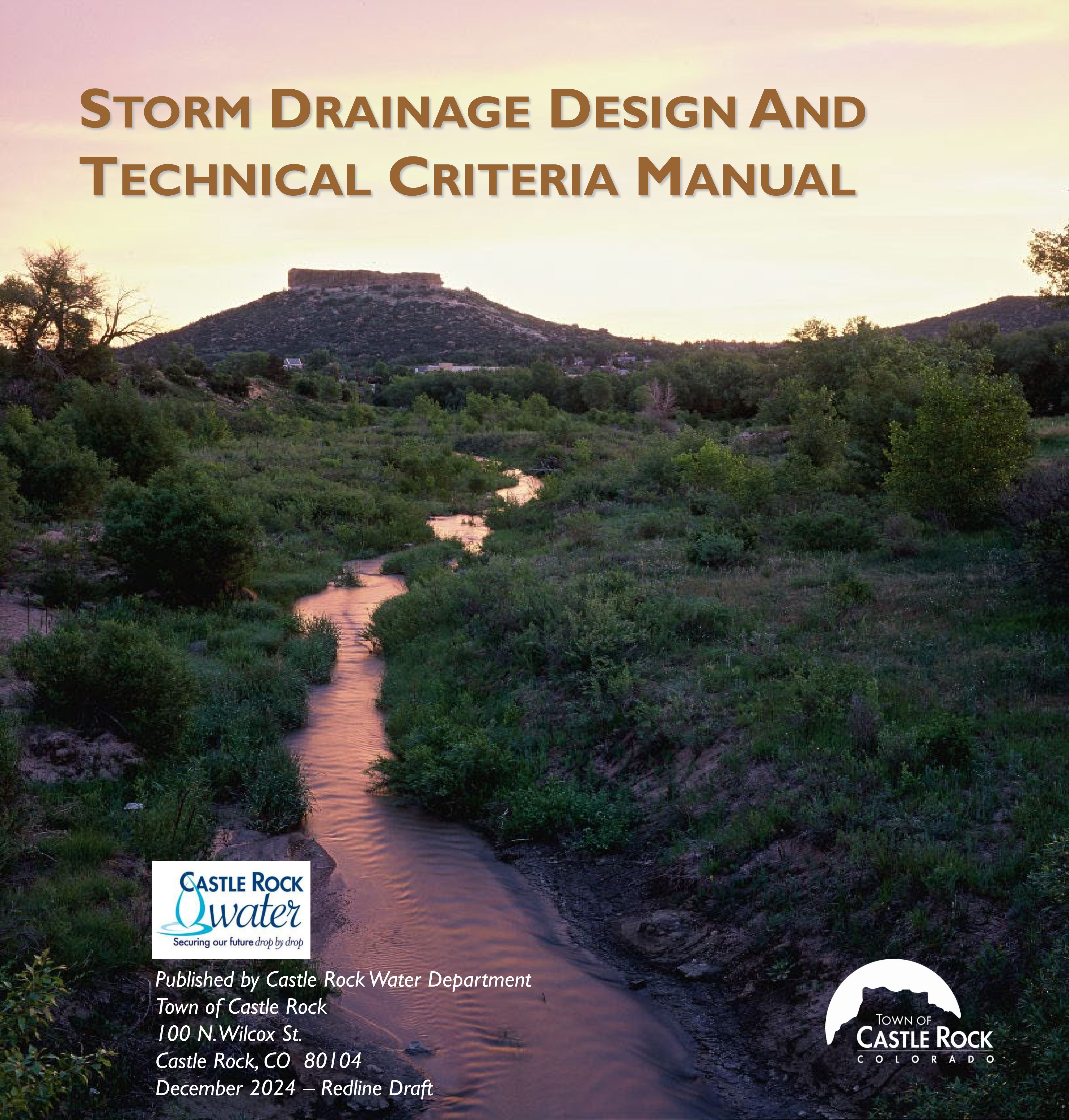
Storm Drainage Design And Technical Criteria Manual



Castle Rock Water
Securing our future *drop by drop*

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Town of Castle Rock
Colorado

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CHAPTER 13. STORAGE

1.0 Introduction

These criteria and design standards, together with all future amendments, shall be known as the Town of Castle Rock Storm Drainage Design and Technical Criteria (hereafter called the "Criteria"). All drainage reports and plans, drainage system analyses, and drainage system designs, submitted as a requirement of the Town of Castle Rock Public Works Regulations (hereafter called "Regulations"), shall comply with these Criteria.

1.1 Enactment Authority

The Regulations have been adopted pursuant to the statutory authority conferred within: Article 28 of Title 30 (County Planning); Article 2 of Title 43 (State, County, and City Highway Systems); Article 67 of Title 24 (Planned Unit Development Act); Article 20 of Title 29 (Land Use Control and Conservation); and other applicable sections of Colorado Revised Statutes, as amended.

1.2 Jurisdiction

These Criteria shall apply to all land within the incorporated area of the Town of Castle Rock, including any public lands. These Criteria shall apply to all systems and facilities constructed in or on Town Rights-of-Way, easements dedicated for drainage across public or private property, easements for public use, and to all privately owned and maintained stormwater conveyance, detention, retention, or water quality facilities.

1.3 Purpose

Presented in these Criteria are the policies and minimum technical criteria for the planning, analysis and design of storm drainage systems within the boundaries of the Town of Castle Rock. All subdivisions, resubdivisions, planned unit development, or any other proposed construction submitted for acceptance under the provisions of the Regulations shall include adequate and appropriate storm drainage system planning, analysis, and design. Such planning, analysis, and design shall conform with or exceed the criteria set forth herein. Storm drainage system planning, analysis, and design that require policies and technical criteria not specifically addressed in these Criteria shall follow the provisions of the ~~Urban Drainage and Flood Control~~Mile High Flood District's (~~UDFCD~~MHFD) Urban Storm Drainage Criteria Manual, Volumes 1, 2, and 3, as amended (~~UDFCD Manual~~MHFD Manual), which is incorporated in these *Criteria* by reference.

1.4 Amendments and Revisions

The policies and criteria may be amended as new technology is developed or if experience gained in the use of these Criteria indicate a need for revision. All technical criteria and policy changes must be recommended by the Director of Castle Rock Water. Minor revisions will require the approval of the Director of Castle Rock Water. All major revisions will require approval of the Town Council following a Public Hearing thereon.

The Director of Castle Rock Water shall monitor the performance and effectiveness of these Criteria and will recommend amendments and revisions as needed.

TABLE 1-1
EXAMPLES OF MINOR AND MAJOR REVISIONS

MINOR	MAJOR
Grammar	Policy Changes
Submittal Requirements	Technical Criteria Changes
Clarifications	Major Construction Detail Revisions
Construction Detail Revisions for clarification, minor modification	

1.5 Enforcement Responsibility

Castle Rock Water shall review all drainage reports and plans, drainage system analyses, and drainage system designs, submitted as a requirement of the Regulations, for compliance with these Criteria. The Regulations are enforced by the Town of Castle Rock and authorized representatives.

1.6 Review and Acceptance

1.6.1 The Town shall review all drainage submittals for general compliance with these Criteria. An acceptance by the Town **does not** relieve the owner, engineer, or designer from the responsibility of ensuring that the design, calculations, plans, specifications, construction, and record drawings are in compliance with these Criteria as stated in the owner's and engineer's certifications.

1.6.2 Submittals that impact FEMA designated floodplains will be required to be submitted to FEMA for review in accordance with the provisions of Chapter 5.

1.6.3 The Town may, but is not required to, refer submittals to other agencies that have an interest or responsibility for drainage and/or water quality issues. Other review agencies may include State agencies responsible for floodplain and water quality, water rights and other stormwater related issues, the Cherry Creek Basin Water Quality Authority, Chatfield Watershed Authority, or any relevant jurisdictions.

1.7 Interpretation

In the interpretation and application of the provisions of these Criteria by the Director of Castle Rock Water, the following shall govern:

1.7.1 In the interpretation and application of these Criteria, the provisions shall be regarded as the minimum requirements for the protection of the public health, safety, comfort, morals, convenience, prosperity, and welfare of the residents of the Town. These Criteria shall therefore be regarded as remedial and shall be liberally construed to further its underlying purposes.

1.7.2 Whenever a provision of these Criteria and any other provision of the Regulations or any provision in any law, ordinance, resolution, rule or regulation of any kind, contains any requirement(s) covering any of the same subject matter, the requirements that are more restrictive or impose higher standards shall govern.

1.7.3 These Criteria shall not abrogate or annul any easements, permits, drainage reports or construction drawings, recorded, issued, or accepted by the Town prior to the effective date of these Criteria.

1.8 Relationship to Other Standards

These Criteria are written to be consistent with the ~~UDFCD Manual~~MHFD Manual, unless otherwise noted. If the State or Federal Government imposes stricter criteria, standards, or requirements, these may be incorporated into the Town's requirements after due process and public hearing(s), if needed, to modify the Town's Regulations and these Criteria.

1.9 Variances from these Criteria

Variances from the provisions of these Criteria may be considered on a case-by-case basis. Formal requests for variances from the standards, policies or submittal requirements of these Criteria shall be submitted with appropriate documentation and justification to the Development Services Department. The variance request and supporting documentation will be reviewed by Castle Rock Water and a final decision will be made by the Director of Castle Rock Water. A formal response to the variance request will be provided to the requestor.

1.9.1 Variance requests must be submitted in writing to the Director of Castle Rock Water through the Development Services Department and must, at a minimum, contain the following information:

- Criteria from which the applicant seeks a variance.
- Engineering justification.
- Alternate criteria or standard that is proposed to comply with the intent of the criteria.
- Supporting documentation, including necessary calculations, etc.
- The variance request must be signed and stamped by a Professional Engineer licensed in the state of Colorado.

1.9.2 **Appeals Process to Variance Denial.** See the Development Procedures Manual for Appeals Process.

1.10 Acronyms

As used in these Criteria, the following acronyms shall apply:

ASCE	American Society of Civil Engineers
ASTM	American Society for Testing and Materials
BCD	Baffle Chute Drop
BFE	Base Flood Elevation
CAP	Corrugated Aluminum Pipe
CAPA	Corrugated Aluminum Pipe Arch
CCBWQA	Cherry Creek Basin Water Quality Authority
CDOT	Colorado Department of Transportation
CDPHE	Colorado Department of Public Health and Environment
CEC	Consulting Engineers Council
CGIA	Colorado Governmental Immunity Act
CLOMR	Conditional Letter of Map Revision
CMP	Corrugated Metal Pipe
CMPA	Corrugated Metal Pipe Arch
CRS	Colorado Revised Statutes
CSP	Corrugated Steel Pipe
CSPA	Corrugate Steel Pipe Arch
CUHP	Colorado Urban Hydrograph Procedure
CWA	Clean Water Act
CWCB	Colorado Water Conservation Board
DCIA	Directly Connected Impervious Area
DRCOG	Denver Regional Council of Governments
EGL	Energy Grade Line
ECCV	East Cherry Creek Valley Water & Sanitation District
EPA	U.S. Environmental Protection Agency
ESA	Endangered Species Act
EURV	Excess Urban Runoff Volume
FAA	Federal Aviation Administration
FEMA	Federal Emergency Management Agency
FHAD	Flood Hazard Area Delineation
FHWA	Federal Highway Administration
FIRM	Flood Insurance Rate Map
FIS	Flood Insurance Study
FPE	Flood Protection Elevation
GSB	Grouted Sloping Boulder
HDPE	High Density Polyethylene
HDS	Hydraulic Design Series
HEC	Hydraulic Engineering Center
HERCP	Horizontal Elliptical Reinforced Concrete Pipe
HGL	Hydraulic Grade Line
HUD	U.S. Department of Housing and Urban Development
H:V	Horizontal to Vertical Ratio of a Slope
ICC	Increased Cost of Compliance
LID	Low Impact Development
LOMR	Letter of Map Revision

MHFD	Mile High Flood District (Formerly Urban Drainage Flood Control District)
MDCIA	Minimizing Directly Connected Impervious Area
MS4	Municipal Separate Storm Sewer Systems
NAVD	North American Vertical Datum
NFIA	National Flood Insurance Act
NFIP	National Flood Insurance Program
NGVD	National Geodetic Vertical Datum
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NWS	National Weather Service
PE	Professional Engineers Licensed by the State of Colorado
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
RCBC	Reinforced Concrete Box Culvert
RCP	Reinforced Concrete Pipe
ROW	Right-of-Way
SBA	Small Business Administration
SCS	Soil Conservation Service
SEO	Colorado State Engineer's Office
SFHA	Special Flood Hazard Area
SFIP	Standard Flood Insurance Policy
SPP	Structural Plate Pipe
SPPA	Structural Plate Pipe Arch
SWMM	Stormwater Management Model
SWMP	Stormwater Management Plan
TESC	Temporary Erosion and Sediment Control
TWE	Tailwater Elevation
~~UDFCD~~	~~Urban Drainage & Flood Control District~~
UDSWM	Urban Drainage Stormwater Management Model
USACE	United States Army Corps of Engineers
USBR	United States Bureau of Reclamation
USDCM	Urban Storm Drainage Criteria Manual
USGS	United States Geological Survey
WEF	Water Environment Federation
VHB	Vertical Hard Basin
WSEL	Water Surface Elevation
WQCV	Water Quality Capture Volume

2.0 Introduction

The provisions for adequate stormwater management are necessary to preserve and promote the general health, welfare, and economic well being of the Town of Castle Rock and surrounding area. Drainage affects all governmental jurisdictions and parcels of property. This characteristic makes it necessary to formulate a program that balances both public and private involvement. The Town of Castle Rock must provide coordination and master planning, but stormwater management must also be integrated on a regional basis.

When planning stormwater management facilities, certain underlying principles provide direction for the effort. The principles are made operational through policy statements. The application of the policy is, in turn, facilitated by technical criteria and data. When considered in a comprehensive manner, on a regional level with public and private involvement, stormwater management facilities can be provided in a manner that will enhance the general health and welfare of the region and assure optimum economic and social relationships.

2.1 Principles

The following principles for urban stormwater management are based on those outlined in the ~~UDFCD Manual~~MHFD Manual.

2.1.1 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.

2.1.2 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, and regional water quality.

2.1.3 Every urban area has an initial (i.e., minor) and a major drainage system, whether or not they are actually planned and designed. The initial drainage system, sometimes referred to as the “minor system”, is designed to provide public convenience and to accommodate moderate, frequently occurring flows. The major system carries more water and operates when the rate or volume of runoff exceeds the capacity of the minor system. To provide for orderly urban growth, reduce costs to future generations, and avoid loss of life and major property damage, both systems must be planned and properly engineered.

2.1.4 **Runoff routing is primarily a space allocation problem.** The volume of water present at a given point in 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, if not, stormwater runoff will conflict with other land uses, resulting in damages and the disruption of other urban systems.

2.1.5 **Planning and design of stormwater management 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 as not to adversely impact downstream properties.

2.1.6 **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 number of objectives, including water quality enhancement, groundwater recharge, recreation, wetland creation, protection of landmarks/amenities, control of erosion and sediment deposition, and creation of open spaces.

2.1.7 **Design of the stormwater management 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 sediments and other pollutants, and recycle nutrients.

2.1.8 **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 imperviousness of the site should be minimized, the rate of runoff should be slowed by maximizing vegetative and porous land cover, and a series of control measures must be provided for water quality enhancement and protection.

2.1.9 **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.

2.1.10 **The stormwater management system must receive regular maintenance to ensure long-term function and effectiveness and stormwater management facilities shall be designed with ease of maintenance, long-term function,**

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 shall be identified, and assigned to an established agency with the resources and understanding, which are required to ensure proper maintenance.

2.1.11 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 the public health, safety, and welfare. Floodplain encroachment is highly discouraged and will only be considered on a case-by-case basis. Floodplain encroachment requires the approval of the Stormwater Manager through a Floodplain Development Permit.

2.1.12 Reserve sufficient Right-of-Way for lateral channel movement of incised floodplains. 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 damage to public and private structures and facilities.

2.1.13 Subdivision water quality capture volume (or equivalent) facilities. Regional or subregional water quality capture volume facilities or equivalent water quality control measures shall be designed and constructed at the time of subdivision to serve all parcels or lots within the subdivision boundary.

2.1.14 Emergency overflow routing shall be accounted for in the design. Emergency overflow conveyance for all stormwater management facilities, equivalent to the major storm discharge, is necessary in the event of clogging or overtopping and shall ensure that private property and structures are not impacted.

2.2 Planning Policy

2.2.1 All land development proposals shall receive full site planning and engineering analyses. A drainage report and plan consistent with the submittal requirements in these Criteria shall be required for all new development and redevelopment within the Town's jurisdiction.

2.2.2 Stormwater management planning shall be required in the initial planning stages, for all developments, to ensure that adequate space is allocated for the required stormwater management facilities.

2.2.3 The Town supports and will pursue a jurisdictionally unified approach to drainage to ensure an integrated comprehensive regional drainage plan.

2.2.4 The Town will continue to develop detailed regional master plans, which will set forth site requirements for development and identify the required public improvements. Master plans will be approved, adopted by Town Council, and revised as necessary to accommodate changes that occur within the specific drainage basin.

2.2.5 Where practicable and feasible, site planning and design techniques shall be incorporated, which promote the concept of minimizing directly connected impervious areas in order to decrease the volume and velocity of stormwater runoff from a site.

2.2.6 The Town shall encourage the development of multipurpose, aesthetic detention facilities that are safe, maintainable, and community assets.

2.2.7 The definition of a major drainageway is necessary for the clarification and administration of these *Criteria*. The Town defines a major drainageway as any drainage flow path with a tributary area of 130 acres or more.

2.2.8 The Town considers stormwater runoff to be an integral part of the Town's surface and groundwater resource and recognizes its potential for other uses.

2.2.9 The Town recognizes that some intra-watershed transfer or diversion of runoff occurs within major drainageway watersheds, as sub-watershed boundaries are changed with development. Those diversions and transfers should be minimized, to the extent possible, historic outfall locations to natural drainageways shall be maintained, and any potential adverse impacts that result shall be mitigated with the stormwater management design.

2.2.10 Inter-watershed transfer or diversion of runoff from one major drainageway watershed to another major drainageway watershed shall be avoided unless specific and prudent reasons justify and dictate a transfer; transfers such as this must be approved by the Stormwater Manager.

2.2.11 There are areas within the Town defined by specific drainage or water quality concerns. The Town will require additional jurisdictional cooperation and drainage analysis in the specified areas. In some cases, additional improvements may be required.

2.2.12 Encroachment into the 100-year floodplain through floodplain filling is strongly discouraged. When considering requests for floodway fringe filling, the Town shall consider the impacts to adjacent properties, the channel hydraulics and design and the channel aesthetics and adjacent land use. The Town's Stormwater Manager shall make final decisions regarding floodplain filling through a Floodplain Development Permit.

2.2.13 Groundwater or sub-surface water can adversely impact the construction, capacity, long-term function, and maintainability of public streets and stormwater management facilities. Those potential impacts shall be quantified, to the extent possible through groundwater boring, etc., and considered during site drainage design and the design of stormwater management facilities.

2.3 Design Policy

2.3.1 Stormwater management planning and design within the Town shall adhere to the criteria developed and presented in these Criteria, and in accordance with the criteria established in the ~~UDFCD Manual~~MHFD Manual.

2.3.2 All development, redevelopment and expansion must include planning and design for both the minor and major drainage systems. The minor drainage system shall be designed for the 5-year storm recurrence interval. The major drainage system shall be designed for the 100-year storm recurrence interval.

2.3.3 The minor drainage system, as a minimum, shall be designed to transport runoff with minimum disruption to the urban environment. Minor storm drainage can be conveyed in the curb and gutter area of the street or roadside ditch (subject to street classification and capacity, as defined herein), by storm sewer, (without surcharge), channel, or other conveyance facility, provided that capacity exists when future development is considered. The minor drainage system shall be sized without accounting for peak flow reductions from upstream detention.

2.3.4 The major drainage system shall be designed to convey runoff in a manner, which minimizes health and life hazards, damage to structures, and interruption to traffic and services. Major storm flows can be carried in the urban street system (within acceptable depth criteria as provided herein), channels, storm sewers and other facilities, provided that capacity exists when future development is considered.

2.3.5 Determination of rainfall values and runoff quantities shall be based on the information and methodologies presented in Chapter 6, Hydrology.

2.3.6 The Town requires that stormwater detention storage be provided for all new development, redevelopment and constrained redevelopment as defined in Section 13.1.4 of these Criteria. Storage volume and release rate criteria are based on the water quality capture volume, two-year and the 100-year recurrence interval storm events or "Full-Spectrum" Detention. Additional discussion regarding Full-Spectrum Detention can be found in Chapter 13, Storage. Alternative design standards to WQCV will be considered on a case-by-case basis and subject to the minimum design standards as outlined in Section 14.4.

2.3.7 Underground detention is discouraged and only allowed by Variance based on merit and limited circumstances.

2.3.8 Stormwater retention shall not be permitted, except as approved on a case-by-case basis by the Town as an interim solution and as permitted by water law. The control measures described in Chapter 14, Stormwater Quality, are not considered retention facilities assuming the maximum allowable retention volumes as outlined in Section 13.3.11 are demonstrated.

2.3.9 Rooftop detention is prohibited in the Town.

2.3.10 Major drainageways within the Town shall be preserved in their natural state, to the extent possible, and stabilization measures shall be designed to complement and enhance the natural character. Improvements are generally needed to mitigate adverse impacts associated with development, but they can be designed to maintain or enhance the natural environment. Major drainageway runoff shall not be conveyed in storm sewer pipes or culverts, except for the use of culverts at roadway crossings.

2.3.11 In order to preserve the natural character of major drainageways, limit excessive velocities, minimize future rehabilitation and maintenance costs and eliminate potential safety hazards, major drainageway channels shall be constructed to provide a natural, smooth transition from the channel to the natural topography. The Town will not allow the use of constructed retaining walls or bank slopes greater than 4:1 for major drainageway channels unless required to avoid impacts to adjacent property and structures. Stable, vegetated slopes of existing natural channels steeper than 4:1 may be allowed to remain if approved by the Town. Varying of side slopes throughout constructed channels is encouraged, to provide a less structural, more natural appearance.

2.3.12 The Town encourages the application of the major drainageway standards and criteria to minor drainageways. Alternative treatments for minor drainageways will be considered consistent with the criteria provided in Chapter 12, Open Channel Design.

2.3.13 Site drainage design and design of stormwater facilities shall consider the potential impacts of groundwater on streets and other infrastructure. Investigations shall be performed and improvements constructed as needed to avoid and/or mitigate the potential impacts of groundwater on the stormwater facilities and the property. Lot to lot drainage in residential developments is discouraged. Areas where lot to lot drainage cannot be avoided will require the installation of a subsurface drainage system.

2.3.14 The Town requires the implementation of post-construction Control measures for enhancement of stormwater quality with all development and redevelopment within the Town as defined in Section 13.1.4 of these Criteria.

2.3.15 Underground post-construction control measures for enhancement of stormwater quality will only be approved by variance. All underground control measures must meet the minimum pollutant removal design standard as outlined in Section 14.4.2.

2.4 Operations and Maintenance Policy

2.4.1 The design of all stormwater management facilities within the Town must be performed with access and long-term operation and maintenance being priority considerations. See Section 4.6 of these Criteria for additional information.

2.4.2 The property owner shall be responsible for the maintenance of all stormwater facilities located on the property unless otherwise specified in a maintenance agreement. Additional information regarding Stormwater Facility Maintenance can be found in Section 3.5.

2.4.3 Drainage easements or tracts and access easements shall be provided for all stormwater management facilities.

2.4.4 Developing properties shall convey runoff from upstream properties across their site within dedicated drainage easements or tracts.

2.5 Construction of Public Improvements Policy

2.5.1 Water quality control measures as defined by the accepted Phase III Drainage Report and Plan must be designed and constructed with all new development and redevelopment.

2.5.2 The local on-site drainage system, as defined by the accepted Phase III Drainage Report and Plan, including provisions necessary to convey developed flows from upstream properties must be designed and constructed with all new development and redevelopment. Conveyance of off site runoff is discussed in detail in Chapter 6, Hydrology.

2.5.3 The connection of the local drainage system to a major drainageway of adequate conveyance capacity, such as a master planned outfall, storm sewer, or drainageway, as defined by the accepted Phase III Drainage Report and Plan must be designed and constructed with all new development and redevelopment.

2.5.4 The major drainageway system and stabilization improvements, within the development, as defined by Master Drainage Plans or as required by the Town, as defined by the accepted Phase III Drainage Report and Plan must be designed and constructed with all new development and redevelopment.

2.6 Regulatory/Legal Policy

2.6.1 The Town is a permittee under Phase II of the National Pollutant Discharge Elimination System Program requirements of the Federal Clean Water Act, and regulations promulgated by the Colorado Department of Public Health and Environment– Water Quality Control Division in their Stormwater Phase II Program. The Town will comply with its permit requirements to the maximum extent practicable, which include requiring post-construction water quality enhancement control measures with all development or redevelopment as defined in Section 13.1.4 of these Criteria.

2.6.2 The Town is subject to the requirements of the Cherry Creek Reservoir Control Regulation to the maximum extent practicable. The Colorado Department of Public Health and Environment – Water Quality Control Commission Regulation No. 72, Cherry Creek Control Regulation outlines additional requirements, related to the protection of stormwater runoff quality, for Stormwater Permit holders within the Cherry Creek Reservoir watershed. These requirements must be adhered to, above and beyond the requirements of these Criteria, when working in the Cherry Creek Basin.

2.6.3 The Town is subject to the requirements of the Chatfield Reservoir Control Regulation to the maximum extent practicable. The Colorado Department of Public Health and Environment – Water Quality Control Commission, Regulation No. 73, Chatfield Reservoir Control Regulation requires that water quality enhancement control measures be implemented within the Town to control non-point source pollution of stormwater runoff within the Chatfield Reservoir watershed, which includes all tributaries to Plum Creek. These requirements must be adhered to, above and beyond the requirements of these Criteria, when working in the Chatfield Reservoir watershed.

