curb Opening (Type R) Inlet <i>Urban Private - Parking Both Sides (4" Curb)</i> .....	8-10
Figure 8-5	Inlet Capacity Chart Curb Opening (Type R) Inlet <i>Urban Private - Parking Both Sides (6" Curb)</i> .....	8-11
Figure 8-6	Inlet Capacity Chart Curb Opening (Type R) Inlet <i>Urban Local (4" Curb)</i> .....	8-12
Figure 8-7	Inlet Capacity Chart Curb Opening (Type R) Inlet <i>Urban Local (6" Curb)</i> .....	8-13
Figure 8-8	Inlet Capacity Chart Curb Opening (Type R) Inlet <i>Two-Lane Collector</i> .....	8-14
Figure 8-9	Inlet Capacity Chart Curb Opening (Type R) Inlet <i>Four-Lane Collector</i> .....	8-15
Figure 8-10	Inlet Capacity Chart Curb Opening (Type R) Inlet <i>Four-Lane Arterial with Painted Median</i> .....	8-16
Figure 8-11	Inlet Capacity Chart Curb Opening (Type R) Inlet <i>Four-Lane Arterial with Raised Median</i> .....	8-17
Figure 8-12	Inlet Capacity Chart Curb Opening (Type R) Inlet <i>Six-Lane Principal Arterial/Urban Expressway</i> .....	8-18
Figure 8-13	Inlet Capacity Chart Curb Opening (Type R) Inlet <i>Eight-Lane Urban Expressway</i> .....	8-19
Figure 8-14	Inlet Capacity Chart Curb Opening (Type R) Inlet <i>Urban Local (4" Curb) (1986 Manual)</i> .....	8-20
Figure 8-15	Inlet Capacity Chart Curb Opening (Type R) Inlet <i>Urban Local (6" Curb) (1986 Manual)</i> .....	8-21
Figure 8-16	Inlet Capacity Chart Curb Opening (Type R) Inlet <i>60' Minor Collector (1986 Manual)</i> .....	8-22
Figure 8-17	Inlet Capacity Chart Curb Opening (Type R) Inlet <i>80' Major Collector (1986 Manual)</i> .....	8-23
Figure 8-18	Inlet Capacity Chart Curb Opening (Type R) Inlet <i>100' Minor Arterial (1986 Manual)</i> .....	8-24
Figure 8-19	Inlet Capacity Chart Curb Opening (Type R) Inlet <i>120' (4 Lane) Major Arterial (1986 Manual)</i> .....	8-25
Figure 8-20	Inlet Capacity Chart Curb Opening (Type R) Inlet <i>140' (6 Lane) Major Arterial (1986 Manual)</i> .....	8-26
Figure 8-21	Inlet Capacity Chart Sump Conditions Area (Type C) Inlet.....	8-27
Figure 8-22	Inlet Capacity Chart Sump Conditions Curb Opening (Type R) Inlet.....	8-28

## CHAPTER 9. STORM SEWERS

9.0	Introduction.....	9-1
9.0.1	Stormwater Quality Considerations.....	9-1
9.1	Design Storms for Sizing Storm Sewers.....	9-1
9.1.1	Minor Event Storm Sewer Design.....	9-1
9.1.2	Major Event Storm Sewer Design.....	9-1
9.2	Storm Sewer Pipe Material and Size.....	9-2
9.2.1	Storm Sewer Pipe Material.....	9-2
9.2.2	Minimum Pipe Size.....	9-3