2.6.4 The Town is a participant in the National Flood Insurance Program (NFIP) and will implement and enforce floodplain development regulations that meet or exceed the minimum standards provided in 44 Code of Federal Regulations, Part 60. The Town floodplain development regulations are part of the Town of Castle Rock Municipal Code, Title 18.

2.6.5 It is recognized that certain stormwater management facilities may impact water rights. The Town's policy shall be to preserve the integrity of water rights in the planning, design, and construction of stormwater drainage facilities.

2.7 Hazard Minimization & Public Safety Policy

2.7.1 Public safety shall be an essential objective when planning, designing and maintaining stormwater facilities.

2.7.2 Stormwater facilities within the Town shall be designed with careful consideration of the potential hazards associated with the use and long-term operation and maintenance of the facility. The design phase of all projects shall analyze the potential risks associated with the facility, and include appropriate design features to minimize these risks.

2.8 Miscellaneous Policy

2.8.1 Stormwater runoff shall be directed into historic and natural drainageways and avoid discharging into an irrigation canal or ditch, except as required by water rights. Where irrigation ditches cross major drainageways, the developer may be required to design and construct the appropriate structures to separate stormwater runoff from ditch flows. Whenever new development will increase flow rates, volumes, or change the manner or points of discharge into irrigation ditches, the written consent from the ditch owner/operator shall be submitted with the development application.

2.8.2 There is potential for problems relative to dam safety and the hazards associated with breaching, failure, and emergency spillway locations and downstream flow paths. In general, development shall be restricted to areas outside of a reservoir's high water line created by operation of the emergency spillway.

3.0 Introduction

The Town of Castle Rock recognizes the importance of sound stormwater planning and management. Stormwater management is an integral component of overall development planning and site design that must be addressed in the earliest planning stages. Initial feasibility studies or preliminary site analyses cannot be properly performed without a clear understanding of stormwater management regulatory requirements and manual. It is important to implement site design practices, which lead to effective management of stormwater and understand that stormwater must be properly managed early in the planning stages. Stormwater cannot be properly managed by allocating minimal space in a portion of a site or development which is convenient or "out of site". Incorporating stormwater management planning in the initial stages can lead to reduced infrastructure costs, better long term function of stormwater management facilities and increased property values. Facilities which are designed as site amenities can simultaneously lower maintenance costs and provide potential mitigation of impacts to downstream properties or drainageways.

Initiating stormwater management planning independently, after development planning or site layout leads to space allocation problems. Lack of appropriate space for stormwater management then leads to increased infrastructure costs, difficulties in meeting regulatory requirements and criteria, and designs that compromise long term function and maintainability. Stormwater structures that do not meet Town criteria and regulatory requirements will not be approved by the Town. Initiating stormwater management planning independently, after development planning or site layout has been accomplished, may lead to inadequate space allocation for stormwater management and other design challenges. Often, this results in an increase in infrastructure costs and difficulties in meeting regulatory requirements and criteria. The Town of Castle Rock will not accept designs that compromise long-term function and maintenance access.

3.1 Planning for Stormwater Management

The following sections provide some general discussion regarding impacts of urbanization and factors to consider when planning for stormwater management in the site design or development layout processes. Additional guidance for planning of the urban storm runoff system is provided in the Planning section of the ~~UDFCD Manual~~MHFD Manual.

3.1.1 Impacts of Development. The increased runoff rates and volumes associated with urbanization and development can significantly impact downstream properties, existing infrastructure, and natural drainageways and other resources. Flooding of downstream properties can result if existing drainage facilities are not adequate to handle the increased runoff peak flows. Drainageways are subject to increased peak discharges, runoff volumes, and more frequent runoff events. Channel bank erosion and degradation occur if channel stabilization measures are not implemented as development occurs.

In addition to challenges presented by increased runoff quantities, changes in stormwater runoff quality, associated with urbanization, can have significant impacts on rivers, streams, and lakes. Some of the urban stormwater pollutants are sediments, nutrients, microbes, organic matter, toxic pollutants, petroleum, and trash and debris.

3.1.2 Multi-purpose Resource. Although sometimes considered a liability to urbanization, stormwater runoff is an urban resource, having many potential beneficial uses that are compatible with adjacent land uses and Colorado Water Law. When treated as a resource, aesthetic and water quality aspects become increasingly important. The stormwater urban sub-system should be multi-purpose to satisfy the competing demands for land within the Town. For example, stormwater management facilities can be designed to fulfill recreational purposes and open space requirements along with stormwater runoff conveyance or storage. In addition, facilities not intended primarily for stormwater management such as parks, ball fields, etc., may be designed to incorporate water quantity and quality benefits. Stormwater runoff is considered to be an integral part of surface and groundwater resources.

Wetland or habitat areas created for mitigation purposes should not be included in stormwater management facilities.

3.1.3 Allocation of Space. The stormwater management system is an integral part of the total urban system and, therefore, planning of drainage facilities must be included in the urbanization process. Stormwater management facilities, such as channels and storm sewers, may serve conveyance, storage, and water quality functions. When the space requirements are considered, the provision for adequate drainage becomes a competing use for space along with other land uses. If adequate provision is not made in a land use plan for the drainage requirements, storm water runoff will conflict with other land uses and will impair or even disrupt the functioning of other urban systems. The Town requires storm drainage planning for all developments to include the allocation of space for drainage facility construction and maintenance, which includes the dedication of Right-of-Way and/or easements.

3.1.4 Regional and Local Master Planning. In recognition that drainage boundaries are non-jurisdictional, the Town, in cooperation with other local jurisdictions, participates in preparing regional, basin-wide master plans to define the major drainageway stabilization and other stormwater management improvements that are needed to mitigate drainage impacts associated with development. In the absence of regional master plans, the developer will be responsible for providing additional information as necessary, and may be required to participate in master planning efforts to ensure that the proposed development and associated stormwater runoff system will be compatible with the properties in the drainage basin. The Town may require that stormwater management facilities be designed in conformance with approved regional flood control or water quality master plans.

3.1.5 Site Design and Layout. Good site planning and development layout is the key to effective stormwater management. Initial planning must identify important natural features or environmentally sensitive areas, such as floodplains and/or wetlands. Protection of those areas should be incorporated into the site plan or development plan concept. Other existing site characteristics such as topography, geologic features, and soils may also present unique challenges when developing the stormwater management plan for a site or development. Generally, there are significant benefits to implementing practices that reduce runoff volumes, slow runoff velocities, and ensure careful placement of water quality treatment facilities. The incorporation of infiltration, detention, and stormwater conveyance into landscaped areas, furthers the concept of developing stormwater management facilities that are amenities, which are aesthetically pleasing and effective. Attempts to address stormwater management in later stages of development planning will lead to ineffective and costly stormwater management.

In conditions where a residential lot consists of a cut slope greater than 10:1 along the back property line, the toe of the 10:1 slope, or "grade break" location must be a minimum of 25-feet from the back of the foundation of the home. Cut slopes are to be limited within the lot ~~and drainage easement~~ wherever possible to prevent disturbances to open space. ~~If the cut slope continues beyond the limits of the residential lot line into open spaces or where significant open space drains onto the lot, conditions may warrant the need to divert open space runoff away from the downstream lot in a drainage swale or catchment sized for the major storm event and contained within a drainage easement. Drainage swales shall be constructed of concrete, provide for maintenance access and shall have a minimum one-foot of freeboard contained within the easement.~~

Grading within native open space areas may result in negative impacts to water quality and on-going erosion issues due to poor soil conditions and lack of vegetation. Therefore, grading within dedicated Town open space is discouraged and will only be allowed on a case by case basis. Slope easements are required for all areas of land disturbance within Town of Castle Rock Open Space. Maintenance responsibility shall go to a private entity such as a Homeowner Association or Metropolitan District and shall include upkeep of minimum native grass cover and repair of rill and gully erosion in accordance with the Town of Castle Rock Temporary Erosion and Sediment Control Manual, as Amended.

Grading configurations that cause for drainage from one lot to another are discouraged. On new development where residential lots are to be constructed on a slope such that drainage from one or more lots flows to another, the overlot grading plan shall be designed such that no more than one and a half times the downstream lot size drains to the downstream residential lot. Where ~~upstream concentrated flow is conveyed to downstream lots~~lot to lot drainage cannot be avoided, ~~this flow shall be diverted in a concrete drainage swale and~~ a sub-surface collection system is required along the street in front of ~~properties~~ the lot to intercept nuisance flows resulting from lot to lot drainage~~where the swale is installed~~. See Section 3.3.3 for sub-surface collection system requirements and

Section 3.5.4 for further information on drainage easements and tracts for single-family residential development.

If a retaining wall(s) is proposed as part of a common development, there shall be no sheet flow or point discharge conveyed over the top of the retaining wall. Any stormwater that is tributary to the top of a retaining wall must be intercepted by an inlet or routed around the wall through a concrete swale. The retaining wall structural design shall consider the impacts of an adjacent inlet or swale. This rule does not apply to landscape walls constructed independently on an individual single-family residential lot less than four feet in height. Retaining walls equal to or greater than four feet will require a separate Building Permit. Additional information regarding the use of retaining walls in detention basins can be found in Section 13.3.14.

3.1.6 Volume Reduction Practices. Runoff volume and peak reduction, through the implementation of the Minimizing Directly Connected Impervious Areas (MDCIA) concept shall be considered as an important component in effective stormwater management planning. The goals of implementing this practice are to reduce impervious areas or the effective imperviousness of the site and to slow down runoff and promote infiltration. Reduction in size and cost of downstream stormwater management infrastructure is another potential benefit of implementing Minimizing Directly Connected Impervious Areas. Reduction of paved or impervious areas and the use of porous pavement, grass buffers, and grass swales are several of the approaches utilized as part of implementing Minimizing Directly Connected Impervious Areas. The New Development Planning section in Volume 3 of the ~~UDFCD Manual~~MHFD Manual and Chapter 14 Stormwater Quality of these Criteria shall be consulted for more detailed discussion regarding the implementation of Minimizing Directly Connected Impervious Areas.

3.1.7 Design of Stormwater Quantity Management Improvements. Detention storage facilities and improvements, which convey stormwater runoff, must be carefully planned and integrated into the first stages of site planning. SUFFICIENT SPACE MUST BE ALLOCATED to allow for designs that meet all technical requirements and that ensures long-term function and maintainability of stormwater facilities. Conveyance facilities, which are aesthetically pleasing and promote infiltration of stormwater runoff, shall be considered where feasible.

Inlets, when needed to collect stormwater runoff shall be located and designed to maximize collection or interception efficiency and with consideration of the proposed use in the vicinity of the inlet locations. Inlets in vehicular traffic or parking areas are much different than inlets in landscaped or pedestrian traffic areas. Inlet types and grate designs must be chosen with those considerations in mind. Potential inundation depths and limits at inlets must also be acceptable when considering the adjacent property use. Type 16 inlets shall be used in neighborhoods and in local and minor collector streets. Type R or Type 16 inlets shall be used in major collectors or arterials.

Underground storm sewer systems, required to convey stormwater runoff collected at inlets, must be integrated and located within the site, to facilitate proper function and ease of maintenance. Issues to be considered when developing preliminary storm sewer locations include, but are not limited to, proximity to proposed structures, other utilities, adjacent properties, depth of cover, traffic loading, proposed surface improvements, and accessibility for future maintenance.

Detention storage facilities have special design considerations and space allocation requirements. These facilities should not be designed based on minimum required volume calculations, by assuming that retaining walls or steep slopes can be used to minimize the land area needed for the improvements. Generally, aesthetics and long-term operation and ease of maintenance are severely compromised when detailed design criteria and maintenance access requirements are not considered in the earliest planning stages. Detention pond designs which incorporate detention storage into the overall landscape plan can lead to detention ponds that are viewed as site amenities.

3.1.8 Water Quality Treatment. Post-construction water quality control measures are required with all applicable new development or re-development within the Town. In addition to stormwater volume and peak flow reduction, practices that meet one or more of the Town's design standards for post-construction water quality treatment will also be required for the excess runoff that remains after the volume reduction practices are accounted for. The most common control measure is to provide Water Quality Capture Volume to provide for sedimentation of particles and removal of pollutants. Common Water Quality Capture Volume control measures are porous pavement detention, porous landscape detention, extended detention basins, sand filter extended detention basins, constructed wetland basins, and retention ponds. Other allowable design standards are discussed in Chapter 14. Incorporation of one or more of these control measures into a site or development must be addressed in the initial planning stages and requires a well coordinated effort between the land planners, landscape architect, and the engineers responsible for stormwater management design. Implementation of water quality control measures must be addressed hand-in-hand with the stormwater conveyance and detention storage facilities. Consult Volume 3 of the ~~UDFCD Manual~~MHFD Manual and Chapters 13 and 14 of these Criteria for detailed design requirements, considerations, limitations, and information regarding proper implementation.

3.1.9 Channel Stabilization. Drainageways experience more frequent runoff events as a watershed develops. These runoff events increase in rate and volume as the imperviousness in the basin changes. Channel bank erosion and degradation can occur with changes in hydrology, if channel stabilization measures are not implemented with development. There is a common misconception that providing on-site detention mitigates impacts to downstream drainageways for all storm events. Typical detention facilities often do not provide mitigation for the more frequent runoff volumes or events. The Full-Spectrum Detention approach described in Chapter 13 is expected to improve the reduction of runoff rates for more frequent storms, but will not negate the need for effective channel stabilization. Runoff volumes will still increase and elevated flows will still occur in response to large rainfall events. Drainageway stabilization within or adjacent to a development must be addressed in the overall stormwater management plan. Many watershed Master Planning Studies have been developed within the Town. These studies provide conceptual or preliminary design information regarding stabilization of many major drainageways. The overall stormwater management plan for any development must address the recommendations contained within the Basin Master Plan.

3.1.10 Maintenance Considerations. Maintenance activities, including routine maintenance, restorative maintenance, and rehabilitation are required to ensure the long-term function and effectiveness of stormwater management facilities and infrastructure. Initial site planning must incorporate provisions for adequate access and space to perform maintenance activities for all stormwater management facilities. All facility designs will be held to the same standards, regardless of the organization or entity that has accepted responsibility for maintenance. Maintenance responsibilities and access issues are discussed in more detail in Section 3.5 of this Chapter.

3.1.11 Drainage Law. The general principles of Colorado drainage law and specific Colorado Revised Statutes guide and affect many aspects of stormwater management, including, but not limited to, private and municipal liability, maintenance and repair of drainage improvements, construction of drainage improvements by local governments, financing of drainage improvements, floodplain management, irrigation ditches, dams and detention facilities, water rights, and water quality. The Drainage Law Section in Volume 1 of the ~~UDFCD Manual~~MHFD Manual provides a good outline of many of the general principles of Colorado drainage law and it should be consulted for general reference.

3.1.12 Town Permits. The construction of stormwater management facilities within the Town may require one or more of the following permits:

1. Construction Permit. All improvements to a construction site require a Construction Permit as outlined in the Town of Castle Rock Development Procedures Manual, as amended.

2. Floodplain Development Permit. Projects that include work within designated 100-year floodplain limits of drainageways in the Town require a Floodplain Development Permit. Consult Title 18 of the Town of Castle Rock Municipal Code and Chapter 5 Floodplain Management of these Criteria for additional details.

3. TESC Permit. Town of Castle Rock requires that a TESC Permit be obtained prior to the start of land-disturbing activities within the Town. Consult the Town of Castle Rock TESC Manual for detailed requirements.

3.1.13 Environmental Permitting. In addition to Town permitting processes, the construction of stormwater management facilities often requires permitting through the Colorado Department of Public Health and Environment with regard to the Stormwater Construction permitting requirements, and through the United States Army Corps of Engineers (USACE), relative to Section 404 of the Clean Water Act, and through the United States Fish and Wildlife Service regarding compliance with the requirements of Sections 7 and 9 of the Endangered Species Act of 1973. It is strongly recommended that initial project planning incorporate input from the appropriate agencies to determine permitting process requirements, as these processes can be complex and time consuming.

Compliance with state or federal permitting requirements does not preclude the need to fully comply with Town regulations, standards, or criteria. If necessary, joint discussions between all regulatory agencies shall be initiated in project planning stages and continued as needed.

3.1.14 Landscape Regulations. Refer to the Town of Castle Rock Landscape and Irrigation Performance Standards and Criteria Manual for additional information.

3.2 Special Planning Areas and Districts

There are Special Planning Areas or Districts within the Town where additional or unique considerations affect stormwater management planning or design. Special policies or recommendations may be implemented for these areas, as discussed in the following sections.

3.2.1 Cherry Creek Basin Water Quality Authority (CCBWQA). The State's Cherry Creek Reservoir Control Regulation No. 72 is in effect for this watershed. The CCBWQA was formed to protect and enhance the overall quality of the water within Cherry Creek Reservoir and, therefore, for all development within the Cherry Creek Basin, including tributaries, the CCBWQA will be a referral agency. The CCBWQA will review development proposals and land use applications for conformance with Cherry Creek Reservoir Control Regulation No. 72 requirements and will provide comments to the Town.

3.2.2 Chatfield Watershed Authority (CWA). The State's Chatfield Reservoir Control Regulation No. 73 is in effect for this watershed. The CWA was formed to protect and enhance the overall quality of the water within Chatfield Reservoir and, therefore, for all development within the Chatfield Basin, including tributaries, the CWA will be a referral agency. The CWA will review development proposals and land use applications for conformance with Chatfield Reservoir Control Regulation No. 73 requirements and will provide comments to the Town.

3.2.3 Areas with Existing Drainage Problems. General principles regarding the management of stormwater, engineering expertise and methodologies, accepted design practices, local government oversight, and the development of minimum design standards or criteria have evolved over time. There are areas of the Town that developed during the earlier stages of this evolution when there may not have been a thorough understanding of how to properly convey stormwater or mitigate the potential adverse impacts associated with increased peak flow rates and volumes. As a result, some of these areas experience drainage problems and lack adequate infrastructure to properly convey stormwater runoff. In those areas additional analysis and improvements may be required by the Town in order to ensure that the existing problem area is not exacerbated by new development or redevelopment.

3.3 Special Considerations

3.3.1 Irrigation Ditches. There are a few irrigation ditches and reservoirs in the Town. The ditches and reservoirs have historically intercepted the storm runoff from rural and agricultural basins. Urbanization of the basins, however, has increased the rate, quantity and frequency of stormwater runoff, and has had negative effects on water quality. Irrigation ditches are designed with flat slopes and have limited carrying capacity, decreasing in the downstream direction. As a general rule, irrigation ditches cannot be used as an outfall point for the storm drainage system because of these physical limitations. In addition, certain ditches are abandoned after urbanization and, therefore, cannot be successfully utilized for storm drainage.

In certain instances, however, irrigation ditches have been successfully utilized as outfall points for the drainage system, but only after a thorough hydrological and hydraulic analysis. Since the owner’s liability from ditch failure increases with the acceptance of storm runoff, the responsibility must be clearly defined before a combined system is approved. Irrigation facilities shall not be utilized indiscriminately as drainage facilities and, therefore, policies have been established to achieve compatibility between urbanization and the irrigation facilities.

In general, stormwater runoff generated by urbanization or development shall be directed into historic flow paths and drainageways, thus avoiding discharging into irrigation canals or ditches, except as required by water rights. The engineer or developer shall coordinate with the ditch owner when specific site characteristics or circumstances present challenges relative to separation of irrigation and stormwater flow paths or conveyance facilities.

The engineer should perform an analysis to verify that an irrigation ditch does not intercept the storm runoff from the upper basin and that the upper basin remains tributary to the basin area downstream of the ditch.

Whenever new development or improvements will alter patterns of the storm drainage into irrigation ditches by increasing flow rate volumes, or changing points of concentration, the written consent from the ditch company shall be submitted with the development application. The discharge of runoff into the irrigation ditch shall be approved only if such discharge is consistent with an adopted master drainage plan.

3.3.2 Jurisdictional Dams and Reservoirs. Jurisdictional dams are classified by the State Engineer as low, moderate, or high hazard structures when, in the event of failure, there is a potential loss of life. Dams presently rated as low or moderate hazard structures may be changed to high hazard rating if development occurs within the potential path of flooding due to a dam breach. In this case, the reservoir owners would be liable for the cost of upgrading the structure to meet the higher hazard classification.

Pursuant to Section 37-87-123, CRS, as amended, the Office of the State Engineer has prepared flood hazard maps that predict potential results of a failure of the high hazard dams within the state. These reports have been made available to various cities, towns, and counties that may be affected by a dam breach. The following shall apply when development is proposed in the vicinity of dams or reservoirs:

- Development shall be restricted to areas outside of the reservoir's high water line, plus freeboard, created by the design flood for the emergency spillway.
- Development shall be restricted to areas outside of the high water line created by the breach of a dam (excepting high hazard classified dams which have passed inspection by the State Engineer's Office in accordance with *37-87-105 et seq CRS 1973*). For more information refer to the State Engineer's Office.
- Development shall be restricted to areas outside of the existing or potential spillway paths, beginning at the dam and proceeding to the point where the floodwater returns to the natural drainage course.

Due to the potential liabilities and regulatory and administrative requirements, the creation of jurisdictional dams is prohibited. The creation of a jurisdictional dam shall not be allowed, unless approval is granted through a formal variance request by the Town. Detention pond embankment heights shall be limited, and other elements of pond design shall be considered to avoid the creation of a jurisdictional dam.

3.3.3 Groundwater Investigations and subsurface collection systems. Groundwater can affect the function of stormwater management facilities, and other infrastructure. It is the geotechnical engineer's responsibility to perform investigations and analyses to quantify potential impacts and to develop designs, which mitigate any potential impacts from groundwater. Geotechnical investigations, groundwater data and recommendations regarding subsurface collection systems shall be discussed in the design.

There are also cases where groundwater or sub-surface flows seem to increase with development and urbanization. Foundation drains and sump pumps collect and discharge these flows to the surface. If quantities are excessive, icing and algae nuisances can result, which affect the quality of life of residents. Mitigation of these problems typically requires an additional collection system, which must ultimately discharge into the storm sewer system. Appropriate measures should be taken to ensure stormwater runoff does not surcharge the subsurface drainage collection system. There are likely many factors, including increased irrigation, introduction of non-native soils during grading operations, varying levels of compaction adjacent to structures, etc. that lead to excessive sub-surface flows being discharged to the surface.

Surfacing groundwater issues have been found to increase significantly with multi-lot drainage configurations and when ~~significant open space is allowed to drain through residential lots~~residential lots are placed in a cut slope at the base of a hill resulting in reduced design life of pavement and sidewalks. The design engineer shall take measures to ensure individual residential lots drain directly to the right-of-way wherever possible. Where multi-lot drainage configurations or where ~~significant open space drains to the right-of-way through residential lots~~residential lots are placed in a cut slope configuration at the base of a hill, installation of a sub-surface collection system and extension of required storm sewer facilities to allow for sub-surface drain connections are required along the receiving right-of-way line.

To the extent possible, efforts need to be made during the development process to identify potential problems and provide the appropriate mitigation so that the function of storm sewer facilities is not impacted in the future. The developer will be responsible for mitigation of groundwater impacts that arise during the warranty period of the development.

It is the developer’s responsibility to provide an appropriate analysis and discussion of potential groundwater impacts within the proposed development and address any potential impacts to surrounding properties.

3.4 Construction of Improvements

When Phase III Drainage Reports, Drainage Master Plans, or other applicable reports or studies identify public improvements that are necessary to properly manage stormwater runoff, mechanisms for funding the improvements are required. In accordance with the Regulations, subdividers or developers are required to construct, or guarantee to construct, stormwater management facilities that are necessary to serve the subdivision or development, which shall include improvements to convey off-site flows through the property, and participation in the stabilization or improvement of the major drainageway system within their property boundary. Public improvements typically consist of the Local Drainage System and the Major Drainageway System, as described in the remainder of this section.

3.4.1 Local Drainage System. The Local Drainage System, as defined by the Phase III Drainage Report and Plan, must be designed and constructed with all new development and redevelopment. The Local Drainage System consists of curb and gutter, inlets and storm sewers, culverts, bridges, swales, ditches, channels, detention facilities, and water quality control measures within the subdivision or development. The Local Drainage System also includes facilities required to convey the minor and major storm runoff to the Major Drainageway System and those facilities necessary to convey off-site flows across or through the developing property.

3.4.2 The Major Drainageway System. The Major Drainageway System consists of channels, storm sewers, bridges, culverts, detention facilities, and water quality Best Management Practices generally serving a tributary area of 130 acres or greater and in many cases, more than one subdivision or development. The Major Drainageway System within the development, as defined by master drainage plans or as required by the Town and defined in the Phase III Drainage Report and Plan, must be designed and constructed with all new development and redevelopment.

3.4.3 Drainageway Improvements. It is recognized that the development of a property which is directly adjacent to a drainageway may require the design and construction of drainageway improvements. The drainageway improvements may be master planned, or may require the preparation of a detailed analysis by the developer. It is the responsibility of the developer’s engineer to design improvements that will ensure that the site and infrastructure to be constructed by the development will be protected from minor and major storm flows, flooding, and from channel degradation and bank erosion.

3.5 Stormwater Facility Maintenance

Stormwater management facilities must be properly maintained to function as designed. The Town will require that all stormwater management facilities be designed to minimize facility maintenance as well as to provide adequate maintenance access. Routine maintenance of facilities may include removal of debris and sediment, trash rack clearing, mowing, noxious weed control, etc. Non-routine restorative maintenance activities include repairs to, or replacement of, structures and other improvements necessary to retain the effectiveness of the system. Such tasks are necessary to preclude the facility from becoming unhealthy and to avoid reduced conveyance capability, unsightliness, and malfunction. Operation and Maintenance must be addressed and documented with the final design of stormwater management facilities. Additional information regarding Operation and Maintenance can be found in Section 4.6.