## Table of Contents

---

	Table 9-1	Minimum Storm Sewer Pipe Diameters.....	9-3
	9.2.3	Driveway Culverts.....	9-3
9.3		Other Design Considerations.....	9-3
	9.3.1	RCP Pipe Class, Fill Height, and Installation Trench.....	9-3
	9.3.2	Storm Sewer Joints.....	9-3
	9.3.3	Trash Racks.....	9-4
	9.3.4	Conduit Outlet Structures.....	9-4
9.4		Easements and Maintenance.....	9-4
	9.4.1	Storm Sewer Easements.....	9-4
	9.4.2	Minimum Acceptable Storm Sewer Easements.....	9-4
	Table 9-2	Minimum Acceptable Storm Sewer Easement Widths.....	9-4
	9.4.3	Allowable Landscaping and Surface Treatment in Storm Sewer Easements.....	9-4
9.5		Storm Sewer Vertical Alignment.....	9-5
	9.5.1	Minimum Cover.....	9-5
	9.5.2	Minimum Cover in Roadways.....	9-5
	9.5.3	Utility Clearance.....	9-5
9.6		Horizontal Alignment.....	9-6
	9.6.1	Storm Sewer Alignment.....	9-6
	9.6.2	Utility Clearance.....	9-6
9.7		Manholes.....	9-6
	9.7.1	Required Locations.....	9-6
	Table 9-3	Maximum Manhole Spacing.....	9-6
	9.7.2	Manhole Types and Minimum Sizes.....	9-7
	Table 9-4	Manhole Types Based on Pipe Diameter.....	9-7
	9.7.3	Large Pipe Manhole Structures.....	9-7
	9.7.4	Steps and Platforms.....	9-8
	9.7.5	Drop Manholes.....	9-8
	9.7.6	Energy Dissipation in Manholes for Small Storm Drainage Outfalls.....	9-8
	9.7.7	Manhole Shaping.....	9-9
	9.7.8	Other Design Considerations.....	9-9
9.8		Hydraulic Design.....	9-9
	9.8.1	Allowable Storm Sewer Velocity and Slope.....	9-9
	9.8.2	Hydraulic Evaluation of Storm Sewers in the Minor Storm Event...	9-10
	9.8.3	Hydraulic Evaluation of Storm Sewers in the Major Storm Event...	9-11
	9.8.4	Computer Programs.....	9-12
	Figure 9-1	Energy Dissipation in Manholes for Small Storm Drainage Outfalls.....	9-14

## CHAPTER 10. CONDUIT OUTLET STRUCTURES

10.0		Introduction.....	10-1
	10.0.1	Design Considerations.....	10-1
10.1		General Layout Information.....	10-1
	10.1.1	Inlet and Outlet Configuration.....	10-1
	10.1.2	Safety Rails.....	10-1
	10.1.3	Flared End Sections.....	10-1
	10.1.4	Conduit Elevations Relative to Drainageways.....	10-2
10.2		Conduit Outlet Erosion Protection.....	10-2

## Table of Contents

---

	10.2.1	Types of Erosion Protection.....	10-2
	Table 10-1	Erosion Protection at Conduit Outlets.....	10-3
	10.2.2	Selecting Type of Erosion Protection.....	10-3
10.3		Design Criteria for Culvert and Storm Sewer Outlet Erosion Protection .....	10-4
	10.3.1	Riprap Lining.....	10-4
	10.3.2	Low Tailwater Riprap Basins .....	10-4
	10.3.3	Concrete Impact Stilling Basin.....	10-4
	10.3.4	Concrete Baffle Chute .....	10-5
	Figure 10-1	Conceptual Toewall Detail.....	10-6
	Figure 10-2	Pipe Outfall Joint Restraint Requirements.....	10-7
 <b>CHAPTER 11. CULVERTS AND BRIDGES</b>			
11.0		Introduction .....	11-1
11.1		General Design Information .....	11-1
	11.1.1	Design Criteria .....	11-1
	11.1.2	Design Flows .....	11-1
	11.1.3	UDFCD Maintenance Eligibility.....	11-1
	11.1.4	Permitting and Regulations.....	11-2
	11.1.5	Aesthetics and Safety .....	11-2
	11.1.6	Easement, Ownership and Maintenance Requirements .....	11-2
	11.1.7	Trail Coordination .....	11-3
11.2		Culvert and Bridge Sizing Criteria .....	11-3
	11.2.1	Culvert and Bridge Sizing Factors .....	11-3
	Table 11-1	Allowable Bridge and Culvert Overtopping for Minor Drainageways .....	11-4
	11.2.2	Sizing Procedures for Type A and B Streets when Overtopping is Allowed .....	11-4
	11.2.3	Headwater Considerations .....	11-5
11.3		Culvert Design Standards .....	11-5
	11.3.1	Construction Material.....	11-5
	11.3.2	Minimum Pipe Size .....	11-5
	11.3.3	Culvert Sizing and Design .....	11-5
	11.3.4	Capacity Curves .....	11-5
	11.3.5	Design Forms .....	11-6
	11.3.6	UD-Culvert Spreadsheet.....	11-6
	11.3.7	Velocity Considerations .....	11-6
	11.3.8	Structural Design .....	11-6
	11.3.9	Alignment.....	11-7
	11.3.10	Minimum Cover.....	11-7
	11.3.11	Multiple-Barrel Culverts .....	11-7
	11.3.12	Trash Racks/Safety Grates.....	11-7
	Table 11-2	Use of Trash/Safety Racks .....	11-8
	11.3.13	Inlets and Outlets.....	11-8
11.4		Driveway Culverts .....	11-9
	11.4.1	Applicable Criteria.....	11-9
	11.4.2	Construction Material.....	11-9
	11.4.3	Minimum Size .....	11-9
	11.4.4	Minimum Cover.....	11-9
	11.4.5	Culvert End Treatments.....	11-9