3.5.1 Maintenance Responsibility. Maintenance responsibility lies with the owner of the land, except as modified by specific agreement. Maintenance responsibility shall be defined on Final Plats and Final Development Plans. The property owner or designee shall be responsible for the maintenance of all drainage facilities including inlets, pipes, culverts, channels, ditches, hydraulic structures, and detention basins located on their land unless modified by specific agreement. Maintenance access for all facilities must be adequate for the anticipated maintenance vehicles and equipment and should be shown on the Final Plats and Final Development Plans. The Operation and Maintenance section in the Phase III Drainage Report, as described in Section 4.6, shall define those entities responsible for the maintenance and management of stormwater facilities. If the property owner fails to maintain a facility, the Town has the right to complete maintenance and charge the owner at 1.25 times the cost of maintenance.

3.5.2 Easements. Drainage easements are required in order to ensure for the proper construction, maintenance, and access to drainage improvements that have the potential to affect the public drainage system and other properties. Drainage easements shall be granted to the Town for inspection and maintenance purposes, and shall be shown on the Drainage Plan, Final Plat and Site Improvement Plan, as applicable. The drainage easement shall state that the Town has the right of access on the easements for inspection and maintenance purposes. In general, easements are required for detention or retention ponds, water quality enhancement ponds and other control measure facilities, storm sewers, swales, channels, parking lot areas that convey runoff from adjacent properties (blanket type easements), major drainageways, and floodplains. Easement requirements are specific to the type of stormwater management facility and are discussed in more detail in later chapters.

3.5.3 Operation and Maintenance. Long-term operation and maintenance of all permanent stormwater facilities is required to ensure that they remain functional as designed. Operation and maintenance guidance documents have been developed by the Town and made available on the Town's website for commonly used facilities. The purpose of these documents is to provide guidance and standard forms for those entities that will be responsible for the long-term inspection and maintenance of the facility. For more information refer to Section 4.6.

3.5.4 ~~**Easements on Residential Lots.** It is recognized that there are certain liabilities and responsibilities associated with the ownership and maintenance of drainage facilities within drainage easements. It is undesirable to assign this responsibility/liability to single family lots with individual ownership. An exception shall be provided for the drainage of the individual lot, or a maximum of two adjacent lots. The Town's regulation shall be to require that in residential areas, drainage easements that convey flows from the subdivision, be allowed only on areas that are within a common ownership, such as an HOA, or a similar approved entity. Drainage easements are allowed at a width of ten to twenty feet centered along residential lot lines. Swales placed within these easements may only accept a limited amount of drainage from no more than two upstream residential lots such that no more than one and a half times the downstream lot size drains to the swale. In areas where more than two upstream lots are draining to a swale located at a residential lot line, a tract is required which is owned by a homeowners association, district, or other appropriate entity. A drainage easement shall be provided on the tract for drainage facilities.~~

Drainage Easements on Residential Lots. Drainage Easements on residential lots are prohibited. It is recognized that there are certain liabilities and responsibilities associated with the ownership and maintenance of drainage facilities within drainage easements. It is undesirable to assign this responsibility/liability to single family lots with individual ownership. The Town's regulation shall be to require that in residential areas, drainage facilities that convey flows from the subdivision, be allowed only in areas that are within a common ownership, such as a Homeowner Association, Metropolitan District, or a similar approved entity. An exception shall be provided for the drainage of the individual lot and a minor amount of off-site drainage. Swales placed within residential lots may only accept a limited amount of drainage such that no more than one and a half times the downstream lot size drains to the swale. In areas where more than one and a half times the downstream lot size drain to a residential lot or where lots are within the designated emergency overflow path of a sump inlet or detention facility, the major storm discharge shall be captured in a drainage facility within a privately owned tract to divert drainage away from the lot. A drainage easement shall be provided on the tract for drainage facilities.

There are certain circumstances where drainage easements are required on residential lots for storm drainage infrastructure such as storm sewers, drainage channels or detention ponds. This will only be considered in extreme circumstances when it has been demonstrated that no other alternatives exist to place improvements in a drainage tract or public right-of-way.

4.0 Introduction

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

4.1 Review Process

4.1.1 Drainage Report Requirements. Drainage Report submittal requirements related to the type of development or land use proposals are generally outlined in Table 4-1. One paper or electronic copy of the Drainage Report shall be submitted for all proposals. In any case, additional copies of the Drainage Report may be requested by the Town. The report shall include a cover letter stating the type of report submitted (e.g., Master, Phase I, Phase II, or Phase III) and for what purpose the report has been prepared. Templates for the Phase I, Phase II and Phase III Drainage Reports can be found on the Town's website at CRgov.com/codecentral. Checklists are required with every Drainage Report submittal; see Section 4.4.5 of these Criteria for additional information regarding checklists.

4.1.2 Stand-Alone Document. The Drainage Report shall be a stand-alone document. When references are made or assumptions are based on previously submitted studies or 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 in all new reports. All submitted reports shall be legible. If reports are unreadable, resubmittal of readable copies shall be required.

4.1.3 Submittal Adequacy. Submittals with incomplete or absent information shall result in the report being returned to the author without review. The Town reserves the right to require additional information with any submittal.

4.1.4 Pre-application Consultation. A pre-application consultation with Development Services Staff is required for all applicants undertaking any land development processing steps presented either herein or in the Regulations. The applicant shall consult with the Town for general information regarding the Regulations, required procedures, possible drainage problems, and specific submittal requirements.

4.1.5 Review by Referral Agencies. The review and approval by other agencies such as State or Federal agencies, 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.

TABLE 4-1
DRAINAGE REPORT SUBMITTAL REQUIREMENTS

SUBMITTAL TYPE	DRAINAGE SUBMITTAL REQUIREMENTS
Annexation, Planned Development Plan or Straight Zoning	Phase I Drainage Report and Flood Hazard Area Delineation Study, if applicable
Site Development Plan	Phase II Drainage Report and Preliminary Floodplain Modification Study, if applicable.
Construction Documents	Phase III Drainage Report and Final Floodplain Modification Study, if applicable.

NOTE: The Drainage Report submittal requirements as outlined in this Table are general guidelines and do not represent all circumstances under which specific drainage submittals may be required. Prior to submittal, the applicant shall consult with Development Services and Castle Rock Water for submittal requirements regarding applications or processes not addressed in this Table.

4.2 Acceptance

4.2.1 Phase III Drainage Report Acceptance Required for Construction. The acceptance of a Phase III Drainage Report and construction drawings must be obtained prior to construction of any drainage improvements within the Town. Phase I and Phase II drainage studies are conceptual and are reviewed by the Town, but cannot be used for construction.

4.2.2 Post-Construction Control Measures Plan Required Prior to Land Disturbance. A Phase II Drainage Report and Plan, as outlined in Section 4.4, must be reviewed and accepted by the Town prior to the issuance of a TESC Permit for land disturbance activities associated with a Construction Permit for early grading. This requirement will not apply to proposed land disturbance activities or projects where post construction water quality enhancement control measures are not required, as described in Chapter 14 Stormwater Quality, or as determined by the Town.

4.2.3 One Year Acceptance for Phase III Drainage Reports. Phase III Drainage Reports will be valid for one year from the date of Town acceptance. If the improvements on the construction drawings have not been constructed and accepted by the Town, or extended in conformance with the Town of Castle Rock Municipal Code, within one year of the Drainage Report acceptance, the Phase III Drainage Report must be submitted for re-acceptance. In order to be re-accepted, it must be demonstrated that the concepts, designs, and calculations presented in the report are consistent with current Town criteria and standards. If new concepts, criteria, or standards have been adopted since the Drainage Report was accepted and then expired, submittal of an updated Phase III Drainage Report will be required. The updated Phase III Drainage Report must be accepted by the Town and that report will provide the foundation for development of the construction drawings. Phase I, Phase II, and Master Plan of

Drainage studies are not formally accepted, and therefore not affected by the one year acceptance period.

4.3 Phase I Drainage Report and Plan

4.3.1 Requirement for Phase I Drainage Report and Plan Submittal. Submittal of a Phase I Drainage Report and Plan is required with specific development or land use proposals, as generally outlined in Table 4-1. The Phase I report will describe, at a conceptual level, the feasibility and design characteristics of stormwater management facilities within the proposed development. The Phase I report shall be prepared on 8½" x 11" paper and bound. The drawings, figures, and tables shall be bound with the report or included in a pocket attached to the report. The report shall include a cover letter presenting the preliminary design for review, shall be certified by a Professional Engineer licensed in Colorado, and shall be in accordance with the information presented in the following section.

4.3.2 Report Contents. The following is an outline of the **minimum** Phase I Drainage Report requirements:

I. COVER SHEET

A. Name of Project
B. Address
C. Owner
D. Developer
E. Engineer
F. Submittal date and revision dates as applicable

II. GENERAL LOCATION AND DESCRIPTION

A. Site Location
1. Site Vicinity Map
2. Township, Range, Section, and ¼ Section
3. Streets, Roadways, and Highways adjacent to the proposed development, or within the area served by the proposed drainage improvements
4. Names of surrounding or adjacent developments

B. Description of Property
1. Area in Acres
2. Ground cover, vegetation, site topography and slopes
3. Natural Resources Conservation Service (NRCS) Soils Classification Map and discussion
4. Major and minor drainageways
5. Floodplains delineated by Town FHAD Studies or on FEMA FIRM Maps
6. Existing irrigation canals or ditches
7. Significant geologic features

8. Proposed land use

III. DRAINAGE BASINS AND SUB-BASINS

A. Major Drainage Basins
1. On-site and off-site major drainage basin characteristics and flow patterns and paths
2. Existing and proposed land uses within the basin if known
3. Reference all drainageway planning or floodplain delineation studies that affect the major drainageways, such as FHAD Studies and Master Planning Studies
4. Discussion of the impacts of the off-site flow patterns and paths, under fully developed conditions

B. Minor Drainage Basins
1. On-site and off-site minor drainage basin characteristics and flow patterns and paths
2. Existing and proposed land uses within the basins
3. Discussion of the impacts of the off-site flow patterns and paths, under fully developed conditions

IV. EXISTING STORMWATER CONVEYANCE OR STORAGE FACILITIES

A. Existing Stormwater Conveyance Facilities
1. Existing conveyance facilities that will be incorporated into the design
2. Existing conveyance facilities that will be incorporated into the design with modifications
3. Existing conveyance facilities that will be rebuilt or abandoned

B. Existing Stormwater Quality and Storage Facilities
1. Existing water quality and storage facilities that will be incorporated into the design
2. Existing water quality and storage facilities that will be incorporated into the design with modification
3. Existing water quality and storage facilities that will be rebuilt or abandoned

V. PROPOSED STORMWATER CONVEYANCE OR STORAGE FACILITIES

A. Proposed Stormwater Conveyance Facilities
1. Discussion of proposed conveyance facilities and design concept
2. Conceptual plan for conveyance of off-site runoff
3. Discuss the content of any pertinent tables, charts, figures, graphs, drawings, etc. that are presented in the report

4. Discussion of anticipated conveyance problems and potential solutions
5. Discuss the ownership, maintenance and access aspects of the design

B. Proposed Stormwater Storage Facilities
1. Discuss design approach for detention including regional, sub-regional or on-site facilities
2. Detention storage locations and conceptual outlet structure design
3. Discuss anticipated storage problems and potential solutions
4. Discuss the ownership, maintenance and access aspects of the design

VI. WATER QUALITY ENHANCEMENT CONTROL MEASURES

A. Project approach for achieving the four-step process for water quality best management practices
1. Reducing runoff volume
2. Providing WQCV or equivalent and flood control
3. Utilizing stream stabilization techniques
4. Undertaking source control

B. Discuss the ownership, maintenance, and access aspects of the design

VII. FLOODPLAIN MODIFICATIONS – (For additional information on floodplain modification, see Chapter 5.)

A. Major Drainageway – Undesignated Floodplain
1. Submit Flood Hazard Area Delineation Study, including floodplain delineation and base flood elevations. Study shall assume fully developed peak flow hydrology on existing topography.
2. Discuss potential modifications of existing major drainageway floodplains
3. Discuss why the floodplain modifications are proposed

B. Major Drainageway – Designated Floodplain
1. Discuss potential modifications of existing major drainageway floodplains that have a designated floodplain
2. Discuss the source of the floodplain information and level of detail (Flood Hazard Area Delineation or FEMA Flood Insurance Rate Maps)
3. Discuss why the floodplain modifications are proposed
4. Discuss Conditional Letter of Map Revision (CLOMR) and Letter of Map Revision (LOMR) requirements
5. Discuss Town floodplain development regulations

VIII. MASTER PLAN RECOMMENDATIONS

Provide reference to adopted drainageway master plans and discuss the proposed project improvements based on recommendations of the master plan.

IX. POTENTIAL PERMITTING REQUIREMENTS

Identify other potential local, State and Federal permitting requirements.

X. REFERENCES

Reference all criteria, master plans, reports, or other technical information used in development of the concepts discussed in the Drainage Report.

XI. APPENDICES

Provide copies of all pertinent information from referenced materials.

4.3.3 Phase I Drainage Plan Requirements. The following is an outline of the **minimum** Phase I drainage plan requirements. All plans must be bound.

I. OVERALL DRAINAGE PLAN

A. 24”x36” or 22”x34” are acceptable plan sizes
B. Title block and legend
C. Existing or proposed streets, roadways, or highways
D. Show the limits of all major basins, including off-site basins where feasible
E. General drainage patterns and flow paths, including those entering and leaving the site
F. Topographic information with a five-foot maximum contour interval
G. Identify existing stormwater management facilities, upstream, downstream, or within the site, which will provide a stormwater management function for the site
H. Overlay or figure showing layout of detailed drainage plan sheets if more than one detail drainage plan sheet is required

II. DETAILED DRAINAGE PLANS

A. 24”x36” or “22”x34” are acceptable plan sizes
B. Title block and legend
C. Scale 1”=20’ to 1”=100’, as required to show sufficient detail
D. Existing topographic contours with a five-foot maximum contour interval
E. Existing stormwater conveyance or storage facilities
F. Floodplain limits, based on available information
G. Major drainage basin boundaries

H. Conceptual locations of stormwater conveyance or storage facilities, including detention ponds, water quality enhancement features, storm sewers, culverts, swales, etc., consistent with the proposed development plan
I. Proposed flow directions
J. Proposed contours, if they are available

4.4 Phase II Drainage Report and Plan

4.4.1 Requirement for Phase II Drainage Report and Plan Submittal. Submittal of a Phase II Drainage Report and Plan is required with specific development or land use proposals, as generally outlined in Table 4-1. The purpose of the Phase II Drainage Report is to identify and refine conceptual stormwater management solutions to the challenges that may be present or occur on-site and off-site. All reports shall be prepared on 8-1/2"x11" paper and shall be bound. The drawings, figures, and tables shall be bound with the report or included in a pocket attached to the report. The report shall include a cover letter presenting the preliminary design for review and shall be certified by a Professional Engineer licensed in Colorado.

4.4.2 Report Contents. The Phase II Drainage Report generally consists of a narrative portion and appendices with supporting calculations and other pertinent information. The narrative shall lead the reader logically through the entire analysis and design process and provide a clear picture of all stormwater management issues. The narrative portion shall provide detailed discussion regarding the general location and description of the site, off-site and on-site drainage basins and sub-basins, drainage design criteria, stormwater management facility design, and conclusions, as provided in Sections III through VI of the outline presented in this section. Discussion of methodology, assumptions, input, and a summary of results shall be provided in the narrative for all hydrologic or hydraulic modeling efforts. Peak flow rates, storage volumes, critical water surface elevations, and stormwater management facility sizes shall also be summarized or discussed in the report narrative. The appendices must provide the appropriate backup information and calculations, but the reader should not have to review information contained in the appendices to have a clear and thorough understanding of the project and the stormwater management analysis and facility designs.

The following is an outline of the **minimum** Phase II Drainage Report requirements:

I. COVER SHEET

A. Name of Project
B. Address
C. Owner
D. Developer
E. Engineer

F. Submittal date and revision dates as applicable

II. GENERAL LOCATION AND DESCRIPTION

A. Site Location
1. Site Vicinity Map
2. Township, Range, Section, and ¼ Section
3. Existing and proposed streets, roadways, and highways adjacent to and within the proposed development, or within the area served by the proposed drainage improvements
4. Names of surrounding or adjacent developments, including land use or zoning information

B. Description of Property
1. Area in Acres
2. Ground cover, vegetation, site topography and slopes
3. NRCS Soils Classification Map and discussion
4. Major and minor drainageways
5. Floodplains delineated by FHAD studies or on FEMA FIRM Maps
6. Existing irrigation canals or ditches
7. Significant geologic features
8. Proposed land use

III. DRAINAGE BASINS AND SUB-BASINS

A. Major Drainage Basins
1. On-site and off-site major drainage basin characteristics and flow patterns and paths
2. Existing and proposed land uses within the basins if known
3. Discussion of all drainageway planning or floodplain delineation studies that affect the major drainageways, such as FHAD Studies and Master Planning studies
4. Discussion of the condition of any channel within or adjacent to the development, including existing conditions, need for improvements, and impact on the proposed development
5. Discussion of the impacts of the off-site flow patterns and paths, under fully developed conditions

B. Minor Drainage Basins
1. On-site and off-site minor drainage basin characteristics and flow patterns and paths under historic and developed conditions
2. Existing and proposed land uses within the basins
3. Discussion of irrigation facilities that will influence or be impacted by the site drainage
4. Discussion of the impacts of the off-site flow patterns and paths, under fully developed conditions

IV. DRAINAGE DESIGN CRITERIA

A. Regulations
1. Town criteria and optional provisions selected, when applicable
2. ~~UDFCD Manual~~MHFD Manual criteria and optional provisions selected, when applicable

B. Drainage Studies, Master Plans, Site Constraints
1. Discuss previous drainage studies or master plans for the site or project that influence the stormwater facility design
2. Discuss drainage studies for adjacent developments and how those developments affect the stormwater facility design
3. Discuss Town Master Plans and how recommendations in those studies affect the design
4. Discuss impacts to stormwater management facility design caused by site constraints, such as streets, utilities, existing structures, downstream infrastructure, etc.

C. Hydrology
1. Runoff calculation method(s)
2. Design storm recurrence intervals
3. Design rainfall
4. Detention storage calculation method(s)
5. Detention storage release rate calculation method

D. Hydraulics
1. Methods used to determine conveyance facility capacities
2. Hydraulic grade line calculation method and discussion of loss coefficients
3. Methods used to calculate water surface profiles
4. Detention pond routing

E. Storage and Water Quality Enhancement
1. Discuss approach used for detention including regional, sub-regional or on-site facilities
2. Discuss approach for achieving the four step process including runoff volume reduction, WQCV or equivalent, stream stabilization and source control

V. STORMWATER MANAGEMENT FACILITY DESIGN

A. Stormwater Conveyance Facilities
1. Discuss general conveyance concepts
2. Discuss proposed drainage paths and patterns
3. Discuss storm sewer design, including inlet and pipe locations and sizes, tributary basins and areas, peak flow rates at design points, hydraulic grade lines, sump inlet ponding depths, emergency overflow routes, etc.

4. Discuss storm sewer outfall locations and design, including method of energy dissipation
5. Discuss how runoff is conveyed from all outfalls to the nearest major drainageway, including a discussion of the flow path, capacity, and stability downstream of the outfall to the nearest major drainageway, and any improvements that are necessary
6. Discuss open channel and swale designs, including dimensions, alignments, tributary basins and areas, peak flow rates at design points, stabilization and grade control improvements, low flow or trickle channel capacities, water surface elevations, freeboard, etc.
7. Discuss allowable street capacities and adjacent grading requirements to maintain flow within the right-of-way, including street cross sections reflecting minimum high points adjacent to roadway.
8. Discuss maintenance aspects of the design and easements and tracts that are required for stormwater conveyance purposes
9. Discussion of the facilities needed off-site for the conveyance of minor and major flows to the major drainageway
10. Discuss lot-to-lot drainage assumptions and plan in detail as it relates to the overall grading of the site; include maximum flow conveyed between houses

B. Stormwater Storage Facilities
1. Discuss detention pond designs; including release rates, storage volumes and water surface elevations for the two-year, 100-year and emergency overflow ~~conditions~~routing, outlet structure design, emergency spillway design, etc.
2. Discuss pond outfall locations and design, including method of energy dissipation
3. Discuss how runoff is conveyed from all pond outfalls and emergency ~~spillways~~ overflow routes of inlets and ponds to the nearest major drainageway, including a discussion of the flow path, capacity and stability downstream of the outfall to the nearest major drainageway
4. Demonstrate compliance with water right exemption status.
5. Discuss maintenance aspects of the design and easements and tracts that are required for stormwater storage purposes

C. Water Quality Enhancement Control Measures
1. Itemize and discuss the design of all structural and non-structural water quality control measures associated with the four-step process, including type, location, tributary areas, sizing, treatment volumes, design features, etc. Each step shall be listed and discussed separately in the report.
2. Discuss how runoff is conveyed from all pond outfalls to the nearest major drainageway, including a discussion of the flow

path, capacity and stability downstream of the outfall to the nearest major drainageway

3. Discuss the operation and maintenance aspects of the design and easements and tracts that are required for stormwater quality enhancement purposes

D. Floodplain Modification
   1. Discuss why the floodplain modifications are proposed
   2. Discuss the source of the floodplain information and level of detail (Flood Hazard Area Delineation or FEMA Flood Insurance Rate Maps)
   3. Discuss details of floodplain modifications, including level of encroachment, velocities, depths, stabilization measures, water surface elevations, etc.
   4. Discuss Conditional Letter of Map Revision (CLOMR) and Letter of Map Revision (LOMR) requirements
   5. Discuss Town floodplain development regulations
   6. Submit Preliminary Floodplain Modification Study following the outline in Section 5.6.3

E. Geotechnical Investigation and Sub-surface Collection System Design
   1. Discuss results of geotechnical investigations, groundwater table measurements and recommendations for groundwater mitigation measures.
   2. Identify areas where lot-to-lot drainage occurs and sub-surface collection systems to mitigate for right-of-way impacts.

F. Operation and Maintenance
   1. Identify the responsible party for operation and maintenance of water quality enhancement control measures and stormwater management facilities.
   2. Discuss maintenance requirements and information to ensure the long-term operation of water quality enhancement control measures and other stormwater management facilities (see Section 4.6).
   3. Identify frequencies for operator inspections and routine and non-routine maintenance activities.

G. Additional Permitting Requirements
   1. Section 404 of the Clean Water Act
   2. The Endangered Species Act
   3. Other local, state, or federal requirements

H. General
   1. Discuss all tables, figures, charts, drawings, etc. that were used in design of stormwater management facilities and describe materials that are included in the appendix of the report

VI. CONCLUSIONS

A. Compliance with Standards
1. Town of Castle Rock Criteria
2. Master Plans
3. Cherry Creek Reservoir Control Regulation No. 72
4. Chatfield Reservoir Control Regulation No. 73

B. Variances
1. Identify provisions by section number for which a variance will be requested, or has been approved by the Town (final version of Drainage Report). Additional information on variances is available in Chapter 1, General Provisions
2. Provide justification for each variance request

C. Drainage Concept
1. Discuss overall effectiveness of stormwater management design to properly convey, store and treat stormwater

VII. REFERENCES

Reference all criteria, master plans, reports or other technical information used in development of the concepts discussed in the Drainage Report

VIII. APPENDICES

A. Hydrologic Computations
1. Determination of runoff coefficients and times of concentration
2. Land use assumptions for off-site areas
3. Colorado Urban Hydrograph Procedure input parameter determination
4. SWMM input parameter determination
5. Peak flow rate calculations for the minor and major storms
6. Rainfall information
7. CUHP/SWMM input and output
8. Hydrograph data (if applicable)
9. Connectivity diagram showing relationship/connectivity of basins, conveyance facilities, detention ponds, and design points

B. Hydraulic Computations
1. Culvert capacities
2. Storm sewer capacities and hydraulic grade lines, including the loss coefficients
3. Street capacities
4. Inlet capacities
5. Open channel or swale capacities
6. Low flow and trickle channels
7. Stabilization and grade control improvements

8. Water surface profiles
9. Stage-storage-discharge determination for detention ponds
10. Detention pond routing calculations
11. Emergency spillway sizing calculations
~~11.~~12. Emergency overflow routing calculations
~~12.~~13. Downstream/outfall capacity to the nearest major drainageway
~~13.~~14. Energy dissipation at pipe outfalls

C. Water Quality Enhancement Control measures
1. Design and sizing

D. Referenced Information
1. Copies of pertinent portions of all referenced materials or drainage reports

Note: Hydraulic computations will be required with the Phase II Drainage Report if the information necessary to perform the calculations is available. Availability of information will be determined by the Castle Rock Water staff, based on the level of detail contained in the application submitted to Development Services. Regardless of present availability, all hydraulic computations will be required in the Phase III Drainage Report.

4.4.3 Certification Statement. The report shall contain a certification page with the following statement:

"I affirm that this report and plan for the Phase II drainage design of (Name of Development) was prepared by me (or under my direct supervision) in accordance with the provisions of the Town of Castle Rock Drainage Design and Technical Criteria for the owners thereof. I understand that the Town of Castle Rock does not and will not assume liability for drainage facilities designed by others."

SIGNATURE: ______________________________
Registered Professional Engineer State
Of Colorado No. ______________
(Affix Seal)

4.4.4 Standard Forms. Use appropriate copies of the Town's Standard Forms and ~~UDFCD~~MHFD Design Spreadsheets applicable to the design. When using Town and ~~UDFCD~~MHFD standard forms, charts, nomographs, etc., the form must be annotated as necessary to depict the specific information pertinent to the site. The engineer is required to show the appropriate information relative to the design and provide the lines, notes, etc. to depict how the design information was arrived at. For example, when using street gutter capacity charts, a separate chart for each street section shall be submitted, with the specific street criteria highlighted and the final result circled. Forms that are copied out of the book without the appropriate annotations are not adequate.