## Table of Contents

---

	11.4.6	Minimum Slope .....	11-9
	11.4.7	Design and Construction of Driveway Culverts .....	11-9
	11.4.8	Driveway Culvert Permit .....	11-10
11.5		Low Water Crossings/Pedestrian Bridges.....	11-10
	11.5.1	Pedestrian Bridges .....	11-10
	11.5.2	Minimum Conveyance .....	11-10
	11.5.3	Minimum Clearance.....	11-10
	11.5.4	Structural Design/Tethering.....	11-10
	11.5.5	Handrails.....	11-10
	11.5.6	Maintenance .....	11-11
11.6		Bridges Design Guidance.....	11-11
	11.6.1	General .....	11-11
	11.6.2	Location of Stream Crossing .....	11-11
	11.6.3	Structural Design .....	11-11
	11.6.4	Freeboard .....	11-11
	11.6.5	Flow Distribution .....	11-13
	11.6.6	Bridge Scour .....	11-13
	11.6.7	Deck Drainage .....	11-14
	11.6.8	Waterway Enlargement .....	11-14
	11.6.9	Auxiliary Opening.....	11-14

## CHAPTER 12. OPEN CHANNEL DESIGN

12.0		Introduction .....	12-1
	12.0.1	Functions of Drainageways .....	12-1
	Figure 12-1	Functions and Benefits of Healthy Streams.....	12-1
	12.0.2	Drainageway Degradation .....	12-1
	Figure 12-2	Impacts of Stream Degradation.....	12-2
	12.0.3	Vision for Drainageways .....	12-3
	12.0.4	Definition of Major and Minor Drainageways .....	12-3
	12.0.5	Jurisdictional Streams.....	12-4
	12.0.6	Governing Criteria.....	12-4
12.1		Drainageway Preservation and Stabilization.....	12-4
	12.1.1	Preservation of Natural Drainageways .....	12-4
	12.1.2	Stabilization of Natural Drainageways .....	12-5
	12.1.3	Design Considerations.....	12-6
	12.1.4	Master Planning.....	12-6
	12.1.5	Design Flows .....	12-7
	12.1.6	Permitting and Regulations.....	12-7
12.2		Design Criteria for Major Drainageways.....	12-8
	12.2.1	Natural Channel Approach .....	12-8
	Figure 12-3	Design Elements Associated with Major Drainageway Stabilization .....	12-8
	12.2.2	Create Shallow Base Flow Channel .....	12-9
	12.2.3	Establish Longitudinal Slope Using Grade Control Structures .....	12-10
	Table 12-1	Grade Control Drop Height Criteria .....	12-10
	Figure 12-4	Base Flow Channel Slope Criteria.....	12-11
	12.2.4	Utilize Vegetated Benches to Convey Overbank Flow .....	12-11
	12.2.5	Slope Back and Stabilize Eroding Banks.....	12-11
	12.2.6	Analyze Floodplain Hydraulics.....	12-12
	Table 12-2	Hydraulic Design Criteria for Natural Channels .....	12-13