4.4.5 Checklists. Design or report checklists as referenced in the individual sections of this manual, and as available on the Town of Castle Rock website (CRgov.com/codecentral), must be completed and submitted with the Drainage Report. Appropriate notations shall be provided with the checklist to assist the reviewer in determining whether the design is complete (i.e., if a specific item is not addressed, an explanation should be provided). All design or report checklists that have been developed will be available on the Town of Castle Rock website. New and/or revised checklists will be added as they are developed.

4.4.6 Phase II Drainage Plan Requirements. The following is an outline of the **minimum** Phase II drainage plan requirements. All plans must be bound:

I. OVERALL DRAINAGE PLAN

A. 24” x 36” or 22” x 34” are acceptable size
B. Title block and legend
C. Show boundaries of entire development or project
D. Existing or proposed streets, roadways, or highways
E. Show limits of all major basins, including off-site basins where feasible
F. General drainage patterns and flow paths, including those entering and leaving the site
G. Topographic information with a five-foot maximum contour interval
H. Identify existing and proposed stormwater management facilities, upstream, downstream, or within the site, which will provide a stormwater management function for the site
I. Overlay or figure showing layout of Detailed Drainage Plan sheets

II. DETAILED DRAINAGE PLANS

A. 24” x 36” or 22” x 34” are acceptable sizes
B. Title block and legend
C. Basin designations, design points, flow rates, volumes and release rates
D. Scale 1”=20’ to 1”=100’, as required to show sufficient detail
E. Existing (dashed or screened) and proposed (solid) contours with a two-foot maximum contour interval. In terrain where the slope exceeds fifteen percent, the maximum interval is five-feet. Contours must extend a minimum of 100 feet beyond property lines and contour elevation labels must be included
F. Existing utilities and structures
G. All property lines and easements with type of easements noted
H. Adjacent developments or ownerships
I. Streets and roadways with right-of-way and flow line widths, type of curb and gutter or roadside swale, slopes, flow directions, and crosspans
J. Drainage basin and sub-basin limits

K. Existing and proposed stormwater management facilities, including irrigation ditches, roadside swales, open channels and drainageways, storm sewer, culverts, detention ponds, water quality enhancement structures or features, etc. Information must be included regarding materials, sizes, shapes, and slopes; also include detailed lot-to-lot drainage patterns with flow direction arrows

~~K.~~L. Detailed emergency overflow routing alignments for detention facilities and sump inlets

~~L.~~M. Proposed outfall points and existing or proposed facilities to convey runoff to the nearest major drainageway, without damage to downstream properties

~~M.~~N. Location and elevation of all existing and proposed 100-year floodplain boundaries, including the source of designation. All floodplain designations that exist for the site should be included (i.e. FEMA Flood Insurance Rate Maps, Flood Hazard Area Delineation, and others)

~~N.~~O. Summary runoff table

NOTE: The items listed above will be required with the Phase II Drainage Report or a written explanation as to why information cannot be provided.

4.4.7 Master Plan of Drainage. The Town of Castle Rock Subdivision Resolution makes reference to a Master Plan of Drainage in the Sketch Plat and Preliminary Plat discussion regarding procedures and submittal requirements, and that is reflected in Table 4-1. The Master Plan of Drainage shall be considered equivalent to a Phase I Drainage Report for the Sketch Plat and Preliminary Plat submittals, respectively, and must meet those minimum requirements.

4.5 Phase III Drainage Report and Plan

4.5.1 Requirement for Phase III Drainage Report and Plan Submittal. The purpose of the Phase III Drainage Report is to update the concepts, and to present the design details on construction plans for the drainage facilities discussed in the Phase II Drainage Report. Also, any change to the Phase II concept must be presented. All reports shall be typed on 8½" x 11" paper and bound. The drawings, figures, charts and/or tables shall be bound with the report or included in a folder/pocket attached at the back of the report.

4.5.2 Report Contents. The Phase III Drainage Report shall be prepared in accordance with the outline shown in Section 4.4.2.

4.5.3 Certification Statement. The report shall be prepared by or under the direction of an engineer licensed in Colorado, certified as shown below. The report shall also contain a developer certification sheet as follows:

"I affirm that this report and plan for the Phase III drainage design of (Name of Development) was prepared by me (or under my direct supervision) in accordance with the provisions of the Town of Castle Rock Drainage Design and

Technical Criteria for the owners thereof. I understand that the Town of Castle Rock does not and will not assume liability for drainage facilities designed by others."

SIGNATURE: ________________________________
Registered Professional Engineer State
Of Colorado No. ______________
(Affix Seal)

"(Name of Developer) hereby certifies that the drainage facilities for (Name of Development) shall be constructed according to the design presented in this report. I understand that the Town of Castle Rock does not and will not assume liability for the drainage facilities designed and/or certified by my engineer and that the Town of Castle Rock reviews drainage plans pursuant to the Municipal Code; but cannot, on behalf of (Name of Development), guarantee that final drainage design review will absolve (Name of Developer) and/or their successors and/or assigns of future liability for improper design."

____
Name of Developer

____
Authorized Signature

4.5.4 Phase III Drainage Plan Requirements. The report drawings shall follow the requirements presented in Section 4.5.4.

4.6 Stormwater Management Facility Operation and Maintenance

4.6.1 Stormwater Management Facility Operation and Maintenance Requirements. Detention ponds, open channels, post-construction water quality control measures, and other stormwater management facilities require proper maintenance in order to ensure that they function as designed. Operation and maintenance factors must be considered and documented in the Phase III Drainage Report to educate and provide guidance for those entities that will be responsible for the maintenance of the stormwater management facilities. Maintenance and repair costs, life cycle expectancy and landscape guidelines may also be relevant information depending on the type of facility.

4.6.2 Operation and Maintenance Guidelines. The Town has developed a standard guidance document for the operation and maintenance of stormwater management facilities for use by engineers and entities that are responsible for developing and implementing long-term maintenance plans. This document provides general guidelines for developing a maintenance program and outlines Town regulations that govern long-term operation of stormwater facilities.

4.6.3 Standard Operating Procedures. The Town has developed Standard Operating Procedure templates for certain types of stormwater management facilities that provide detailed information regarding the critical components and guidelines for determining maintenance action of each facility. It's the design engineer's responsibility to document specific facility maintenance requirements based on the nature of the infrastructure.

The O&M guidance document and facility-specific Standard Operating Procedures are available on the Town of Castle Rock website at CRgov.com/stormwater.

4.6.4 Operation and Maintenance Procedures. The design engineer shall document operation and maintenance procedures to ensure the long-term observation, maintenance and operation of stormwater management facilities in the Phase III Drainage Report. The documentation shall include frequencies for routine inspections and routine and non-routine maintenance activities.

4.7 Construction Drawings

4.7.1 Stormwater Management Improvements. Stormwater management improvements within the public right-of-way or easements are required to be designed, constructed, and accepted in accordance with Town standards and criteria. Construction drawings must be developed for all stormwater management improvements and submitted to the Town for review. Town acceptance of final construction drawings is a condition for issuance of construction permits.

4.7.2 Construction Plan Submittal. Detailed information regarding construction drawing submittal procedures is provided in the Town of Castle Rock Development Procedures Manual.

4.7.3 Construction Plan Requirements. In general, the information required for stormwater management facility construction drawings shall be in accordance with sound engineering principles, Town of Castle Rock Criteria and the Town requirements for subdivision design and stormwater quality control measures sample drawings. Construction drawings shall include geometric, dimensional, structural, foundation, bedding, hydraulic, landscaping, and other details as needed to construct the stormwater management facilities. Detailed information regarding construction drawing requirements and certification is provided in the Town of Castle Rock Development Procedures Manual.

4.8 Record Drawings

All stormwater improvements that have been constructed within the Town right-of-way and stormwater easements must be accepted by the Town. The Town's acceptance process verifies that the improvements have been constructed in accordance with the requirements.

4.8.1 Record Drawing Requirements. Record drawings, including the required "Statements of Substantial Completion" by the Project Engineer and Surveyor shall be submitted in accordance with Town of Castle Rock Criteria and

Regulations. Additional details regarding the submittal of record drawings are provided in the Town of Castle Rock Development Procedures Manual.

4.8.2 Pond Volume Certification. A pond volume certification letter is required for all water quality capture volume and flood control facilities. The engineer may choose to provide the pond volume certification and as-constructed volumes on the record drawings in lieu of a letter. The certification shall be prepared by a registered professional engineer that demonstrates the as-constructed volume(s) meet or exceed the required design volume(s) for WQCV, EURV, and 100-year detention, as applicable. The letter shall include the following statement:

> "I hereby certify that the stormwater management facility identified above meets or exceeds the design requirements as approved in the Phase III Drainage Report for [project name and construction permit number]. I understand that the Town of Castle Rock does not and will not assume liability for drainage facilities designed, constructed and/or certified by others."

SIGNATURE:______________________________
Registered Professional Engineer State of Colorado No. ________________
(Affix Seal)

5.0 Introduction

This chapter summarizes the Town's rules and regulations regarding floodplain management and development. The requirements presented in this chapter should be used by the design engineer or applicant to determine the appropriate procedures, regulations, and limitations for development within the limits of a floodplain.

5.0.1 Floodplain Philosophy. Nature has claimed a prescriptive easement for floods, via its floodplains, that cannot be denied without public and private cost (White 1945). Flooding can result in loss of life, increased threats to public health and safety, damage to public and private property, damage to public infrastructure and utilities, and economic impacts to the residents of the Town. In contrast, natural floodplains provide many benefits to the citizens of the Town, including natural attenuation of flood peaks, water quality enhancement, groundwater recharge, wildlife habitat and movement corridors, and opportunities for recreation.

5.1 Floodplain Management and Regulation

Title 18 of the Town of Castle Rock Municipal Code contains the Floodplain Regulations for the Town, as discussed in Section 5.1.6 of this chapter. The detailed requirements outlined in Title 18 of the Town of Castle Rock Municipal Code are not reproduced in this chapter.

5.1.1 Floodplain Management. Floodplain management is generally defined as a comprehensive program of preventative and corrective measures to reduce losses associated with flooding. Floodplain management measures may include, but are not limited to, land use regulations (including new development and construction policy), construction of flood control projects, flood-proofing, floodplain preservation, acquisition of flood prone properties, education, and implementation of early warning systems. These measures must be implemented in a consistent manner to be of value.

5.1.2 Standard Level of Protection. The standard of practice, as defined by the Federal Emergency Management Agency (FEMA) and the Town, requires implementation of floodplain management criteria within the 100-year floodplain, or area of special flood hazard. The 100-year floodplain is the land area that will be inundated or flooded, based on the stormwater runoff produced by the 100-year storm event. The 100-year storm event is defined as the rainfall event that has a one percent probability of being equaled or exceeded in any given year. Discharge flow rates in excess of the 100-year estimate will occur, but with lower probability. In those instances, typically the depth of flow and floodplain width would be greater than indicated on the floodplain maps provided by FEMA and the Town of Castle Rock.

5.1.3 Higher Level of Protection. In some cases, a higher level of protection should be provided for flooding events that are produced by storm events in excess of the 100-year storm event. A higher level of protection should be considered for facilities and access routes that are critical for the protection of public health, safety, and welfare, or where flooding in excess of the 100-year storm event flooding could result in loss of life, significant damage to utilities and infrastructure, or result in hazardous materials being transported in flood waters.

5.1.4 National Flood Insurance Program. The National Flood Insurance Program is a federal program enabling property owners to purchase insurance protection against losses from flooding. Participation in the National Flood Insurance Program is based on an agreement between local communities and the federal government, which states that if a community will implement and enforce measures to reduce future flood risks to new construction in Special Flood Hazard Areas or designated floodplains, the federal government will make flood insurance available within the community. In the past, the national response to flooding disasters was generally limited to constructing flood control projects and providing disaster relief to flood victims after a flood occurred. This did not reduce losses or discourage unwise development in flood prone areas. Additionally, the public could not buy flood coverage from insurance companies. Faced with mounting flood losses and escalating costs to the general taxpayers, Congress created the National Flood Insurance Program. The Town of Castle Rock entered the Regular Program of the National Flood Insurance Program in 1980 and the Town has agreed to adopt and enforce floodplain development regulations that meet or exceed the minimum outlined in 44 Code of Federal Regulations, Part 60. If the community does not enforce the regulations that have been adopted, that community can be put on probation or suspended from the program. If suspended, our community would become non-participating and flood insurance policies could not be written or renewed in the Town of Castle Rock.

5.1.5 Colorado Water Conservation Board. The Colorado Water Conservation Board is the State Coordinating Agency of the National Flood Insurance Program. The Flood Protection Program of the Colorado Water Conservation Board assists in the prevention of and recovery from flood disasters. The Colorado Water Conservation Board is responsible for technical review and approval of all reports and maps that are normally used by local governments for regulatory, floodplain administration, and insurance purposes. The Colorado Water Conservation Board review and approval process is officially known as floodplain designation. Designation and approval of the existing floodplain mapping enhances a community’s ability to regulate 100-year floodplains more effectively. State enabling law for local zoning and subdivision regulation requires that technical information used for regulation of flood-prone areas be designated and approved by the Colorado Water Conservation Board.

5.1.6 Floodplain Regulations. The floodplain development regulations that have been adopted by the Town are incorporated in the Town of Castle Rock Municipal Code, Title 18, Floodplain Regulations. The Floodplain Regulations are applied as supplemental regulations to existing zoned areas where potential flooding hazards have been identified. The regulations generally identify uses that are <u>permitted</u> within the Floodway District and the Floodway Fringe District, uses that are prohibited within the Floodway District and Floodway Fringe District, standards for development in flood prone areas, and it outlines the Floodplain Development Permit process. A Floodplain Development Permit is required for any change in land use or development proposed in the Floodway or Floodway Fringe District. Title 18 of the Town of Castle Rock Municipal code defines development as “any man-made change to improved or un-improved real estate, including but not limited to buildings or other structures, mining, dredging, filling, grading, paving, excavation or drilling operations.” The Floodplain Development Permit is in addition to other required permits and shall be acquired prior to the issuance of any other Town permits, after the issuance of required State and Federal permits, and prior to approval of any construction drawings.

The Stormwater Manager or designated representative, administers and implements the Floodplain Development Permit process, provides review of technical information that is required to ensure compliance with the regulations, and makes determinations regarding the boundaries of the Floodway and Floodway Fringe Districts. The Stormwater Manager will evaluate the application and submittal information and approve the permit, approve the permit with conditions or deny the permit.

The boundaries of the Floodway District and Floodway Fringe District are generally defined by the Special Flood Hazard Areas shown on Flood Insurance Rate Maps (FIRMs), which are produced by FEMA, by the 100-year floodplain limits shown on Flood Hazard Area Delineation studies, produced by the Town, and other floodplain delineations or studies that have been approved for designation by the Colorado Water Conservation Board.

Requirements outlined in Title 18 of the Town of Castle Rock Municipal Code are enforced by the Director of Castle Rock Water or authorized representative. Failure to comply with the requirements of the Floodplain Regulations or the conditions of an approved Floodplain Development Permit is considered a violation of these Criteria.

5.1.7 Unstudied or Unmapped Floodplains. There are numerous channels and streams in the Town of Castle Rock that do not have FEMA-designated Special Flood Hazard Areas. The potential for loss of life and/or property along these streams exists, just as it does along those channels or streams where floodplain limits or Special Flood Hazard Areas have been identified. The Town of Castle Rock will regulate these unstudied floodplains in the same manner as those floodplains within a FEMA-designated Special Flood Hazard Area.

5.2 Sources of and Use of Existing Floodplain Information

5.2.1 FEMA Flood Insurance Rate Maps (FIRMs) and Flood Insurance Study. The FIRMs are generally based on existing watershed conditions at the time the engineering analyses and accompanying survey were completed. In addition, detailed contour mapping may not have been available or used in the preparation of the original FIRMs. The purpose of these maps is to identify flood prone areas, by approximate or more detailed methods, and to establish flood risk zones for insurance rate purposes, within those flood prone areas. Typically, the information provided on the FIRMs and in the Flood Insurance Study is not based on consideration of changes that may occur due to future development in the watershed. Therefore, this information should not be solely relied upon as the actual limits of the 100-year floodplain. Further investigation of the assumptions, methodologies, and mapping that was used to produce the flood information on the FIRM should be performed by a Professional Engineer registered in the State of Colorado. In some cases, the FIRM maps are the only source of information available, and can be used as an aid, but it is likely that additional investigation and analyses will be required to define the actual floodplain limits.

The FIRM maps, however, are the official regulatory maps published by FEMA, and therefore must be used when determining limits of the Special Flood Hazard Area, and for complying with the floodplain regulations, as discussed previously in Section 5.1.6.

1. <u>Detailed Studies.</u> The FIRM maps generally contain Special Flood Hazard Area designations that were developed through a detailed study or by approximate methods. For drainageways that have a detailed study, Base Flood Elevations are provided on the maps and information is available in the Flood Insurance Study regarding floodplain and floodway widths, drainage areas, and peak discharges at select locations. In most cases, the Base Flood Elevations can be used in conjunction with detailed topographic information to produce a reasonable estimate of the floodplain limits on a particular site, as long as it can be verified that the topographic information and the Base Flood Elevations are referenced to the same vertical datum.

2. <u>Approximate Zones.</u> Special Flood Hazard Area designations that were developed by approximate methods (Zone A) are generally less accurate and Base Flood Elevations are not provided. Typically, there is no published information regarding peak flow rates. As a result, making floodplain determinations and correctly delineating the floodplain on a specific property is more difficult. Floodplain limits must be developed using topographic mapping and an acceptable level of hydrologic and hydraulic analysis. The level of analysis required may vary depending on the proposed activity or land use proposal and the Town must be consulted as to what level of analysis is acceptable. FEMA has published guidance that can be utilized to help determine elevation information in Special Flood Hazard Areas developed by approximate methods. Procedures for making floodplain estimations in Zone A areas are outlined in the FEMA publication <u>*Managing Floodplain Development in Approximate Zone A Areas*</u>, however, the applicant's engineer must consult with the Stormwater Engineering Division prior to selection of methodology or level of detail to confirm that they are reasonable and appropriate.

3. <u>Map Revisions.</u> FIRM maps are often updated due to development or construction projects, changes in hydrology, the use of better topographic

information, or other factors that affect the accuracy of the current Special Flood Hazard Area limits. In most cases, the updates occur through a process called a Letter of Map Revision (LOMR). A LOMR provides revised floodplain information for a particular area, which supercedes the previous information and becomes the effective Special Flood Hazard Area designation. However, the LOMR is a separate document and the FIRM maps are not re-published with the changes resulting from every revision. When reviewing FIRM maps, it is important to determine whether any LOMRs have been completed for the area in question.

4. Map Availability. Current copies of the FIRM maps and LOMR information are available for review at Castle Rock Water. Maps can also be acquired through the FEMA Region 8 Office in Denver, or on-line at fema.gov.

5.2.2 Flood Hazard Area Delineation Studies. Flood Hazard Area Delineation studies and maps are prepared by the Town of Castle Rock. The development of the FHAD is based upon the process established by ~~UDFCD~~MHFD to develop ~~UDFCD~~MHFD FHAD studies. However, since the Town is outside the ~~UDFCD~~MHFD boundary the FHAD is completed by the Town of Castle Rock without ~~UDFCD~~MHFD participation. Mapping used to define flooding limits is typically developed using aerial photogrammetric methods from aerial photography and the contour interval for the mapping is generally two-feet. Flood Hazard Area Delineation studies provide relatively accurate representations of the floodplain limits. In many cases, Flood Hazard Area Delineation studies have been used as the basis for updating the FIRM maps.

1. Existing and Future Watershed Conditions. The Flood Hazard Area Delineations generally contain floodplain information for projected future land use conditions. The future conditions are based on the projected land use and associated impervious percentages within the basin.

2. Verify Assumptions. When relying on Flood Hazard Area Delineation information, it is important to verify that the current land use conditions and projections are consistent with the assumptions made in the Flood Hazard Area Delineation study. Existing topographic conditions must also be compared to mapping used to define the floodplain limits in the Flood Hazard Area Delineation study. Topography can change through natural erosive processes, grading, or construction of physical improvements. The construction of improvements upstream or downstream of a particular site or channel reach can also impact the floodplain limits and elevations that were previously defined.

3. Flood Hazard Area Delineation Revision. Revisions of a Flood Hazard Area Delineation study is completed by the Town, when necessary, due to significant changes in development or other assumptions, on which the original Flood Hazard Area Delineation study was based. Modifications to the floodplain, resulting from adjacent development, construction of road crossings or improvements, should generally be documented in drainage

reports, floodplain studies, or construction drawings, which are submitted to the Town during the development process. The Town should be consulted when questions arise regarding the validity of floodplain limits or elevations presented in Flood Hazard Area Delineation studies.

4. Flood Hazard Area Delineation Availability. Flood Hazard Area Delineation studies are generally available for purchase or review through Castle Rock Water.

5.2.3 Other Floodplain Information. Floodplain data may be obtained from other sources, including the Colorado Water Conservation Board, Castle Rock Water, and studies that have been prepared by private property owners or developers. In some cases, the information may be used as a basis for floodplain delineation for permitting and land development purposes, but the accuracy of all such information will be required to be verified and the use of the information approved by the Town's Stormwater Manager or designated representative.

5.2.4 Confirmation of Floodplain Data. Prior to using any published floodplain information for design or planning purposes, the source of the data, accuracy, modeling methodology, assumptions, etc. must be investigated. Numerous factors can change floodplain limits. Therefore, floodplain data is periodically updated to reflect changes due to floodplain modifications or the use of better technical data. The applicant is solely responsible for acquiring or developing accurate floodplain information for design and planning purposes.

5.3 Floodplain Information Unavailable

Floodplain limits or information has not been developed for all reaches of major drainageways in the Town. Floodplain limits and elevations must be determined for these unstudied drainageways when development, including but not limited to, home construction, channel modification, grading and earthmoving, other construction activities, or storage is proposed. In general, where floodplain information is unavailable, the applicant will be responsible for delineating the floodplain, based on fully-developed conditions in the watershed, consistent with the requirements outlined in Sections 6.7 through 6.9 of these Criteria. It is understood that the resources available for providing this information are varied, and the methodology and level of detail may also vary, depending on the proposed activity and the need for accurate representations of the floodplain limits. If discrepancies or questions regarding the level of effort arise, the Stormwater Manager will be responsible for determining the level of effort necessary for delineating the floodplain on a specific property. The determination will be made based on Town, FEMA, and Colorado Water Conservation Board requirements, as applicable, as well as potential impacts and type of development or activity proposed. For floodplain determination regarding individual structures, consideration will be given to the proximity of the structure to the drainageway, the topography of the land between the drainageway and the structure, and the height of the finished floor (including basement) with respect to the adjacent topography and drainage channel.

5.4 Construction in or Development Adjacent to Floodplains

5.4.1 General. The following sections identify the two areas within the floodplain that are generally defined for regulatory purposes and discuss additional issues related to development adjacent to floodplains.

5.4.2 Floodway District. The Floodway District is defined as the stream channel and that portion of the floodplain that must be reserved in order to discharge the base flood without cumulatively increasing the water surface more than a designated height. The floodway limits are typically generated through hydraulic modeling by assuming equal encroachment on both sides of the floodplain. The floodway can't be identified by visual inspection on a specific site or stream reach. The floodway is defined for regulatory purposes and development in or use of the floodway is severely restricted. It should not be assumed that there is an inherent right to fill in the floodway fringe, if a floodway has been identified.

5.4.3 Floodway Fringe District. The Floodplain Fringe District is the portion of the 100-year floodplain that is not within the floodway, and in which development and other forms of encroachment may be considered. In simple terms, the Town may permit encroachments within the floodway fringe to the extent that complies with Title 18 of the Town's Municipal Code.

5.4.4 Floodway Fringe District Encroachments. In many cases, it can be demonstrated that encroachment into the floodway fringe has little or no impact on the base flood elevations at a specific location, because the encroachment is occurring in a backwater or ineffective flow area. This practice; however, reduces or eliminates valuable floodplain storage areas and the cumulative effect can have significant impacts on downstream properties. Reduction of floodplain storage areas can increase peak flow rates and associated base flood elevations downstream, even though there may be little impact at the site where the encroachment occurs. For that reason, this practice may be contrary to the Town objective of precluding damage to life and property and it is contrary to the objective of maintaining floodplains as open space. For those reasons, encroachments into the floodway fringe will be considered on a case-by-case basis and in accordance with Title 18.28 of the Town of Castle Rock Municipal Code. When considering requests involving floodway fringe encroachment, the Town shall consider, at a minimum, the following:

- <u>Impacts to adjacent properties.</u> If the encroachment creates a rise in the Base Flood Elevation on properties other than that of the applicant, the applicant will be required to obtain floodplain easements for the additional floodplain property.
- <u>Channel hydraulics and design.</u> If the encroachment creates a significantly narrow channel, with steep side slopes and undesirable velocities, the Town may require mitigating channel improvements, or not support the floodplain encroachment.
- <u>Channel aesthetics and land use.</u> If the floodway fringe encroachment significantly impacts the aesthetics of the natural drainageway, and the

resulting channel improvements create a drainageway that is not deemed compatible with the surrounding land uses, the Town may not support the floodway fringe encroachment.

5.4.5 Subdivision Platting and Floodplains. All platted lots must be located outside of the 100-year floodplain limits. That being the minimum criteria, subdivision layout should also consider the size of the tributary watershed and higher degrees of protection where 500-year floodplains have been identified, the stability of the drainageway and anticipated improvements in the floodplain, access and trail requirements adjacent to the floodplain, the proximity of steep or vertical banks relative to the location of lot lines, the potential for the channel to migrate horizontally over time, topography of the proposed lots, and the differences in elevation between the flooding elevation and potential structure locations. The Town will not allow improved commercial or residential lot development to be placed immediately adjacent to the floodplain limits without consideration of all these factors.

1. <u>Actual Floodplain Limits.</u> The floodplain limits used for subdivision layout must be based on existing or proposed floodplain information that has been verified for accuracy or floodplain limits must be developed through detailed hydrologic and hydraulic analyses, based on fully developed conditions in the upstream watershed.

2. <u>FEMA Special Flood Hazard Areas.</u> In addition to the physical floodplain limits, FEMA-designated Special Flood Hazard Area boundaries must be considered in subdivision layout, where applicable. When the Special Flood Hazard Area boundary accurately represents the proposed floodplain limits, lots can be platted as discussed in the previous sections. There are many cases, however, where the Special Flood Hazard Area is much wider than the actual or proposed floodplain. This situation frequently arises in locations where the Special Flood Hazard Area was delineated using approximate methods or where improvements are proposed to confine the floodplain. In this case, platted lots must be outside of the Special Flood Hazard Area and the actual floodplain, whichever is more restrictive. Alternatively, subdivision layout can be based on the actual or proposed floodplain, with the other considerations outlined in this section. All lots that are affected by the Special Flood Hazard Area will be plat restricted to deny conveyance of lots or issuance of building permits on those lots until a LOMR has been issued by FEMA and the LOMR appeal period has expired. In some cases, a CLOMR may be required prior to acceptance of the final plat, to ensure that FEMA will issue a LOMR after improvements are constructed. The LOMR and other FEMA map revision processes are discussed in further detail in Section 5.5 of this chapter. Although outside of the actual floodplain, if lots are partially or totally within the Special Flood Hazard Area, owners can be burdened with mandatory flood insurance purchase requirements, which is not acceptable to the Town of Castle Rock.

5.4.6 Freeboard Requirements. A minimum clearance, or freeboard shall be provided between the 100-year base flood elevation and structures and other applicable facilities, which may be impacted by the floodplain. Freeboard is required to allow for uncertainty in the floodplain modeling, changes to the drainageway (i.e., increased invert due to sedimentation), and to provide an additional factor of safety for structures and facilities, which would result in damages or hazards during inundation. A minimum of two-feet of freeboard shall be provided between the 100-year base flood elevation and the lowest finished floor elevation of all structures (this includes basements). For facilities, which are not structures (typically not requiring a building permit) such as roadways, utility cabinets, parks and trails structures, etc., a minimum of two-feet of freeboard is also required. Where possible the required freeboard should be contained within the floodplain tract and/or easement.

5.5 FEMA Map Revisions and Amendments

5.5.1 General. FEMA FIRM maps are the official regulatory maps that Town of Castle Rock must use for implementation and enforcement of the floodplain development regulations, which are generally discussed in Section 5.1.6 of this chapter. In addition, the maps show projected flooding elevations, flood velocities, floodway dimensions, and flood risk zones used for insurance purposes. It is important, and required, that the maps be updated to correct non-flood-related features, include analyses based on better ground elevation data, reflect changes in ground elevations within the floodplain, revised flooding data, and to reflect flood control projects or other construction in the floodplain. Detailed information, revision request forms, technical requirements for map revisions or amendments, and construction requirements are included in the National Flood Insurance Program Regulations in 44 Code of Federal Regulations or are available through FEMA. The following sections provide brief descriptions of the various types of map revisions or amendments and how the requirements impact proposed projects.

5.5.2 Conditional Letter of Map Revision (CLOMR). A CLOMR is FEMA’s comment on a proposed project or the use of better data that would affect the hydrologic or hydraulic characteristics of a flooding source and thus result in the modification of the existing regulatory floodway, Base Flood Elevations, or limits of the Special Flood Hazard Area. A CLOMR is required by FEMA, prior to construction, for projects or construction in the floodway that will result in an increase in the Base Flood Elevations. The Town may also require processing of a CLOMR for other projects when it is important to ensure that the Special Flood Hazard Area will be revised, based on a proposed project or the use of better data.

5.5.3 Conditional Letter of Map Revision Based on Fill (CLOMR-F). A CLOMR-F is FEMA’s comment on whether a proposed project involving the placement of fill outside of the regulatory floodway, would exclude an area from the Special Flood Hazard Area. The Town may require processing of a CLOMR-F for a project when it is important to ensure that the Special Flood Hazard Area will be revised, based on a proposed project, which involves fill in the floodway fringe.

5.5.4 Letter of Map Revision (LOMR). A LOMR is an official revision, by letter, to an effective FIRM map. A LOMR may change flood insurance risk zones, floodplain and/or floodway boundary delineations, planimetric features, and/or Base Flood Elevations. The LOMR may be based on the use of better data or as-built conditions reflecting flood control or other construction projects. The LOMR must be completed and issued in order to revise the effective Special Flood Hazard Area within six (6) months of the completion of floodplain revisions.

5.5.5 Letter of Map Revision Based on Fill (LOMR-F). A LOMR-F is a document issued by FEMA that officially removes a property and/or structure from the Special Flood Hazard Area. A LOMR-F provides FEMA's determination concerning whether a structure or parcel has been elevated on fill above the Base Flood Elevation and excluded from the Special Flood Hazard Area.

5.5.6 Conditional Letter of Map Amendment (CLOMA). A CLOMA is FEMA's comment on a proposed structure or group of structures that would, upon construction, be located on existing natural ground above the Base Flood Elevation. Generally, a CLOMA involves parcels, portions of parcels, or individual structures that were inadvertently included in the Special Flood Hazard Area.

5.5.7 Letter of Map Amendment (LOMA). A LOMA is a document issued by FEMA that officially removes a property and/or structure from the Special Flood Hazard Area. A LOMA establishes a property or structure's location in relation to the Special Flood Hazard Area.

5.6 Floodplain Modification Study

5.6.1 Requirement. A Floodplain Modification Study is required when development or other activities are proposed that require modification of, or construction in, the existing floodplain, the FEMA Special Flood Hazard Area, or when proposals involve use of property within the floodplain limits. Activities or projects that may potentially affect floodplains are not limited to new development. Some other activities include, but are not limited to, bridge or culvert construction, utility installation, channel stabilization projects, trail crossing construction, and proposed storage of equipment or materials. This requirement applies to all proposed activities within the Floodway District, Floodway Fringe District and proposed activities along any major drainageway associated with development projects.

5.6.2 Incorporation into Other Submittals. The Floodplain Modification Study will be required in support of Floodplain Development Permit applications and in some cases it will be an independent document. Often, the Floodplain Modification Study requirements could be incorporated into the Phase II or Phase III Drainage Reports for development projects, or form the basis for CLOMR or LOMR submittals to FEMA.

5.6.3 Floodplain Modification Study Outline. The floodplain modification study must be certified by a Professional Engineer registered in the State of Colorado and it must address the following items through detailed analysis or through reference to adopted drainage master plans:

1. A description of the site consistent with the outline for a Phase III Drainage Report.

2. A description of the major drainage basin in accordance with the outline for a Phase III Drainage Report.

3. The identification of drainage master plan reports, Flood Hazard Area Delineation studies, or Flood Insurance Studies with a discussion of the applicability of published information or data to the proposed activity or modification and the Floodplain Modification Study.

4. Hydrologic analysis. This section should include a narrative on the source of peak flow rates used for design. The flow rates used should be those generated by the 100-year event under future development conditions for the entire watershed, unless the floodplain modification study is for a CLOMR/LOMR application, in which case, the Flood Insurance Study discharges should be used.

5. Characteristics of the proposed channel including, but not limited to, slope, roughness, depth, velocity, Froude Number, centerline alignment and stationing, and cross sections. Existing topographic mapping may be utilized if it has been field verified to determine if changes have occurred. The profile and plan shall be given for existing condition and for the proposed channel alignment including the cross section locations.

6. A description of the method of hydraulic analysis (HEC-RAS) and its application in the study.

7. Identification and discussion of all input parameters and basis for input parameters.

8. Discussion of the results and conclusions of the hydraulic analysis. This shall include a narrative summary of the results, printed comprehensive output file free of modeling errors, and an electronic file of the modeling effort for Town review.

9. The delineation of the existing and proposed 100-year floodplain and water surface profiles for both conditions, including cross-section locations.

10. A description of potential impacts to other properties, in the vicinity of the modification or activity, and to downstream properties adjacent to the floodplain.

11. A description of measures proposed to mitigate potential impacts.

12. A conceptual design for the channel including bank protection, drop structures, culverts, bridges, and hardened trickle channel or low flow channel.

13. If appropriate, an analysis of sediment transport and fluvial morphology.

The report should be prepared using the drawing size, map scale, and engineer certification requirements that are outlined in Section 4.5 for a Phase III Drainage Report.

5.6.4 Agency Review Requirements. Requests to modify the floodplain must be reviewed by several agencies, depending on the existing mapping of the flood hazard area and the extent of the modifications proposed, but in general conformance with the following:

1. The Town of Castle Rock. The Town has land use control and authority and is responsible for regulating use of or modification of floodplain areas. The Town will review all floodplain modification submittals and determine requirements regarding review or approval of the proposed modification or activity by the other agencies. The initial submittal of any Floodplain Modification Study shall be to the Town.

2. Colorado Water Conservation Board. As discussed in Section 5.1.5, the Colorado Water Conservation Board is the State Coordinating Agency of the National Flood Insurance Program. The Colorado Water Conservation Board is responsible for technical review and approval of all reports and maps that are normally used by local governments for regulatory, floodplain administration, and insurance purposes.

3. FEMA. This agency administers the National Flood Insurance Program. FEMA publishes Flood Hazard Boundary Maps and Flood Insurance Rate Maps that show floodplain boundaries for major drainageways. FEMA reviews applications to modify these FEMA designated floodplains. The Town will require that all floodplain modifications that impact a FEMA-designated floodplain be submitted to FEMA for review and approval via a CLOMR/LOMR process.

5.6.5 Conceptual Approval. Floodplain modifications must be permitted by the Town and approved by the agencies listed previously, depending on the proposed modification and site location. All projects or proposed modifications should be discussed with the Town, in concept, prior to commencement of efforts required to produce the Floodplain Modification Study.

6.0 Introduction

This chapter summarizes methodology for determining rainfall and runoff information for the design of stormwater management facilities in the Town. The methodology is based on the procedures presented in the ~~UDFCD Manual~~MHFD Manual in the Rainfall and Runoff chapters. The design procedures outlined in the ~~UDFCD Manual~~MHFD Manual, supplemented by the information provided in this chapter, apply to all projects in the Town.

6.0.1 Stormwater Quality Considerations. One of the most significant impacts of urbanization is the increase in peak flow rates, runoff volumes, and frequency of runoff from impervious areas. This increase in runoff can lead to severe stream erosion, habitat disruption, and increased pollutant loading. At the same time, with proper planning, the increased runoff volumes can be managed to create or supplement existing wetland areas or riparian habitats, which may provide significant benefits to the watershed. The increase in runoff from development is especially pronounced when drainage systems are designed to quickly and “efficiently” convey runoff from paved areas and roofs directly into inlets and storm sewers, discharging eventually into drainageways that are typically designed to convey flows at maximum acceptable velocities. Whether for one site or for a whole watershed, this increase in runoff and acceleration of flood peaks is reflected accurately by the hydrologic methods discussed herein.

As discussed in Chapter 14, Stormwater Quality, effective stormwater management today seeks to disconnect impervious surfaces, slow down flows, and convey runoff over vegetated ground surfaces, leading to filtering, infiltration, and attenuation of flows. These principles can also be reflected in the hydrologic variables discussed in this chapter, yielding longer times of concentration and reduced peak runoff. Specifically, Section 6.6 provides design guidance to account for the hydrologic effects of Minimizing Directly Connected Impervious Areas.

6.1 Design Rainfall

Rainfall data to be used in the Town of Castle Rock is based on the *National Oceanic and Atmospheric Administration Precipitation-Frequency Atlas of the Western United States, Volume III-Colorado* (NOAA Atlas), published in 1973. Precipitation depth maps shown in the NOAA Atlas were used to determine representative one-hour and six-hour point rainfall values for the Town. Following the guidelines in the NOAA Atlas, these point values were used to develop two-hour and three-hour values as well as the intensity-duration curves for use in the Town. The Rainfall chapter of the ~~UDFCD Manual~~MHFD Manual provides additional discussion on the use of rainfall data obtained from the NOAA Atlas.

6.1.1 One-hour Rainfall. There is very little variation in the NOAA Atlas isopluvial (equal precipitation depth) map within the Town of Castle Rock; therefore, one set of one hour design point rainfall values, indicated in Table 6-1, apply to the Town.

TABLE 6-1
1-HOUR POINT RAINFALL VALUES FOR THE TOWN OF CASTLE ROCK (INCHES)

2- YR	5-YR	10-YR	50-YR	100-YR
1.06	1.43	1.66	2.26	2.60

The one-hour rainfall depths are the basis of the Town's intensity-duration rainfall curves and are used to formulate design storm distributions.

6.1.2 Intensity-Duration Curves. Rainfall intensity based on storm duration for a variety of storm return periods can be found on Figure 6-1 at the end of this chapter. These curves were developed using distribution factors provided in the NOAA Atlas and also provided in Table RA-4 of the ~~UDFCD Manual~~MHFD Manual. These Intensity-Duration curves are based on Equation RA-3 in the Rainfall Section of the ~~UDFCD Manual~~MHFD Manual.

6.1.3 Six-hour Rainfall. In order to use the Colorado Urban Hydrograph Procedure (CUHP), two, three or six-hour rainfall distributions are required, depending on watershed area. Table RA-1 in the ~~UDFCD Manual~~MHFD Manual summarizes storm durations, area adjustments, and incremental rainfall depths to be used in CUHP based on watershed area. The UD-Raincurve Spreadsheet included in the ~~UDFCD Manual~~MHFD Manual shall be used to generate the rainfall distribution curves necessary for a CUHP model. In order to generate these distribution curves, the one-hour and six-hour rainfall depths for the design return periods are necessary. Since the Town of Castle Rock is not located within ~~UDFCD~~ MHFD boundaries, the rainfall depth-duration-frequency curves provided in the ~~UDFCD Manual~~MHFD Manual do not provide rainfall values for the entire Town. Therefore these values are provided in these Criteria. The 1-hour point values can be found in Table 6-1 of this chapter. The six-hour point values are as follows:

TABLE 6-2
6-HOUR POINT RAINFALL VALUES FOR THE TOWN OF CASTLE ROCK (INCHES)

2- YR	5-YR	10-YR	50-YR	100-YR
1.5	2.0	2.2	3.0	3.4

The UD-Raincurve spreadsheet shall be used for all portions of the Town. Once the rainfall distribution curves are generated using the ~~UDFCD~~ MHFD UD-Raincurve Spreadsheet, the CUHP model is to be set up following the procedures provided in the Runoff chapter in Volume 1 of the ~~UDFCD Manual~~MHFD Manual.

6.2 Selecting a Method to Estimate Runoff

Two primary methods for estimating storm runoff, peak flow rates and total volumes are used in the Town.

- Rational Method
- CUHP/SWMM

The Rational Method is a simpler approach generally used for smaller sub-watersheds where hydrograph information is not required. CUHP and SWMM are computer models that are typically run sequentially; CUHP generates runoff hydrographs from individual subwatersheds and SWMM combines and routes individual hydrographs through channels and detention basins. Additional information on the CUHP and SWMM computer programs is provided in the ~~UDFCD Manual~~MHFD Manual.

Table 6-3 compares the Rational Method with CUHP/SWMM and provides information useful for selecting one of the approaches for a particular project. Additional information on each method is provided in Sections 6.3 and 6.4, respectively.

TABLE 6-3
COMPARISON OF HYDROLOGICAL METHODS

	Is the Rational Method Applicable?	Is CUHP/SWMM Applicable?
Hydrologic Information Desired:		
Runoff peak discharge	Yes	Yes
Combining peak flows from separate sub-watersheds	Yes	Yes
Runoff volume (V=I*A*Duration)	Yes	Yes
Runoff hydrograph	No	Yes
Watershed Size (Acres)[1]		
0 to 5	Yes	No
5 to 90	Yes	Yes[2]
90 to 160	Yes	Yes
160 to 3,000	No	Yes
Greater than 3,000	No	Yes

[1] Subdividing watersheds into smaller sub-watersheds may be desirable to obtain runoff information at multiple design points or to accurately model areas of different character. The maximum sub-watershed size shall be approximately 130-acres in accordance with the Town master planning guidance. Methods to combine flows from individual sub-watersheds are discussed in Sections 6.3 and 6.4.

[2] Time of concentration must be estimated and entered into CUHP.

As shown in Table 6-3, either the Rational Method or CUHP/SWMM may be used for watershed sizes from 5 to 160-acres. The following considerations may direct the user to one or the other of these methods.

- If no detention facilities are planned or if detention facilities are to be sized using simplified methods shown in Chapter 13 Storage, hydrograph information is not required and the Rational Method would be the simpler of the two methods.

- If detention facilities are to be sized based on hydrograph routing, or if hydrograph information is desired for any other reason, CUHP/SWMM must be used.
- If more detailed information on time to peak, duration of flow, rainfall losses, or infiltration is desired, CUHP/SWMM offers this information.

Regardless of the method used, the maximum sub-watershed size shall be approximately 130-acres in accordance with the Town master planning guidelines. This is to reduce discrepancies in peak flow predictions between master plan hydrology and flow estimates based on single sub-watersheds significantly larger than 130-acres.

6.3 Rational Method

The Rational Method is used to determine runoff peak discharges for watersheds up to 160-acres in size (see Table 6-3). Sections 2.2 and 2.3 in the Runoff chapter of Volume 1 of the ~~UDFCD Manual~~MHFD Manual provide detailed explanations of the Rational Method, assumptions behind its use and its limitations.

All Rational Method design calculations for projects in the Town of Castle Rock shall be completed using Standard Form 2 (SF-2) and Standard Form 3 (SF-3) which are located at the end of this chapter as Figure 6-2 and Figure 6-3, respectively. The UD-Rational spreadsheet or the UDSEWER software can also be used to complete Rational Method calculations and can be found at the ~~UDFCD~~ MHFD website, mhfd.org ~~udfcd.org~~. The SF-3 form is used to estimate accumulated peak discharges from multiple basins as storm runoff flows downstream in a channel or pipe. Results from the Rational Method calculations shall be included with the drainage report submittal.

6.3.1 Rational Method Equation. The Rational Method is based on the direct relationship between rainfall and runoff, and is expressed by the following equation:

$$Q = CIA$$

In which:

Q = the maximum rate of runoff (cubic feet per second [cfs])
C = the runoff coefficient that is the ratio between the runoff volume from an area and the average rainfall depth over a given duration for that area
I = the average intensity of rainfall for a duration equal to the time of concentration (inches/hour)
A = basin area (acres)

6.3.2 Time of Concentration (t_c). The time of concentration, used to determine the average intensity of rainfall, is equivalent to the amount of time needed for runoff to travel from the most remote point of the basin to the design point. The time of concentration consists of two components, the initial or overland flow time "t_i" (usually as sheet flow) and the time of travel "t_t" in a concentrated form (i.e., in a storm sewer, gutter, swale, channel, etc.). The time of concentration is summarized by the following equation:

$$t_c = t_i + t_t$$

In which:

t_c = time of concentration (minutes)
t_i = overland flow time (minutes)
t_t = travel time in the ditch, channel, gutter, storm sewer, etc. (minutes)

The specific parameters and equations for calculating the overland travel time (t_i) and the channelized travel time (t_t) are provided in the ~~UDFCD Manual~~MHFD Manual. For an urbanized catchment, the time of concentration shall not exceed the value determined from Equation RO-5 in the ~~UDFCD Manual~~MHFD Manual. The minimum time of concentration is as follows:

t_c *(min)* = five minutes for urbanized watersheds
t_c *(min)* = ten minutes for non-urban watersheds

A common error in estimating the time of concentration occurs when a designer does not check the peak runoff generated from smaller portions of the catchment that may have a significantly shorter time of concentration (and a higher intensity) than the watershed as a whole. Sometimes calculations using the Rational Method for a lower, urbanized portion of a watershed will produce a higher peak runoff than the calculations for the watershed as a whole, especially if the watershed is long or the upper portion has little or no impervious cover. UDSEWER software checks for these eventualities as long as the sub-catchment is properly subdivided.

The Rational Method can be used for estimating peak runoff rates for multiple design points. The time of concentration for a downstream design point is calculated by adding the travel times from the previous design point to the time of concentration for the previous point. This cumulative relationship is represented by the following equation:

$$t_{cn} = t_{c1} + t_{t2} + \ldots + t_{tn}$$

In which:

t_{cn} = total time of concentration at the design point of the n^{th} subwatershed area
t_{c1} = time of concentration at the design point of the first subwatershed area
t_{t2} = travel time from the design point of the first subwatershed area to the design point of the second subwatershed area.
t_{tn} = travel time from the design point of the n-1 subwatershed area to the design point of n^{th} subwatershed area

6.3.3 Rainfall Intensity (I). The average rainfall intensity (I), in inches per hour, for a storm duration equal to the time of concentration for the Town can be found in Figure 6-1. Once the time of concentration has been calculated, the rainfall intensity can be read from the intensity-duration curve and then used in the Rational Method equation.

6.3.4 Runoff Coefficient (C). The runoff coefficient represents the integrated effects of infiltration, detention storage, evaporation, retention, flow routing, and interception, all of which affect the time distribution and peak rate of runoff. Runoff coefficients are based on the imperviousness of a particular land use and the hydrologic soil type of the area and are to be selected in accordance with the information shown in Section 4.6~~2.7~~ in the Runoff chapter of Volume 1 of the ~~UDFCD Manual~~MHFD Manual. The procedure is as follows:

1. Categorize the ~~site~~ catchment delineation areas into one or more ~~similar~~ land uses or surface types, each with a representative imperviousness, according to the information in ~~Table~~ ~~RO-3~~ Tables 6-2 and 6-3.
2. For master planning, preliminary design and when the specific layout of the development is not known, ~~Find the percent imperviousness for single-family residential developments using Figures RO-3 through RO-5~~use values in Table 6-2 to estimate land use impervious values.
3. For final design and when the specific layout of the development is known, use Table 6-3 to assign imperviousness to various surface types. Calculate an area-weighted average imperviousness for individual catchment delineations based on the imperviousness values selected for each surface type.
~~3.~~4. Based on the dominant hydrologic soil type in the area, use ~~Figures RO-6~~ Tables 6-6 through 6-8 ~~RO-8~~ or Table 6-5~~RO-5~~ to ~~estimate~~ calculate the runoff coefficient for the ~~particular land use category~~catchment delineation for the design storms of interest.
~~4. Calculate an area-weighted average runoff coefficient for the site based on the runoff coefficients from individual land use areas of the site.~~

Runoff coefficients for the five-year and smaller storms may be reduced for sites that incorporate grass buffers and swales to Minimizing Directly Connected Impervious Areas, as described in Volume 3 of the ~~UDFCD Manual~~MHFD Manual. See Section 6.6 of this chapter for additional information.

When analyzing an area for design purposes, ~~urbanization~~ full buildout of the full watershed, including both on-site and off-site areas, shall be assumed. See Section 6.7 of this chapter for further discussion.

~~Weighted runoff coefficients are not acceptable in single land use areas, such as commercial or single family residential areas. In single land use areas, the landscaping and the impervious areas cannot be separated and a new weighted coefficient calculated. Only the accepted values for individual land use classifications can be used, even if they appear to be on the high side for a given situation.~~

All weighted runoff coefficient calculations for projects in Town of Castle Rock shall be completed using the UD-Rational spreadsheet provided with the ~~UDFCD Manual~~MHFD Manual.

There are some circumstances where the selection of impervious percentage values may require additional investigation due to unique land characteristics (i.e., recent burn areas). When these circumstances arise, it is the designer's responsibility to verify that the correct land use assumptions are made.

6.3.5 Basin Area (A). The size of a sub-watershed contributing runoff to a design point, in acres, is used to calculate peak runoff in the Rational Method. The area may be determined through the use of planimetric-topographic maps, supplemented by field surveys where topographic data has changed or where the contour interval is too great to distinguish the direction of flow. The drainage basin lines are determined by the pavement slopes, locations of downspouts and inlets, paved and unpaved yards, grading of lawns, and many other features found on the urban landscape.

6.3.6 Computer Programs/Equivalent Software. The Town of Castle Rock requires that the ~~UDFCD~~ MHFD UD-Rational spreadsheet and/or UDSEWER be used to complete Rational Method calculations. Alternate computer programs will be considered on a case-by-case basis. The Town of Castle Rock must grant approval for the use of an alternative computer program prior to its use.

6.4 CUHP/SWMM

6.4.1 CUHP. The Colorado Urban Hydrograph Procedure (CUHP) is a hydrologic analysis method based upon the Snyder's unit hydrograph principle. It has been calibrated by ~~UDFCD~~ MHFD for this region using local simulations of rainfall-runoff data collected over an eight-year period in the 1970's. Table 6-3 provides information to help the designer determine if CUHP is appropriate for a particular project and watershed area.

Procedures, assumptions, and equations used for a CUHP computer model shall conform to the protocols described in the Runoff Chapter of the ~~UDFCD Manual~~MHFD Manual. The CUHP program users' manual (distributed by ~~UDFCD~~MHFD) may also be used for reference.

6.4.2 SWMM. SWMM is used to route the hydrographs generated by CUHP through conveyance and storage facilities located within a drainage basin. Large watersheds may be divided into smaller sub-watersheds that contain a number of different conveyance and storage elements. SWMM will add and combine the hydrographs from sub-watersheds and conveyance elements as the flow proceeds downstream. The ~~UDFCD Manual~~MHFD Manual may be used as a reference for this software.