## Table of Contents

---

12.2.7	Undertake Major Drainageway Plan Improvements if Required by County .....	12-14
12.3	Design Criteria for Minor Drainageways.....	12-14
12.3.1	Natural Channels .....	12-14
12.3.2	Grass-Lined Channels .....	12-14
Table 12-3	Hydraulic Design Criteria for Grass-Lined Channels .....	12-15
12.3.3	Composite Channels (Wetlands Bottom Channels) .....	12-15
12.3.4	Bioengineered Channels .....	12-15
12.3.5	Riprap-Lined and Concrete-Lined Channels .....	12-15
12.4	Grade Control Structures .....	12-15
12.4.1	100-year Drop Structures .....	12-16
12.4.2	Low-Flow Drop Structures .....	12-16
12.4.3	Drop Structure Types.....	12-17
12.5	Easements, Maintenance, and Ownership.....	12-17
12.5.1	Drainage Easement .....	12-17
12.5.2	Drainageway Ownership - Residential.....	12-17
12.5.3	Drainageway Ownership - Business/Commercial.....	12-18
12.5.4	Easements for Natural Drainageways .....	12-18
Figure 12-5	Minimum Easement Width for Natural Drainageways .....	12-19
12.5.5	Design for Maintenance.....	12-19
12.5.6	Maintenance Responsibility .....	12-20
12.5.7	Major Drainageways and UDFCD Maintenance Assistance .....	12-20
Table 12-4	Roughness Coefficients.....	12-21

## CHAPTER 13. STORAGE

13.0	Introduction .....	13-1
13.0.1	Stormwater Quality Considerations .....	13-1
13.1	General Requirements .....	13-1
13.1.1	Detention Shall be Provided for all New Development, Redevelopment and Expansion.....	13-1
13.1.2	Compatibility of Full-spectrum Detention with Former 10-year/100-year Criteria.....	13-2
13.1.3	Definition of Redevelopment, Expansion, and/or Improvement.....	13-2
13.1.4	Exemptions .....	13-2
13.1.5	Adjacency to Major Drainageway .....	13-3
13.1.6	Temporary Detention .....	13-3
13.2	Regional, Sub-Regional, and Onsite Detention Facilities.....	13-3
13.2.1	Regional Detention .....	13-3
13.2.2	Sub-regional Detention .....	13-5
13.2.3	Onsite Detention .....	13-5
13.3	Detention Basin Design Criteria .....	13-6
13.3.1	Sizing Methodology .....	13-6
13.3.2	Onsite Detention and Addressing Off-site Flows .....	13-6
13.3.3	Multiple Small Detention Basins .....	13-7
13.3.4	Detention Basins in Series.....	13-7
13.3.5	Interconnected Ponds.....	13-7
13.3.6	Outlets into Streets .....	13-8
13.3.7	Excavated and Embankment Slopes.....	13-8
13.3.8	Freeboard Requirements.....	13-8
13.3.9	Low Flow Channels .....	13-9

## Table of Contents

---

	13.3.10	Bottom Slope .....	13-9
	13.3.11	Inlet Facilities .....	13-9
	13.3.12	Outlet Structure.....	13-9
	13.3.13	Trash Racks.....	13-10
	13.3.14	Emergency Spillway and Embankment Protection .....	13-10
	13.3.15	Retaining Walls.....	13-11
	13.3.16	Landscaping Guidelines .....	13-12
	13.3.17	Signage.....	13-12
	13.3.18	Easement Requirements .....	13-13
	13.3.19	Maintenance .....	13-13
13.4		Design Standards for Parking Lot Detention .....	13-13
	13.4.1	Easement Requirements .....	13-13
	13.4.2	Maintenance Requirements.....	13-13
	13.4.3	Depth Limitation .....	13-14
	13.4.4	Outlet Configuration.....	13-14
	13.4.5	Signage.....	13-14
13.5		Stormwater Retention.....	13-15
	13.5.1	Stormwater Retention .....	13-15
	13.5.2	Facility Requirement .....	13-15
	13.5.3	Minimum Sizing Requirements .....	13-15
	13.5.4	Minimum Design Requirements.....	13-15
13.6		Landscaping Guidelines .....	13-16
13.7		Designing for Maintenance.....	13-17
	13.7.1	Access for Sediment Removal.....	13-17
	13.7.2	Other Improvements to Facilitate Maintenance .....	13-18
	Figure 13-1	Regional Detention Approach.....	13-19
	Figure 13-2	Sub-Regional Detention Approach .....	13-20
	Figure 13-3	Onsite Detention Approach.....	13-21
	Figure 13-4	Design Options for Detention Basins.....	13-22
	Figure 13-5	Typical Low Flow Channel Details.....	13-23
	Figure 13-6	100-year Required Retention Volume .....	13-24
	Figure 13-7	Embankment Protection Details and Rock Sizing Chart.....	13-25