6.5 Other Hydrologic Methods

6.5.1 Published Hydrologic Information. The Town has prepared Major Drainageway Master Planning Reports and/or Flood Hazard Area Delineation Reports that contain hydrologic studies for several of the major drainageways and watersheds within the Town boundaries. These reports contain information regarding peak flow and runoff volume from the two-year through 100-year storm events at numerous design points within the study watersheds. These studies, available at Castle Rock Water, contain information about watershed and sub-watershed boundaries, soil types, percent imperviousness, and rainfall. If there are published flow rate values available from the Town for any drainageway of interest, these values shall be used for design unless there are compelling reasons to use other values or approaches. Use of other values shall be approved in writing by the Town in advance of any related design work.

Published hydrologic information for major drainageways can also be found in Federal Emergency Management Agency (FEMA) Flood Insurance Studies (FIS). For all FEMA-related projects, the FEMA hydrologic data shall be consulted. Flow rates published in FEMA FIS studies typically represent existing conditions at the time the study was completed and generally do not incorporate any future development. The Town's policy is to analyze and design stormwater facilities based on future development flow rates; therefore, FEMA flow rates shall not be used for design without the written approval of the Town.

6.6 Runoff Reduction Associated with Minimizing Directly Connected Impervious Area

Imperviousness and runoff coefficients for the five-year and smaller, more frequent storms may be reduced for sites that incorporate grass buffers and swales to Minimize Directly Connected Impervious Area, as described in Volume 3 of the ~~UDFCD Manual~~MHFD Manual. Figure ND-1 of the ~~UDFCD Manual~~MHFD Manual may be used to estimate a reduced impervious value for practices that qualify for Level 1 or 2 Minimizing Directly Connected Impervious Area. The reduced impervious value may be used to estimate applicable runoff coefficients for five-year and smaller storms (see Section 6.3.4). The reduced imperviousness may also be used to calculate water quality capture volume for stormwater quality facilities (discussed in Chapter 14 Stormwater Quality). Depending on the amount of imperviousness of a site, Level 2 Minimizing Directly Connected Impervious Area may reduce imperviousness by as much as half.

6.7 Design Hydrology Based on Future Development Conditions

6.7.1 On-site Flow Analysis. Full site development shall be considered when the design engineer selects runoff coefficients or impervious percentage values and performs the hydrologic analyses for on-site areas. Changes in flow patterns and sub-basin boundaries due to site grading and proposed street and roadway locations must be considered. Time of concentration calculations must reflect increased surface flow velocities and velocities associated with proposed runoff conveyance facilities.

6.7.2 Off-site Flow Analysis. Fully developed conditions shall be considered when the design engineer selects runoff coefficients or impervious percentage values and performs the hydrologic analyses for off-site areas. Where the off-site area is undeveloped, fully developed conditions shall be projected using the best available land use information, as provided by the Town of Castle Rock Development Services. The Town of Castle Rock Development Services Department shall be consulted to verify all assumptions regarding future development in off-site areas. If information is not available, runoff calculations shall be based on the impervious percentage value presented in Table RO-3, found in the Runoff chapter in Volume 1 of the ~~UDFCD Manual~~MHFD Manual, for off-site flow analysis.

Where the off-site area is full or partially developed, the hydrologic analysis shall be based on existing platted land uses, constructed conveyance facilities, and developed topographic characteristics. Consideration of potential benefits related to detention provided in off-site areas depends on the type of detention provided and whether or not the off-site tributary area is part of a major drainageway basin, as discussed in Section 6.8 of this chapter.

6.8 Consideration of Detention Benefits in Off-Site Flow Analysis

6.8.1 Major Drainageway Basin Distinction. When determining whether on-site detention benefits may be recognized in off-site flow analysis, a distinction is made between systems that are part of the major drainageway basin system (defined in Chapter 13 Storage and generally greater than 130-acres of tributary area) and for those that are higher upstream in the watershed (generally less than 130-acres of tributary area), and are not considered a part of the major drainageway basin system.

6.8.2 Analysis when System is Part of a Major Drainageway Basin. When determining minor storm event peak flow rates from off-site areas, no benefit shall be recognized for detention in the off-site areas.

For determination of peak flow rates from the major storm event and other less frequent events, no benefit shall be recognized for on-site detention in the off-site areas. While the smaller on-site detention ponds provide some benefit immediately downstream, it has been shown that the benefit diminishes as the number of relatively small ponds increases with the accumulation of more tributary area. It has been suggested that there may be very little benefit along the major drainageway when numerous on-site detention ponds are provided in the upstream watershed. The technical paper, “Potential Effectiveness of Detention Policies”, by Ben Urbonas and Mark Glidden, provides more information regarding this subject. The paper is available on-line at ~~udfcd.org~~mhfd.org.

For determination of peak flow rates from the major storm event and other less frequent events, the benefits provided by constructed, publicly operated and maintained, regional detention facilities in the off-site areas may be recognized, if approved by Castle Rock Water. On-site and regional detention facilities are discussed in more detail in Chapter 13, Storage.

Conveyance of runoff along major drainageway basins is also subject to the additional requirements outlined in Section 6.9 of this chapter.

6.8.3 Analysis when System is Not Part of a Major Drainageway Basin. When determining minor storm event peak flow rates from off-site areas, no benefit shall be recognized for detention in the off-site areas.

For determination of peak flow rates from the major storm event and other less frequent events, runoff may be calculated assuming historic runoff rates computed in accordance with procedures outlined in Chapter 13, Storage, if the off-site area is undeveloped. Benefits of constructed and Town accepted on-site detention facilities in the off-site area can be recognized if the off-site area is partially or fully developed.

6.9 Additional Considerations Regarding Conveyance of Runoff from Major Drainageway Basins

Although the benefits provided by constructed, publicly operated and maintained regional detention facilities may be recognized if approved by Castle Rock Water, a fully developed “emergency conditions” scenario must be analyzed that does not consider the benefits of upstream regional detention facilities. Conveyance facilities and channel improvements may be designed considering the benefits of upstream regional detention when approved by Castle Rock Water, as provided in Section 6.8.2. In addition, it must be shown that the “emergency conditions” runoff can be safely conveyed, using additional capacity provided by freeboard or buffer areas, without impacting proposed structures or homes.

FIGURE 6-1
RAINFALL INTENSITY-DURATION CURVE
TOWN OF CASTLE ROCK

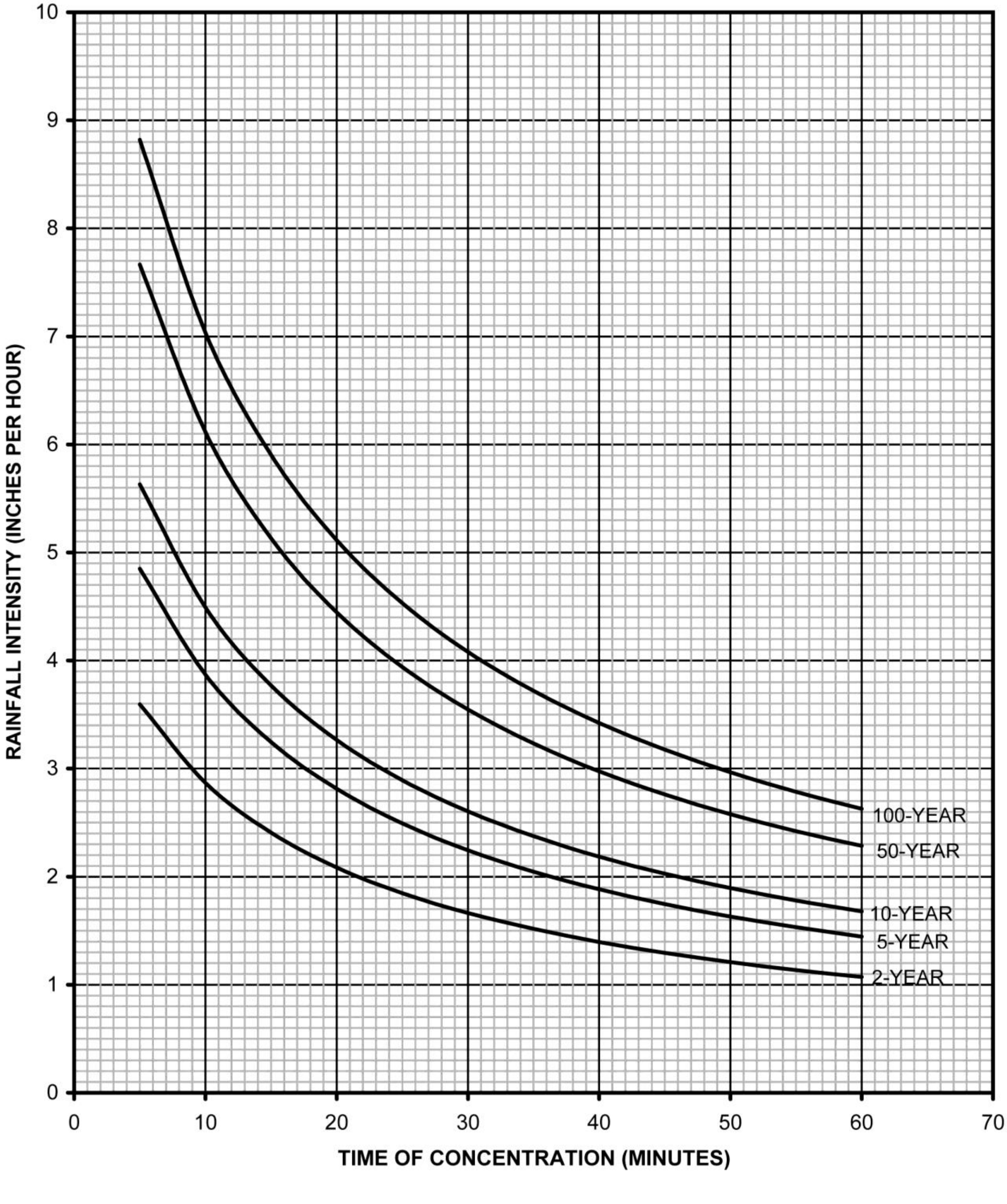

FIGURE 6-2
STANDARD SF-2 FORM

STANDARD FORM SF-2
TIME OF CONCENTRATION

DEVELOPMENT ______________________

CALCULATED BY ________ DATE ________

SUB-BASIN DATA			TIME OF CONCENTRATION ESTIMATE								MINIMUM T_C IN URBAN AREAS			FINAL Tc	REMARKS
			INITIAL/OVERLAND TIME (Ti)			TRAVEL TIME (Tt)					Tc CHECK (urbanized basins)				
DESIG: (1)	AREA Ac (2)	C5 (3)	LENGTH Ft (4)	SLOPE % (5)	Ti Min (6)	LENGTH Ft (7)	SLOPE % (8)	VEL Ft/Sec (9)	Tt Min (10)	Tc Min (11)	COMP. Tc (12)	TOTAL LENGTH Ft (13)	Tc(urban) Min (14)	Min (15)	

FIGURE 6-3
STANDARD SF-3 FORM

STANDARD FORM SF-3
STORM DRAINAGE SYSTEM DESIGN
(RATIONAL METHOD PROCEDURE)

CALCULATED BY: ______
DATE: ______

JOB #: ______
PROJECT: ______
DESIGN STORM: ______

STREET	DESIGN POINT	AREA DESIGN.	DIRECT RUNOFF						TOTAL RUNOFF				STREET		PIPE			TRAVEL TIME					REMARKS
			AREA (Ac)	COEFF C	Tc (min)	C*A (Ac)	I	Q (CFS)	Tc (min)	Sum C*A (Ac)	I (In/Hr)	Q (CFS)	Slope (%)	Street Q (CFS)	Design Q (CFS)	Slope (%)	PIPE SIZE	L (Ft)	VEL (Ft/Sec)	Tt (min)	Q add'l	Q tot	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)			(22)

7.0 Introduction

This chapter summarizes methods to evaluate runoff conveyance in various street cross sections and curb types in the Town of Castle Rock and identifies acceptable upper limits of street capacity for minor and major storm events. Sections 7.1 through 7.6 address conventional curb-and-gutter street sections used in the Town.

A concept that holds promise for reducing urban runoff and pollutant loading consists of curbless (or intermittent curb) streets with adjacent grass swales, which can be used in situations where street grades are favorable to stable flow regimes. This concept gives street runoff a chance to infiltrate and get filtered and slowed in the vegetated swales. The use of curbless streets with grass swales for runoff reduction and enhanced water quality is discussed in Section 7.7.

7.1 Function of Streets in the Drainage System

7.1.1 Primary Function of Streets. Urban streets not only carry traffic, but stormwater runoff as well. The primary function of urban streets is for traffic movement; therefore, the drainage function is subservient and must not interfere with the traffic function of the street. When runoff in the street exceeds allowable limits, a storm sewer system or open channel is required to convey the excess flows.

7.1.2 Design Criteria Based on Frequency and Magnitude. The design criteria for the collection and conveyance of storm water runoff on public streets are based on an allowable frequency and magnitude of traffic interference. The primary design objective is to keep the depth and spread (encroachment) of stormwater on the street below an acceptable value for a given storm event.

7.1.3 Street Function in Minor (five-year) Storm Event. The primary function of streets in a minor storm event is to convey the nuisance flows quickly, efficiently, and economically to the next intended drainage conveyance system with minimal disruption to street traffic.

7.1.4 Street Function in Major (100-year) Storm Event. For the major storm event, the function of streets is to provide an emergency passageway for flood flows while maintaining public safety and minimizing flood damage. In the major event, the street becomes an open channel and must be analyzed to determine when flooding depths exceed acceptable levels.

7.2 Street Classification

7.2.1 Town of Castle Rock Standard Roadway Sections. Cross section drawings of standard street sections are shown in the most recent edition of the ~~Town's Regulations~~Town of Castle Rock Transportation Criteria Manual. The capacity charts located at the end of this chapter also indicate the dimensions of the applicable roadway section. Each roadway section has a different capacity, so it is important to use the section dimensions or capacity chart that applies to the particular street section of interest. The use of these charts will be discussed later in this chapter.

7.2.2 Drainage Classification. The streets in the Town are assigned a drainage classification of Type A, B, or C based on the average daily traffic (ADT) for which the street is designed or the roadway classification. In general, the higher the ADT or mobility that the roadway provides, the more restrictive the allowable drainage encroachment into the driving lanes. Table 7-1 summarizes the drainage classification for each Town roadway section:

TABLE 7-1
DRAINAGE CLASSIFICATION FOR
STANDARD ROADWAY SECTIONS

Street Classification	Drainage Classification
Local Type I/II (SF)	A
Local Type I/II (MF)	A
Local Type III	A
Minor Collector	B
Major Collector	B
Minor Arterial	B
Four-Lane Major Arterial	C
Six-Lane Major Arterial	C

7.3 Minor (Five-Year) Storm Allowable Street Flow

7.3.1 Allowable Flow Depth and Roadway Encroachment for Streets with Curb and Gutter. The Town allows the use of streets for drainage conveyance in the minor storm with limitations on the depth of flow in the curb and gutter and the spread of flow onto the roadway. Table 7-2 summarizes these limitations for each drainage classification. The maximum allowable street capacity is determined by whichever limitation is more restrictive, based on the geometry of the street section.

TABLE 7-2
MINOR STORM ALLOWABLE FLOW DEPTH AND ROADWAY ENCROACHMENT FOR STREETS WITH CURB AND GUTTER

Drainage Classification	Allowable Flow Depth in Gutter Flowline[1]	Maximum Roadway Encroachment
Type A	No curb overtopping.	Flow may spread to crown of street.
Type B	No curb overtopping.	Flow spread must leave at least one 10-foot lane free of water (5-feet either side of the street crown).
Type C	No curb overtopping.	Flow spread must leave at least two 10-foot lanes free of water (10-feet each side of the street crown or median).

[1] If a 4-inch curb with an attached sidewalk is used (i.e., combination or rollover curb), the flow depth ~~may spread to the back of sidewalk~~is limited to 4-inches.

7.4 Major (100-Year) Storm Allowable Street Flow

7.4.1 Allowable Flow Depth for a Street with Curb and Gutter. The Town allows the use of streets for drainage conveyance in the major storm with limitations on the depth of flow in the curb and gutter. Table 7-3 summarizes these limitations for each drainage classification. The maximum street capacity is based on the allowable depth at the gutter flowline.

TABLE 7-3
MAJOR STORM ALLOWABLE FLOW DEPTH FOR STREETS WITH CURB AND GUTTER

Drainage Classification	Allowable Flow Depth
Type A, B and C	The depth of water at the gutter flowline shall not exceed 12-inches.[1]

[1] ~~In some cases the major storm allowable street capacities must be based on a depth of flow in the gutter that is less than 12-inches. Additional discussion regarding this subject is provided in~~ See Section 7.5.~~3~~4 for further information on allowable flow depth limits.

7.5 Hydraulic Evaluation of Street Capacity

Once the design discharge is calculated (see Chapter 6, Hydrology), hydraulic calculations are to be completed to determine the capacity of street gutters and the resulting encroachment onto the street section. All street capacity and encroachment calculations shall conform to the Streets/Inlets/Storm Sewers chapter in Volume 1 of the ~~UDFCD~~MHFD Manual unless otherwise noted herein. For more detailed information on the methodology used for the hydraulic evaluation of street capacity see Section 2.3 of Chapter 7 in Volume 1 of the ~~UDFCD~~MHFD Manual.

7.5.1 Minor (5-year) Storm Street Capacity Worksheet. The Streets/Inlets/Storm Sewers chapter in Volume 1 of the ~~UDFCD~~MHFD Manual provides an analysis tool used for determining the minor storm street capacity and flow encroachment. This tool is ~~the "Q-Allow" worksheet which is contained within~~ the UD-Inlet spreadsheet which can be accessed via the internet at ~~udfcd~~mhfd.org. This worksheet completes a hydraulic evaluation of the theoretical street capacity for the minor storm by calculating the theoretical minor event street gutter flow capacity based on both 1) the allowable spread, and 2) the allowable gutter depth. A reduction factor is then applied to the theoretical gutter flow based on allowable depth and the lesser of the allowable street capacities governs for the minor event.

~~**7.5.2 Minor Storm Street Capacity Charts.** The allowable minor storm street capacity for each Town of Castle Rock standard street cross-section has been calculated based on the "Q-Allow" worksheet and is presented at the end of this chapter. These charts shall only be used for streets that are consistent with all the referenced standard street parameters, including street width, pavement cross slope of two percent, and a depressed gutter consistent with the Town's standard cross-section as noted. A Manning's n-value of 0.016 was used. These minor event capacity calculations were performed for various street slopes to generate the street capacity charts located at the end of this chapter. These charts apply for one-half of the street section, on one side of the street crown or the other.~~

7.5.~~3~~2 Major (100-year) Storm Street Capacity Worksheet. Similar to the minor storm, the Streets/Inlets/Storm Sewers chapter in Volume 1 of the ~~UDFCD~~MHFD Manual provides an analysis tool used for determining the major storm street capacity. This tool is the ~~"Q-Allow" worksheet which is contained within~~ the UD-Inlet spreadsheet which can be accessed via the internet at ~~udfcd~~MHFD.org. This worksheet completes a hydraulic evaluation of the theoretical street capacity for the major storm and then applies the major storm reduction factor. The design engineer must use UD-Inlet to determine the allowable gutter capacity. The engineer must enter the data appropriate for the street section and the minor/major storm criteria for the drainage classification for the worksheet to calculate the allowable gutter capacity based on the data and criteria provided.

7.5.~~3~~4 Major Storm Street Capacity ~~Charts~~Limitations. ~~The allowable major storm street capacity for all Town of Castle Rock street cross-sections has been calculated based on the "Q-Allow" worksheet and is presented at the end of this chapter. These charts shall only be used for streets that are consistent with all the referenced standard street parameters, including street width, pavement cross slope of two percent, and a depressed gutter consistent with the Town's standard cross-section as noted. A Manning's n-value of 0.016 was used. These charts present the allowable capacity for one-half of the street section.~~

~~The major storm street capacity charts at the end of this chapter contain two curves, which represent the capacities at full curb depth and at 12-inches of~~

~~depth at the gutter flowline, respectively. The 12-inch depth allowable capacity curve is based on the assumption of a vertical "wall" at the back of the curb. Although flow may be conveyed in the area behind the curb, the additional capacity is ignored to account for potential obstructions in the gutter and to allow for a reasonable capacity to be calculated, independent of the various grading scenarios and landscaping improvements that may be proposed adjacent to the roadway. The 12-inch~~ Allowable flow depths greater than the minor storm~~curve~~ may only be used if the following conditions apply:

1. The design must demonstrate that the major storm flow is~~must be~~ fully contained, at the assumed depth, within the roadway and the area adjacent to the roadway such that no structures are impacted and no flow is released beyond the typical street section. A cross section of the street is required on the Overlot Grading Plan showing the minimum high points adjacent to the right-of-way.
2. A minimum of 1-foot above the assumed depth ~~of 12-inches~~ shall be provided as freeboard to the ~~lowest~~ finished floor ~~or window well openings~~ for structures that are proposed adjacent to the roadway.
~~2.~~3. All window well openings shall be set at or above the finish floor of the structure. Window wells behind a high point at or above the minimum freeboard elevation are exempt from this rule.
4. Conveyance of the major storm flow at the assumed depth ~~of 12-inches~~ will not result in diversions at driveways, intersections, or other locations~~ prior to the designed outfall point~~.
5. For areas where the finished floor does not meet the minimum freeboard requirement, the overlot grading plan shall establish a high point at or above the freeboard elevation adjacent to the roadway to contain the major storm flow in the area adjacent to the roadway. Such areas shall be secured in a slope easement on the plat.
~~3.~~6. Full consideration to cross street flow implications is to be given in the routing of major storm flow and inlet sizing as per Section 7.6.3.

The design engineer shall use the UD-Inlet worksheet to determine the street capacity at the specific depth between curb full and 12-inches of depth at the flowline, based on the assumptions presented above. When using UD-Inlet, all safety factors as discussed in Section 2 of the Street, Inlets and Storm Drains Chapter of Volume 1 of the MHFD Manual shall apply.

It is the responsibility of the design engineer to verify that the above conditions are satisfied. In subdivisions where ~~overlot grading operations are not proposed or in situations where~~ the conditions outlined above are not met, the allowable capacity in each side of the street during the major storm shall be the same as shown for the minor storm. Particular caution should be made ~~I~~in subdivisions where grading operations are performed simply to construct the streets and at corner lots, since driveways often slope away from the road and structure foundations may be below the roadway. ~~Both the minor and major curves are shown in order to assist the design engineer in determining the appropriate street capacity, based on gutter flow depth. Due to the large scale of the major storm~~

~~capacity chart, the design engineer may refer to the minor storm street capacity chart to read a more accurate allowable capacity for the gutter full condition.~~

~~**7.5.5 Major Storm Street Capacity with Flow Depth Between Curb Full and 12-inches.**~~ ~~There may be situations when the conditions outlined in Section 7.5.4 can be satisfied when the major storm flow depth (at the gutter flowline) is between curb full and 12-inches. An example of this situation would be when the lowest point of water entry into a house is 20-inches above the gutter flowline. Since the finished floor elevation must be at least 1-foot above the assumed gutter flow elevation, the maximum gutter flow depth would be limited to 8-inches (20-inches minus 12-inches). The design engineer may use the "Q-Allow" worksheet in UD-Inlet to determine the street capacity at the specific depth between curb full and 12-inches of depth at the flowline, based on the other assumptions presented in Section 7.5.4.~~

~~**7.5.6 Non-Standard Street Sections.**~~ ~~When a Town standard street section is not used, the design engineer must use the "Q-Allow" worksheet in UD-Inlet to determine the allowable gutter capacity. The engineer must enter the data appropriate for the street section and the minor/major storm criteria for the drainage classification for the worksheet to calculate the allowable gutter capacity based on the data and criteria provided.~~

7.5.4~~7~~ Computer Programs/Equivalent Software. The Town of Castle Rock requires that the ~~UDFCD~~MHFD UD-Inlet spreadsheet be used to complete street capacity calculations. Alternate computer programs will be considered on a case-by-case basis. The Town of Castle Rock must grant approval for the use of an alternative computer program prior to its use.

7.6 Cross-Street Flow

7.6.1 Cross-Street Flow Conditions. Cross-street flow can occur in an urban drainage system under three conditions. One condition occurs when the runoff in a gutter spreads across the street crown to the opposite gutter. The second is when cross-pans are used. The third condition is when the flow in a drainageway exceeds the capacity of a road culvert and/or bridge and subsequently overtops the crown of the street. Allowable cross-street flow or overtopping at culvert crossings is limited by the criteria provided in Chapter 11, Culverts and Bridges. Cross-pans are discussed in Section 7.6.4.

7.6.2 Influence on Traffic. Whenever storm runoff, other than sheet flow, moves across a traffic lane, traffic movement is affected. The cross flow may be caused by super-elevation of a curve, by the intersection of two streets, by exceeding the capacity of the higher gutter on a street with cross fall, or street design that has not met the criteria provided herein. The problem associated with this type of flow is that it is localized in nature and vehicles may be traveling at speeds that are incompatible with the cross flow when they reach the location.

7.6.3 Allowable Cross-Street Flow Due to Gutter Flow Spread Over the Street Crown. Allowable cross-street flow depths when the flow depth exceeds the crown elevation are provided in Table 7-4. In the minor storm event, cross street flow is not allowed, based on the allowable street capacity criteria provided in Table 7-2. In the major storm event, allowable cross-street flow is controlled by the criteria and limitations presented in ~~Table 7-3 and Table 7-4, respectively~~Section 7.5.3. For example, if the maximum allowable gutter flow depth is 12-inches and the crown of the road is 7-inches above the flowline of the gutter, a depth of 5-inches (12-inches minus 7-inches) of cross-street flow is allowed during a major storm event.

TABLE 7-4
ALLOWABLE CROSS-STREET FLOW DUE TO FLOW SPREAD OVER THE STREET CROWN FOR STREETS WITH CURB AND GUTTER

Drainage Classification	Minor Storm Maximum Depth	Major Storm System Maximum Flow Depth
Type A, B and C	Not Allowed	12-inches of depth at gutter flowline.

Note: All criteria in ~~Table 7-3~~Section 7.5.3 must also be met for the major storm event.

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The analysis to quantify the amount of cross-street flow can be complex due to the fact that the runoff is moving longitudinally down the street. In addition, it is often assumed that runoff being conveyed in the gutter will follow the path of the associated gutter at intersections, which generally requires the full flow to turn corners, without the appropriate consideration being given to the momentum that was established in one direction. There is potential for cross street flow, if the flow isn't conveyed around the corner, as assumed. It is the responsibility of the design engineer to make conservative assumptions relative to cross street flow and to design the downstream inlets and storm sewer system accordingly.

7.6.4 Crosspans. The use of crosspans and allowed locations shall adhere to the criteria presented in the Town's *Transportation Criteria Manual, as amended* ~~*Regulations*~~. Crosspans shall be designed to convey the minor and major storm event within the criteria presented in Sections 7.3 and 7.4, respectively. The design engineer shall evaluate the carrying capacity (with calculations provided) of water on the roadway being considered as well as the side street.

7.7 Curbless Streets with Roadside Swales for Enhanced Water Quality

7.7.1 Urban Roadside Swales. The engineer shall use the Town's *Regulations*, or governing regulation, to determine the appropriate standard street section(s) for the project and seek approval for an alternate street section, as necessary. Urban roadside swales provide an opportunity to Minimize Directly Connected Impervious Areas and thereby reduce the volume and peak rate of runoff and enhance stormwater quality. Roadside swales are used in conjunction with curbless (or intermittent curb) streets. The use of urban roadside swales will need to be approved by the Public Works Director prior to submittal.

Urban roadside swales shall be designed based on site-specific conditions. However, they will generally have a depth of 6- to 9-inches below the edge of pavement, a bottom width of at least 2-feet and side slopes of 8:1 or flatter. Swales shall be vegetated with irrigated sod-forming native grasses. The invert of the swale shall be parallel to the street slope to provide a constant depth.

7.7.2 Allowable Capacity. The allowable flow depth and roadway encroachment in the minor and major storm events for curbless streets can be found in Tables 7-2 and 7-3. Tables 7-2 and 7-3 reference allowable flow depth based on the gutter flow line; these tables should be used for curbless streets by applying the depth at the edge of pavement (rather than gutter flowline).

Flow in the grass swale is limited by capacity (this generally governs at low street slopes) and by velocity considerations (this governs at higher street slopes). To limit the potential for erosion during the 100-year event, allowable capacity for roadside grass swales is based on the major storm. Roadside swales shall be designed in accordance to the criteria for grass swales provided in Chapter 14 Stormwater Quality.

The lowest point of water entry (first floor or basement window) of any structure adjacent to the swale shall be at least 1.0-foot above the 100-year water surface, or generally 2.0-feet above the edge of the road.

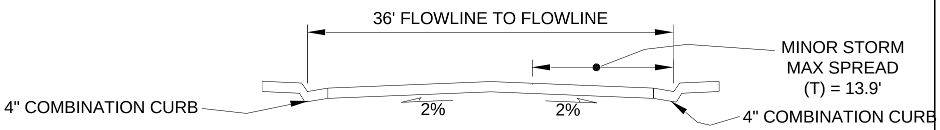
7.7.3 Driveways and Street Cross-flow. In general, driveways or sidewalks that cross the swale are intended to conform to the swale cross section, such that flow will pass over the driveway as opposed to under it. Trench drains are generally required at the low point in the drive to convey any nuisance flows. Crosspans are typically used to convey swale flow across a street at a stop condition intersection.

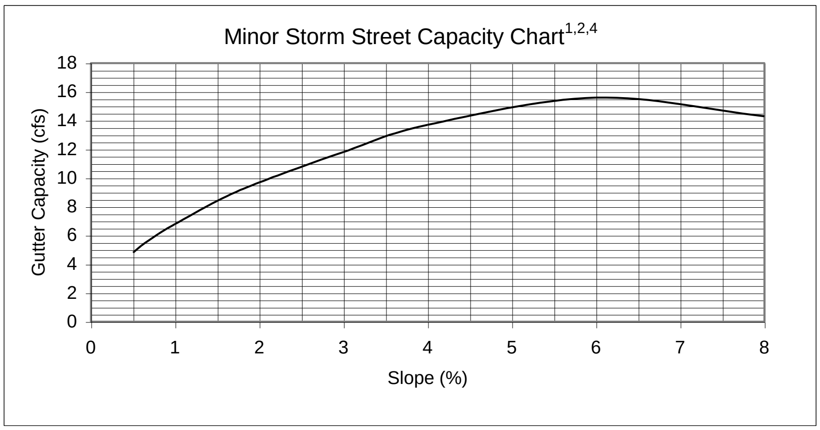
7.7.4 Downstream Facilities. At the point where the maximum capacity or slope of the swale is reached for the design event, runoff must be conveyed in an alternate system. The swale flow shall be diverted into a vegetated drainageway or picked up in an area inlet and storm sewer. Of the two, a vegetated drainageway is preferred to provide further contact of runoff with vegetation and soil. Drainageway design shall be in accordance with Chapter 12, Open Channel Design. Inlets and storm sewers shall be designed in accordance with Chapter 8, Inlets, and Chapter 9, Storm Sewers, respectively.

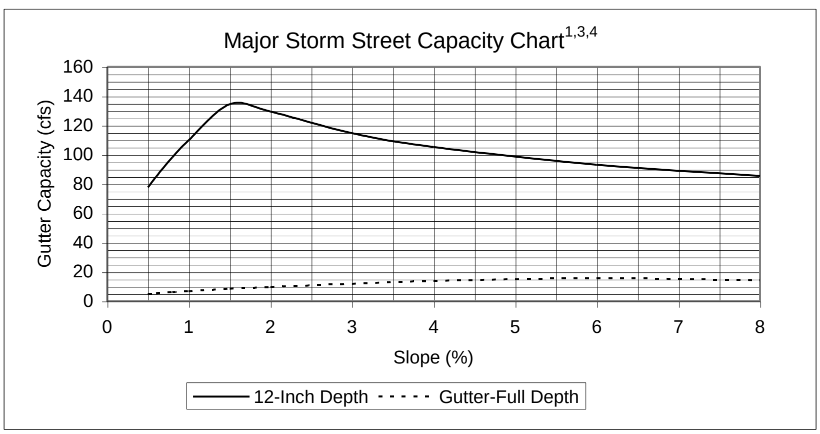
FIGURE 7-1, TOWN OF CASTLE ROCK STREET CAPACITY CHART

LOCAL TYPE I AND TYPE II (SINGLE FAMILY)

Typical Cross Section







[1] The Town of Castle Rock standard street section parameters must apply to use these charts. For non-standard sections, the street capacity shall be calculated using the UDFCD spreadsheets (see Section 7.5). The capacity shown is based on ½ the street section.

[2] The maximum spread width is limited by the curb height based on no curb overtopping allowable during a minor storm.

[3] Calculations for the 12-inch depth curve assume a vertical wall behind the top of curb. For the gutter-full depth case, the Minor Storm Capacity Chart may be used.

[4] The capacity shown assumes gutter-full depth of 4.9" to the back of the attached sidewalk. If a 4" curb without an attached sidewalk is used, the street capacity shall be calculated using the UDFCD spreadsheets.

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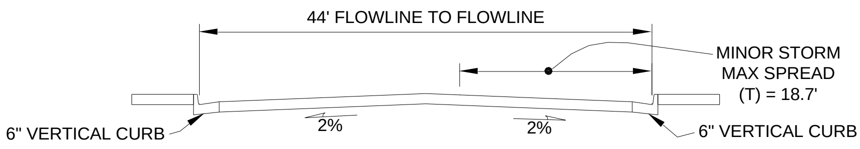
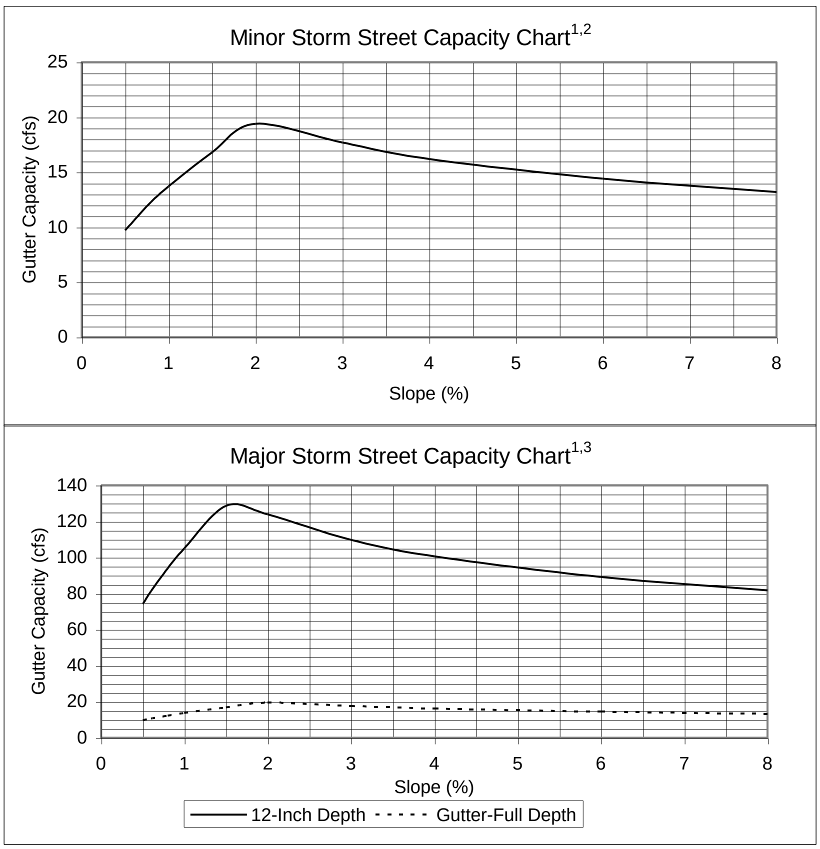
FIGURE 7-2, TOWN OF CASTLE ROCK STREET CAPACITY CHART
LOCAL TYPE I AND TYPE II (MULTI-FAMILY)

Typical Cross Section





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[2] The maximum spread width is limited by the curb height based on no curb overtopping allowable during a minor storm.
[3] Calculations for the 12-inch depth curve assume a vertical wall behind the top of curb. For the gutter-full depth case, the Minor Storm Street Capacity Chart may be used.

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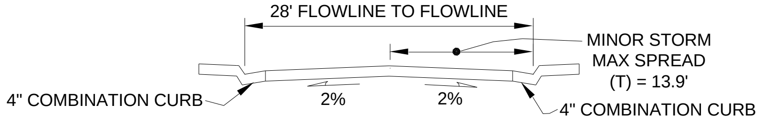
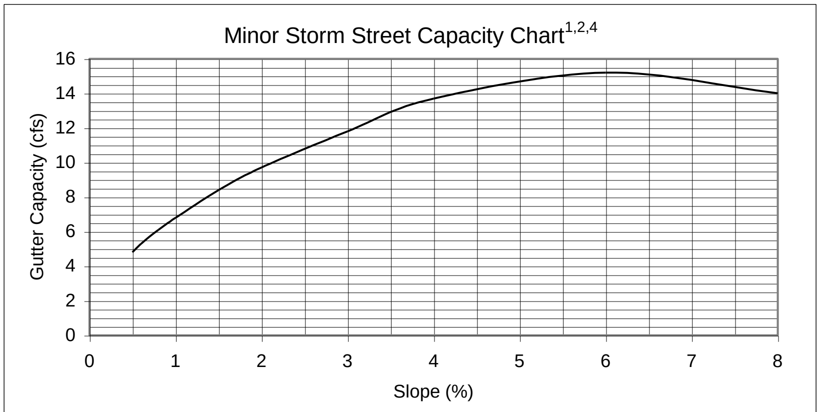
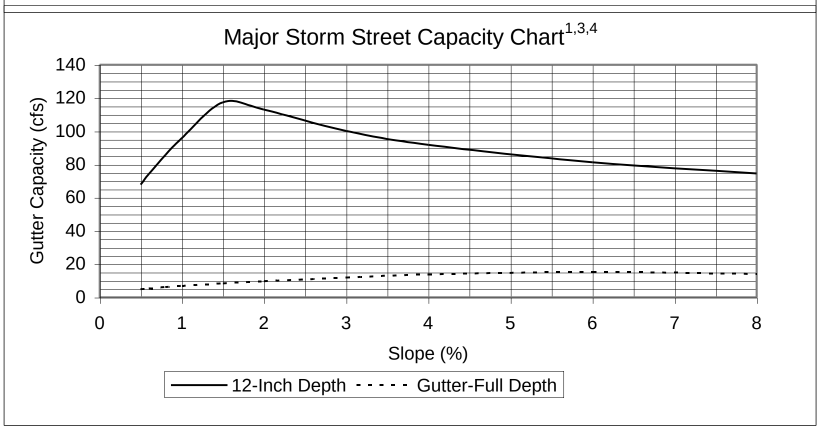
FIGURE 7-3, TOWN OF CASTLE ROCK STREET CAPACITY CHART

LOCAL TYPE III

Typical Cross Section







[1] The Town of Castle Rock standard street section parameters must apply to use these charts. For non-standard sections, the street capacity shall be calculated using the UDFCD spreadsheets (see Section 7.5). The capacity shown is based on ½ the street section.

[2] The maximum spread width is limited by the curb height based on no curb overtopping allowable during a minor storm.

[3] Calculations for the 12-inch depth curve assume a vertical wall behind the top of curb. For the gutter-full depth case, the Minor Storm Capacity Chart may be used.

[4] The capacity shown assumes gutter-full depth of 4.9" to the back of the attached sidewalk. If a 4" curb without an attached sidewalk is used, the street capacity shall be calculated using the UDFCD spreadsheets.

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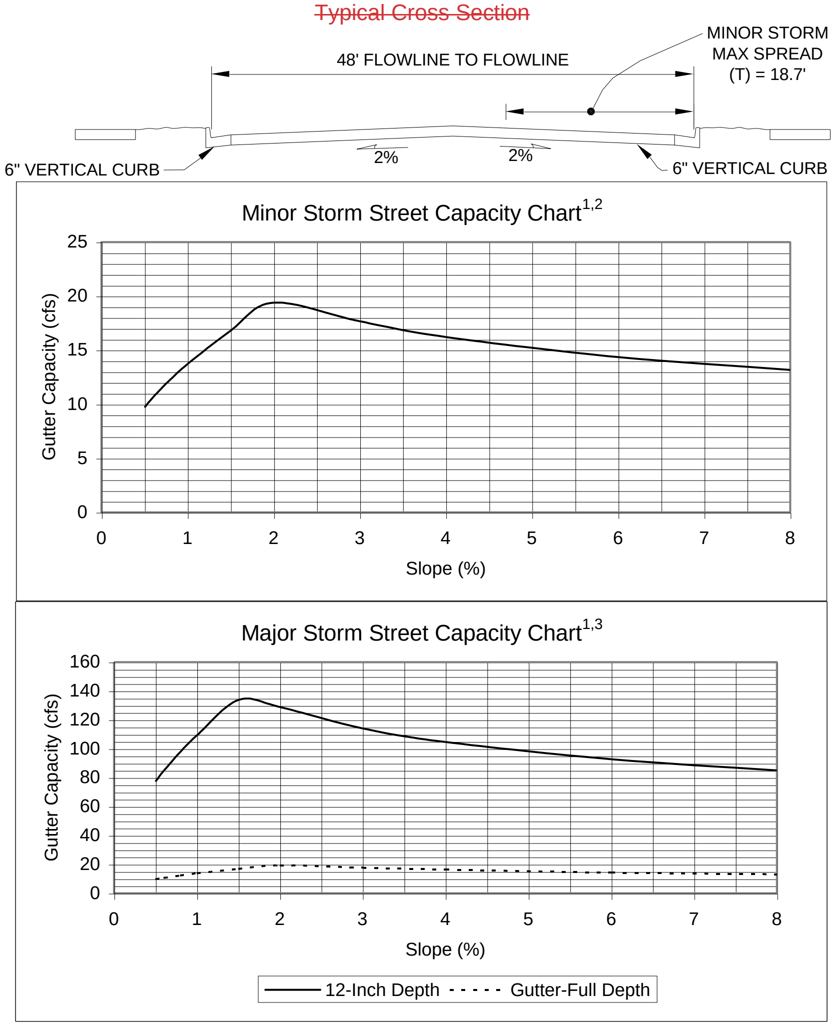
FIGURE 7-4, TOWN OF CASTLE ROCK STREET CAPACITY CHART

MINOR COLLECTOR

Typical Cross Section



[1] The Town of Castle Rock standard street section parameters must apply to use these charts. For non-standard sections, the street capacity shall be calculated using the UDFCD spreadsheets (see Section 7.5). The capacity shown is based on ½ the street section.

[2] The maximum spread width is limited by the curb height based on no curb overtopping allowable during a minor storm.

[3] Calculations for the 12-inch depth curve assume a vertical wall behind the top of curb. For the gutter-full depth case, the Minor Storm Capacity Chart may be used.

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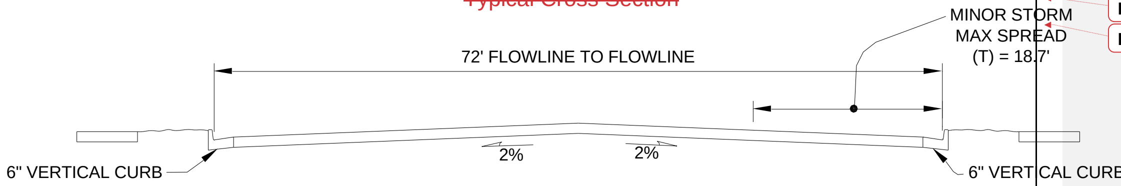
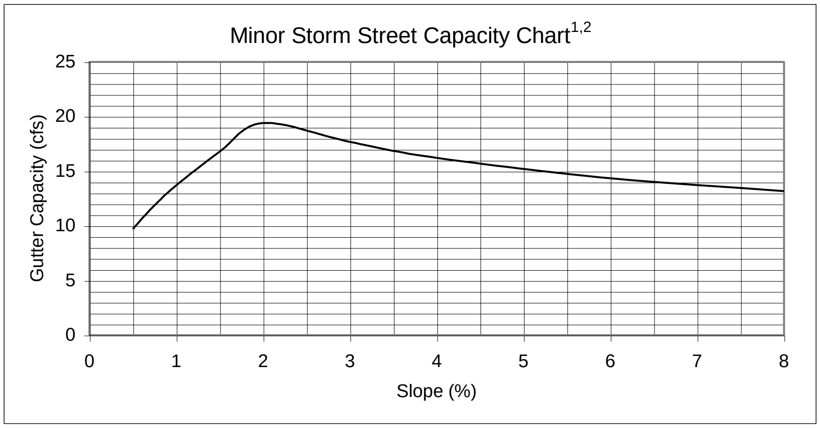
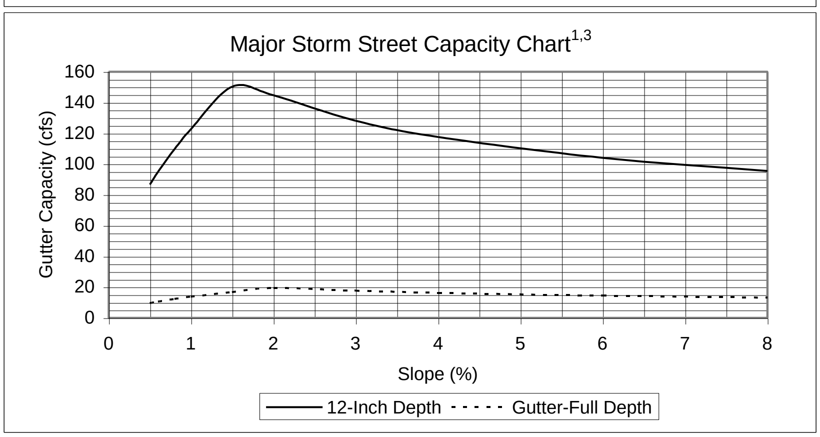
FIGURE 7-5, TOWN OF CASTLE ROCK STREET CAPACITY CHART

MAJOR COLLECTOR

Typical Cross Section







[1] The Town of Castle Rock standard street section parameters must apply to use these charts. For non-standard sections, the street capacity shall be calculated using the UDFCD spreadsheets (see Section 7.5). The capacity shown is based on ½ the street section.

[2] The maximum spread width is limited by the curb height based on no curb overtopping allowable during a minor storm.

[3] Calculations for the 12-inch depth curve assume a vertical wall behind the top of curb. For the gutter-full depth case, the Minor Storm Capacity Chart may be used.

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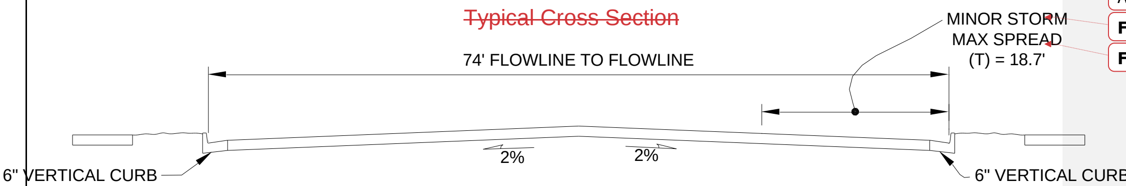
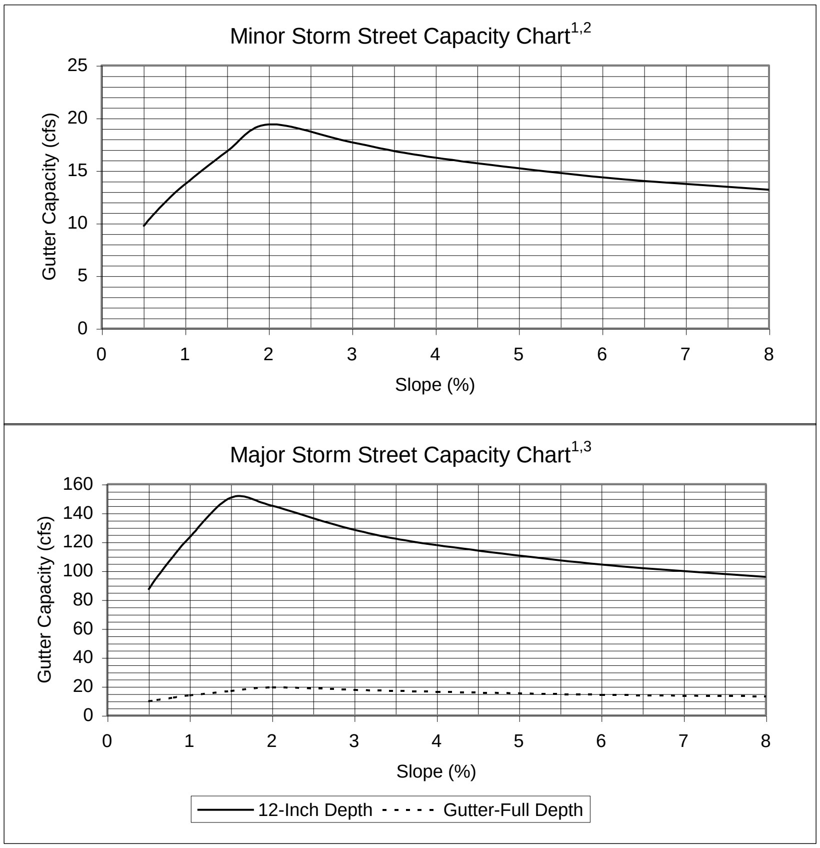
FIGURE 7-6, TOWN OF CASTLE ROCK STREET CAPACITY CHART

MINOR ARTERIAL

Typical Cross Section





[1] The Town of Castle Rock standard street section parameters must apply to use these charts. For non-standard sections, the street capacity shall be calculated using the UDFCD spreadsheets (see Section 7.5). The capacity shown is based on ½ the street section.

[2] The maximum spread width is limited by the curb height based on no curb overtopping allowable during a minor storm.

[3] Calculations for the 12-inch depth curve assume a vertical wall behind the top of curb. For the gutter-full depth case, the Minor Storm Capacity Chart may be used.