## CHAPTER 14. STORMWATER QUALITY

14.0		Introduction .....	14-1
	14.0.1	How to Use this Chapter.....	14-1
	14.0.2	Integrated Approach to Stormwater Quality.....	14-2
14.1		Stormwater Quality Design Process.....	14-2
	14.1.1	Four Step Process .....	14-2
14.2		Sub-Regional, Regional and Onsite Approaches.....	14-5
	14.2.1	General .....	14-5
	14.2.2	Onsite Requirements Developments Tributary to Regional Water Quality Facilities.....	14-5
14.3		Selecting Type of Water Quality Capture Volume Facility.....	14-6
14.4		Exemptions from Post-Construction Best Management Practice Requirements ...	14-6
	14.4.1	Exempt Projects.....	14-6
	14.4.2	Exemptions from Water Quality Capture Volume Requirements (Step 2) .....	14-7
14.5		Design Criteria for Commonly Implemented Best Management Practices .....	14-7

## Table of Contents

---

14.5.1	Example Drawings.....	14-7
14.5.2	Design Checklists .....	14-8
14.5.3	Design Criteria for Grass Buffers and Swales .....	14-8
Table 14-2	Grass Buffer and Swale Design Criteria .....	14-9
14.5.4	Design Criteria for Extended Detention Basins .....	14-11
14.5.5	Design Criteria for Sand Filter Basins.....	14-13
14.5.6	Design Criteria for Porous Landscape Detention .....	14-15
14.5.7	Geotextile Fabric Design Considerations .....	14-17
14.5.8	Geomembrane Liner Design Considerations.....	14-17
14.5.9	Retaining Wall Use in Sand Filter Basins and Porous Landscape Detention .....	14-18
14.5.10	Sand Filter Basin and Porous Landscape Detention Landscaping Requirements.....	14-18
14.6	Design Criteria for Other Best Management Practices .....	14-19
14.6.1	Design Criteria for Constructed Wetlands Basins.....	14-19
14.6.2	Design Criteria for Retention Ponds .....	14-20
14.6.3	Design Criteria for Porous Pavement .....	14-21
14.6.4	Design Criteria for Porous Pavement Detention.....	14-22
14.7	Operation & Maintenance Manual.....	14-23
14.8	Source Control BMPs.....	14-24
14.8.1	General .....	14-24
14.8.2	Direct Connections .....	14-24
14.8.3	Indirect Connections .....	14-24
14.8.4	Structural Source Controls.....	14-25
14.8.5	Non-structural Controls.....	14-25
14.8.6	County Requirements for Illicit Discharge.....	14-25
14.8.7	Operation and Maintenance .....	14-26
Table 14-1	Selection Matrix for Water Quality Capture Volume Facilities .....	14-27
Figure 14-1	Terms for Minimizing Directly Connected Impervious Area.....	14-28
Figure 14-2	Concepts for Grass Swales .....	14-29
Figure 14-3	Concept for Concrete Edger .....	14-30
Figure 14-4	Concept for Outlet Structure with Parallel Wingwalls and Flush Bar Grating (Integral Micropool Shown).....	14-31
Figure 14-5	Concept for Outlet Structure with Flared Wingwalls and Handrail (Integral Micropool Shown) .....	14-32
Figure 14-6	Concept for Outlet Structure with Parallel Wingwalls and Flush Bar Grating (External Micropool Shown) .....	14-33
Figure 14-7	Concept for Outlet Structure with Flared Wingwalls and Handrail (External Micropool Shown) .....	14-34
Figure 14-8	Concept for Integral Forebay at Pipe Outfall .....	14-35
Figure 14-9	Concept for Integral Forebay at End Section.....	14-36
Figure 14-10	Concept for Modified Extended Detention Basin for Small Sites (Concrete Low Flow Channel Shown) .....	14-37
Figure 14-11	Concept for Modified Extended Detention Basin for Small Sites (Benched Low Flow Channel Shown).....	14-38
Figure 14-12	Concept for Porous Landscape Detention in Parking Lot.....	14-39
Figure 14-13	Concept for Porous Landscape Detention in Parking Lot (Detailed View) .....	14-40

## **Table of Contents**

---

Figure 14-14	Concepts for Inflows to Porous Landscape Detention in Parking Lot .....	14-41
Figure 14-15	Concept for Porous Landscape Detention in Landscape Area (if Approved by County) .....	14-42
Figure 14-16	Concepts for Porous Landscape Detention Outlet Structure .....	14-43