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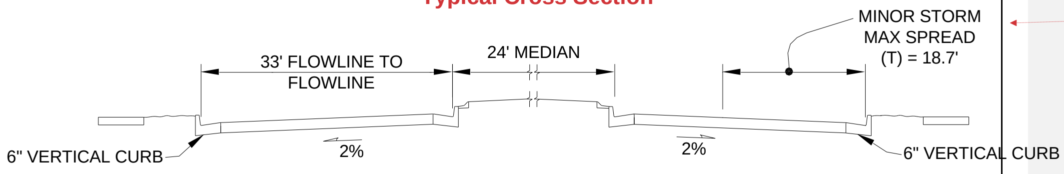
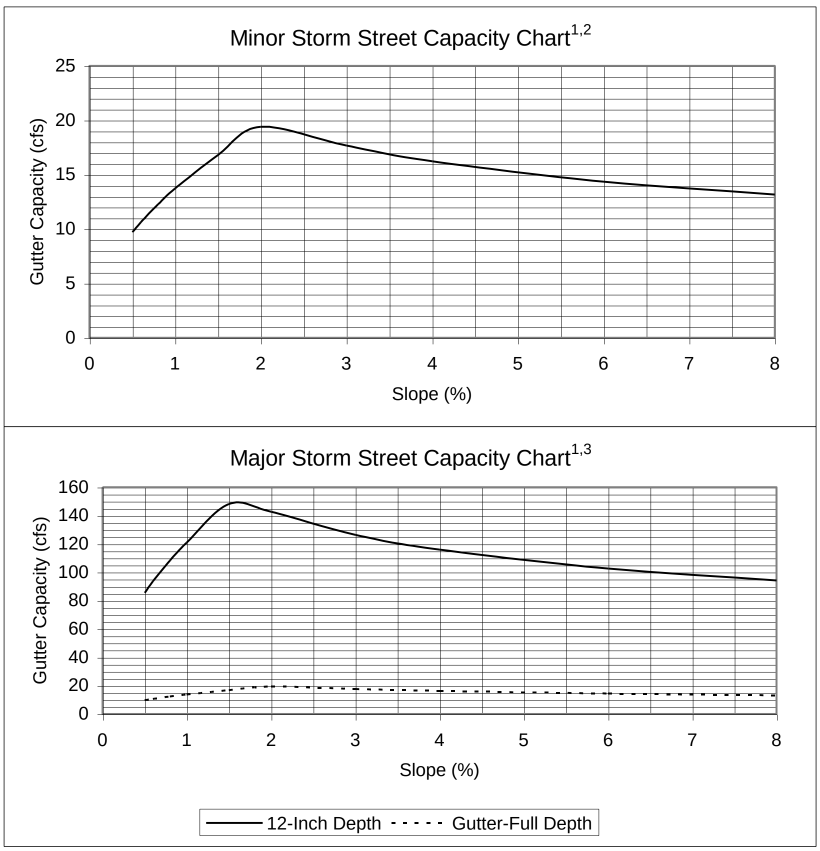
FIGURE 7-7, TOWN OF CASTLE ROCK STREET CAPACITY CHART

4 LANE MAJOR ARTERIAL

Typical Cross Section





[1] The Town of Castle Rock standard street section parameters must apply to use these charts. For non-standard sections, the street capacity shall be calculated using the UDFCD spreadsheets (see Section 7.5). The capacity shown is based on ½ the street section.

[2] The maximum spread width is limited by the curb height based on no curb overtopping allowable during a minor storm.

[3] Calculations for the 12-inch depth curve assume a vertical wall behind the top of curb. For the gutter-full depth case, the Minor Storm Capacity Chart may be used.

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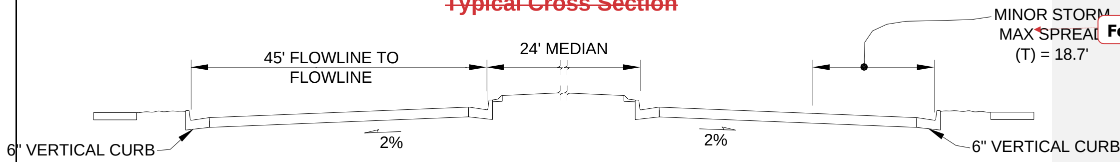
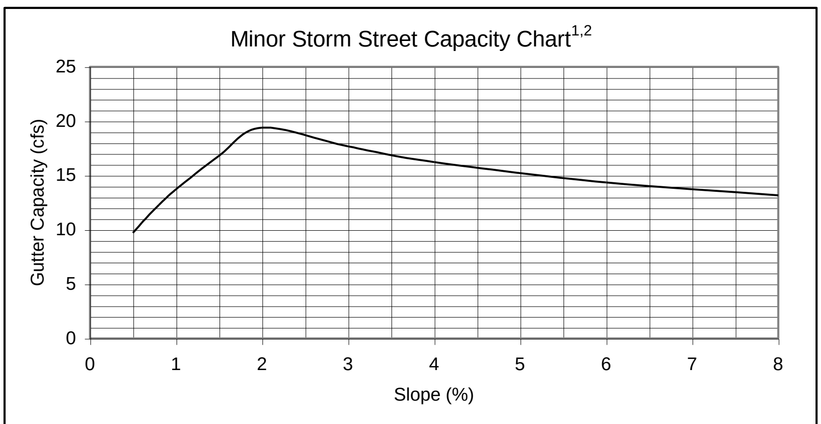
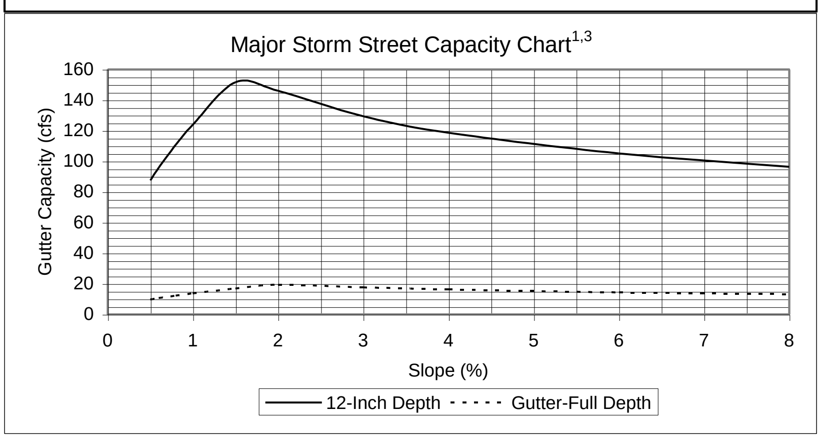
FIGURE 7-8, TOWN OF CASTLE ROCK STREET CAPACITY CHART

6 LANE MAJOR ARTERIAL

Typical Cross Section







[1] **The Town of Castle Rock standard street section parameters must apply to use these charts. For non-standard sections, the street capacity shall be calculated using the UDFCD spreadsheets (see Section 7.5). The capacity shown is based on ½ the street section.**

[2] **The maximum spread width is limited by the curb height based on no curb overtopping allowable during a minor storm.**

[3] Calculations for the 12-inch depth curve assume a vertical wall behind the top of curb. For the gutter-full depth case, the Minor Storm Capacity Chart may be used.

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Chapter 8. Inlets

8.0 Introduction

Presented in this chapter are the criteria and methodology for design and evaluation of storm sewer inlets located in Town of Castle Rock. The review of all planning submittals will be based on the criteria presented herein.

8.1 General

8.1.1 Function of Inlets. The primary purpose of storm drain inlets is to intercept excess surface runoff and convey it into a storm drainage system, thereby reducing or eliminating surface flooding. Roadway geometry often dictates the location of street inlets located along the curb and gutter. In general, inlets are placed at all low points (sumps), along continuous grade curb and gutter, median breaks, intersections, and crosswalks. The spacing of inlets along a continuous grade segment of roadway is governed by the lesser of the allowable depth and spread of flow. See further details of allowable spread of flow in Chapter 7, Street Drainage, of these criteria.

8.1.2 Types of Inlets. There are three types of inlets approved for use within the Town Right-of-Way and drainage easements: curb opening, grate and combination. Inlets are further classified as being on a "continuous grade" or in a "sump". The term "continuous grade" refers to an inlet placed in curb and gutter such that the grade of the street has a continuous slope past the inlet and, therefore, water ponding does not occur at the inlet. The sump condition exists whenever an inlet is located at a low point and the result is ponding water.

8.1.3 General Design Guidelines. The following guidelines shall be used when designing inlets along a street section:

1. Design and location of inlets shall take into consideration pedestrian and bicycle traffic. All inlet grates within the roadway shall be pedestrian and bicycle-safe.
2. Design and location of inlets shall be in accordance with the criteria established in Chapter 7, Street Drainage, of these criteria.
3. Maintenance ~~of inlets~~ shall be considered when determining inlet locations. The slope of the street, the potential for debris and ice accumulations, the distance between inlets and/or manholes etc., shall be considered. Maintenance access shall be provided to all inlets.
4. To avoid potential damage from large vehicles driving over the curb return, inlets shall not be placed in the curb return radii.
5. Selection of the appropriate inlet grate shall be based on a number of factors, including, but not limited to, the adjacent land use and potential for pedestrian or bicycle traffic, the potential for debris accumulation, visibility, expected loading from vehicles, and hydraulic capacity.
6. Flanking inlets are required on each side of the low point when the depressed area has no outlet except through the system. The purpose is to provide relief if the inlet at the low point becomes clogged. Consult FHWA HEC-22 for additional information regarding this concept. The use of flanking inlets in residential developments is discouraged and will be approved by variance

only. As a condition of approval for the use of flanking inlets, the downstream storm sewer system shall be sided for two times the major storm discharge to account for emergency overflow conveyance in lieu of an overland conveyance. The maximum allowable depth of ponding in an emergency overflow condition shall not exceed 12-inches.

7. In many cases, iInlets are necessary at grade breaks, where street or ditch grades change from steep to relative flat because of the reduced conveyance capacities. In addition, it is common for icing or sediment deposition to occur with nuisance flows in reaches where the grades are relatively mild.
7.8. For residential development, there shall be at least one layer of redundancy in the layout of inlets such that sump inlets shall not be the first and only point of entry to the storm sewer system for a subdivision.

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8.1.4 Inlet Capacity. The procedures used to define the capacity of standard inlets under continuous grade or sump flow conditions are described in the following sections. Unless otherwise noted, all storm sewer inlet criteria shall be in accordance with Section 3.0 of the Streets/Inlets/Storm Sewers Chapter in Volume 1 of the UDFCDMHFD Manual. In general, the procedure for calculating inlet capacity consists of defining the quantity and depth of flow in the gutter and determining the theoretical flow interception by the inlet.

8.2 Standard Town Inlets

8.2.1 Applicable Settings for Various Inlet Types. Table ST-5 from Section 3.0 of the Streets/Inlets/Storm Sewers Chapter in Volume 1 of the UDFCDMHFD Manual provides information on the appropriate application of the different types of inlets along with advantages and disadvantages of each. The information provided in this table should be taken into consideration when determining the inlet of choice for a given site condition.

8.2.2 Standard Inlets Accepted for Use in the Town. Table 8-1 provides the standard inlets permitted for use in the Town:

TABLE 8-1
STANDARD TOWN INLETS

Inlet Type	Standard Detail	Permitted Use
Curb Opening Inlet Type R	SD-1	All street types with 6-inch vertical curb and gutter; commercial /industrial areas; along standard roadway sections classified as B or C in Table 7-1
Grate Inlet Type C	SD-2	Roadside or median grass swales; Landscaped area drains; generally non-pedestrian accessible areas; Used in sump condition
Grate Inlet Type D	SD-2A	Roadside or median grass swales; Landscaped area drains; generally non-pedestrian accessible areas; Used in sump

		condition
Combination Inlet Denver Type 16	SD-3	Residential areas with 6-inch vertical and 4-inch mountable curb and gutter, with appropriate transitions; along standard roadway sections classified as A in Table 7-1

The inlets provided in Table 8-1 are accepted for use in the Town. For retrofit situations or when special circumstances exist, other inlets may be used but will be evaluated by the Town on a case-by-case basis. UD-Inlet must be used for hydraulic analysis of all non-standard inlets.

8.3 Inlets on Continuous Grade

8.3.1 Inlet Capacity Factors. The capacity of an inlet located on a continuous grade is dependent upon a variety of factors including gutter slope, depth and velocity of flow in the gutter, height and length of the curb opening, street cross slope, and the amount of depression at the inlet. Inlets placed on continuous grades rarely intercept all of the flow in the gutter during the minor storm. This results in flow continuing downstream of the inlet and is typically referred to as “carryover”. The amount of carryover must be accounted for in the drainage system evaluation as well as in the design of the downstream inlet.

8.3.2 Curb Opening Inlet (Type R). The capture efficiency of a curb opening inlet is dependent on the length of the opening, the depth of flow at the curb, the street cross slope, and the longitudinal gutter slope. If the curb opening is long, the flow rate is low, and the longitudinal gutter slope is small, all of the flow will be captured by the inlet. During the minor storm event, a portion of the stormwater often bypasses the inlet as indicated by the inlet efficiency. See Section 3.~~3~~2.2 of the Streets/Inlets/Storm Sewers chapter in Volume 1 of the ~~UDFCD~~MHFD Manual for additional information on the efficiency and design of curb opening inlets on continuous grades.

8.3.3 Type 16 Combination Inlet. The capture efficiency of a combination inlet is dependent on the length of the opening, the depth of flow at the curb, the street cross slope, and the longitudinal gutter slope. If the combination inlet is long, the flow rate is low, and the longitudinal gutter slope is small, all of the flow will be captured by the inlet. During the minor storm event, a portion of the stormwater often bypasses the inlet as indicated by the inlet efficiency. See Section 3.~~3~~2.3 of the Streets/Inlets/Storm Sewers chapter in Volume 1 of the ~~UDFCD~~MHFD Manual for additional information on the efficiency and design of combination inlets on continuous grades.

8.4 Hydraulic Evaluation of Inlets on Continuous Grade

~~**8.4.1 Preliminary Versus Final Design of Inlets on Continuous Grade.** Capacity charts for Type 16 combination inlets along standard Town street sections with Drainage Classification “A” have been completed for the minor and major storm events, based on the maximum allowable flow in the street section. Capacity~~

charts for Type R inlets along standard Town street sections with Drainage Classifications "B" and "C" have been completed for the minor and major storm events, based on the maximum allowable flow in the street section. Further discussion on the use of these charts can be found in Sections 8.4.3 and 8.4.4. It is recommended that these charts be used for preliminary design phases and rough inlet placement. For final design, the design engineer can use these charts if the street is at maximum allowable flow. When flow in the gutter is less than maximum flow, the UD-Inlet spreadsheets, or equivalent Town approved software, shall be used to determine the interception by the proposed inlet. Further discussion on the use of UD-Inlet for less than maximum allowable flow can be found in Section 8.4.5.

8.4.12 Inlet Analysis Spreadsheets. The design engineer shall use the UD-Inlet spreadsheets, or equivalent Town approved software, to determine the interception by the proposed inlet. Further discussion on the use of UD-Inlet can be found in Section 8.4.5. The Streets/Inlets/Storm Sewers chapter of the UDFCDMHFD Manual provides detailed instruction on the appropriate analysis of inlet capacities including equations, coefficients, and examples. The UD-Inlet spreadsheets are the most accurate means of determining inlet capture rates and completing capacity calculations. The UD-Inlet spreadsheets may be downloaded from the UDFCDMHFD web site at udfcdMHFD.org. The design engineer can elect to use an equivalent software with the approval of Town Staff.

8.4.3 Minor Event Curb Opening and Combination Inlet Capacity Charts for Standard Street Sections at Maximum Capacity. The Town allows Type 16 combination inlets along streets with Drainage Classification "A" and Type R curb opening inlets along streets with Drainage Classifications "B" and "C". Minor event inlet capacity charts for curb opening inlets and combination inlets on continuous grades along their appropriate standard Town street sections have been generated and can be found at the end of this chapter (Figures 8-1 through 8-8). These inlet capacity charts were calculated based on the maximum flow allowed in the street gutter for the minor design storm. These charts also incorporate clogging factors as discussed in Section 3.3.6 in the Streets/Inlets/Storm Sewers chapter in Volume 1 of the UDFCD Manual. Chapter 7, Street Drainage, provides additional information on the maximum street flow allowed for the minor storm event.

8.4.4 Major Event Curb Opening and Combination Inlet Capacity Charts for Standard Street Sections at Maximum Capacity. Major event inlet capacity charts for curb opening inlets and combination inlets on continuous grades along their appropriate standard Town street sections have also been generated and can be found at the end of this chapter (Figures 8-1 through 8-8). These inlet capacity charts were calculated based on the maximum flow allowed in the street gutter for the major design storm. Chapter 7, Street Drainage, provides additional information on the maximum street flow allowed for the major storm event. The major storm inlet capacity charts contain two curves, which correspond to the street capacity charts generated in Chapter 7 Street Drainage. The two curves represent both 6-inches and 12-inches of depth at the gutter flowline. Both curves are provided to assist the design engineer in calculating

~~the inlet capacity based upon the gutter flow depth that meets the Town street flow criteria. Due to the large scale of the major storm inlet capacity chart, the minor storm inlet capacity chart may be used to determine a more accurate interception rate for the gutter-full condition. These inlet capacity charts also incorporate clogging factors as discussed in Section 3.3.6 in the Streets/Inlets/Storm Sewers chapter in Volume 1 of the UDFCD Manual.~~

~~**8.4.5 Procedure for Street Flows Less than Maximum Allowable.** For final design, if the quantity of flow in the street is less than the maximum allowable flow (minor or major event) as determined per Chapter 7 Street Drainage of these criteria, then the design engineer must determine the interception rate of the Type R or Type 16 inlet using UD-Inlet, or equivalent Town approved software, based on the actual flow in the gutter.~~

~~**8.4.6 Non-Standard Street Sections and Other Types of Inlets.** There are two additional cases when the design engineer must use the UD-Inlet worksheets in the UDFCD Manual (or equivalent Town approved software) to determine the minor and major storm allowable inlet capacity. The first case occurs when a non-standard street section is analyzed. The second case is when the inlet being analyzed is not a Type R curb opening or Type 16 combination inlet. The appropriate worksheets from the UD-Inlet spreadsheet (or equivalent Town approved software), should be used for calculating the capacity of an inlet when either of these aforementioned cases occur.~~

8.5 Inlets in Sump Conditions

8.5.1 Capacity Calculation Factors and Inlet Selection. Inlets located in sumps (low points) must be sized to intercept all of the design storm flows at a predetermined reasonable depth of ponding. The capacity of an inlet in a sump is dependent upon the depth of ponding above the inlet and the amount of debris clogging the inlet. Ponded water is a nuisance and can be a hazard to the public; therefore curb opening and combination inlets are highly recommended for sump conditions due to their reduced clogging potential versus grate inlets acting alone.

8.5.2 Hydraulic Capacity Calculations. ~~Capacity charts for Type 16 combination, Type C and Type R inlets in a sump condition are located at the end of this chapter, Figures 8-9 through 8-11. These charts are based upon the depth of ponding above the inlet.~~ <u>UD-Inlet shall be used for the sizing of inlets in the sump condition. The designer shall take specific caution to calculate the limitations of ponding depth based on the site layout and design.</u> The depth of ponded water shall be contained within the Right-of-Way <u>(and area adjacent to the Right-of-Way)</u> and shall not exceed the maximum allowable water depth for the given street classification as summarized in Chapter 7, Street Drainage. All calculations for inlets located in a sump shall conform to the procedures, variables, and coefficients provided in Section 3.<u>2</u>~~3.5 and Table ST-7~~ in the Streets/Inlets/Storm Sewers chapter in Volume 1 of the ~~UDFCD~~<u>MHFD</u> Manual.

8.5.3 Emergency Overflow Path with Drainage Tract. A surface flow path within Town Right-of-Way or a drainage tract shall be provided at all sump inlets to provide for emergency overflows if the inlet becomes clogged. The emergency overflow shall be designed to convey the major storm discharge. The depth of ponding shall not exceed the maximum allowable water depth for the given street classification as summarized in Chapter 7, Street Drainage. Flow routing shall be identified to the nearest major drainageway and the conveyance system shall be designed to provide capacity for the major storm event without causing erosion and without impacting private property or adjacent structures.

8.5.4 Type C and D Inlets. The inlet capacity curve for a Type C inlet is provided. To determine the capacity of a Type D inlet in a sump, the capacity curve for a two grate Type C inlet shall be used. The capacity curves provided at the end of this chapter include a 50 percent reduction factor for a standard grate and a 75 percent reduction factor for a close mesh grate. If a Type C or D inlet is placed in an area with pedestrian traffic, a close mesh grate shall be used.

8.6 Inlet Location and Spacing

8.6.1 Inlet Location and Spacing. The location and spacing of inlets is based upon street design considerations, topography (sumps), maintenance requirements, and the allowable spread of flow within the street. A significant amount of cost savings can be realized if inlets are placed in locations where their efficiency is maximized. The greater the efficiency of an inlet, the smaller the carryover flow, which may result in a smaller number of inlets downstream. Inlets are most efficient in a sump condition or along mild continuous street grades.

8.6.2 Inlet Placement on a Continuous Grade Based on Flow Spread. As the flow increases in the gutter on a long, continuous grade segment of roadway so does the spread. Since the spread (encroachment) is not allowed to exceed the maximum spread specified in Chapter 7 Street Drainage, inlets need to be strategically placed to remove flow from the gutter. A properly designed storm sewer system makes efficient use of the conveyance capacity of the street gutters by positioning inlets at the point where the allowable spread is about to be exceeded for the design storm. Section 3.~~2~~4 of the Streets/Inlets/Storm Sewers chapter in Volume 1 of the ~~UDFCD~~MHFD Manual provides a detailed discussion on inlet placement on continuous grades. A maximum distance of 1,500 feet is allowed between the high point of a road and placing of the first inlet. The maximum spacing between inlets along a continuous grade is 1,500 feet.

8.7 Other Design Considerations

8.7.1 Computer Programs/Equivalent Software. The Town of Castle Rock requires that the ~~UDFCD~~MHFD UD-Inlet spreadsheet be used to complete inlet capacity calculations. Alternate computer programs will be considered on a case-by-case basis. The Town of Castle Rock must grant approval for the use of an alternative computer program prior to its use.

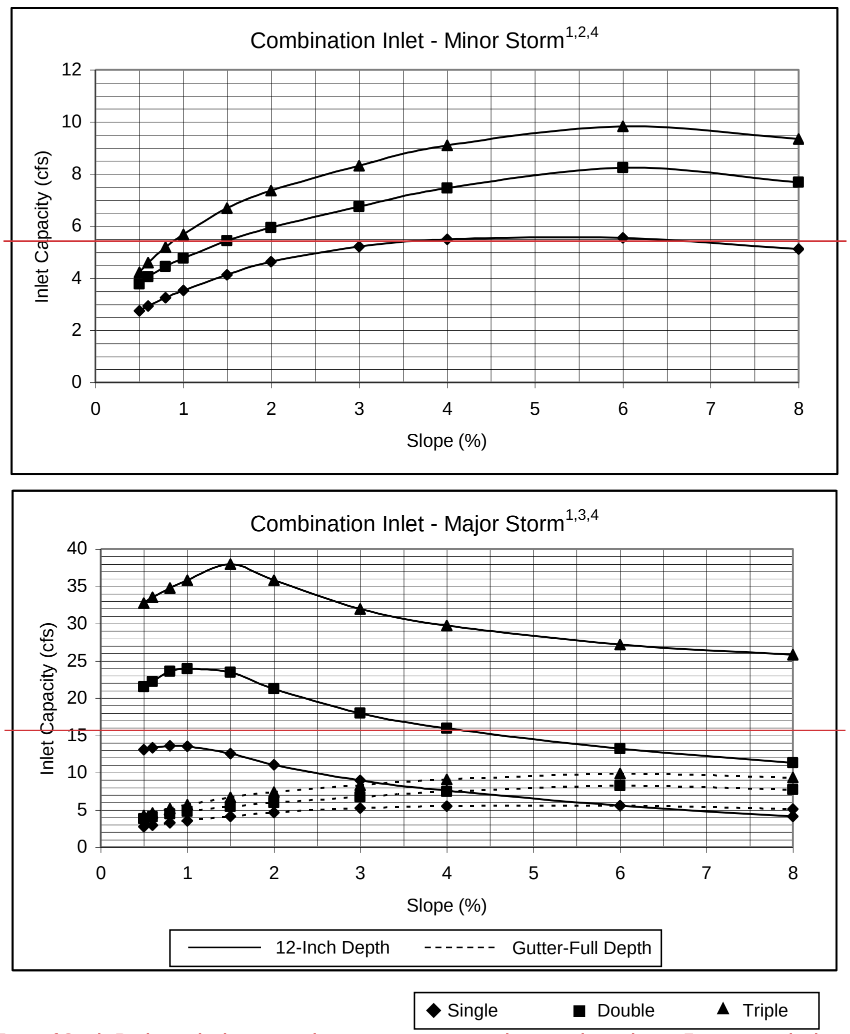
8.7.2 Curb Chase Drain (Sidewalk Chase). Curb chase drains shall NOT be used in place of a standard inlet to remove runoff from a street section. Curb chase drains have limited efficiency and have poor long-term performance. Use of curb chase drains shall be evaluated on a case-by-case basis and must be approved by the ~~Stormwater~~ Technical Engineering Manager.

8.7.3 Maximum Inlet Length. Inlets shall be designed to blend in with the streetscape, and not present a dramatic structural departure from the general surroundings. The use of extremely long inlets is discouraged, as they are generally not aesthetic, require increased maintenance, and are viewed as a hazard by the public. The maximum length of an inlet in a specific location shall not exceed the length of a triple unit (i.e., 9-feet for a Type 16 combination inlet or 15-feet for a Type R inlet).

~~FIGURE 8-1, INLET CAPACITY CHART COMBINATION (TYPE 16) INLET~~

~~LOCAL TYPE I AND TYPE II (SINGLE FAMILY)~~

~~Street Section Data: Street Width Flowline to Flowline = 36'~~
~~Type of Curb and Gutter = 4" combination~~
~~Minor Storm Maximum Spread = 13.9'~~



~~[1]The Town of Castle Rock standard street section parameters must apply to use these charts. For non-standard sections, the inlet capacity shall be calculated using the UDFCD spreadsheets (see Section 8.4).~~
~~[2] The maximum spread width is limited by the curb height based on no curb overtopping allowable during a minor storm.~~
~~[3]Calculations for the 12-inch depth curve assume a vertical wall behind the top of curb. For the gutter-full depth case, the Minor Storm Capacity Chart may be used.~~
~~[4]The capacity shown assumes gutter-full depth of 4.9" to the back of the attached sidewalk. If a 4" curb without an attached sidewalk is used, the street capacity shall be calculated using the UDFCD spreadsheets.~~

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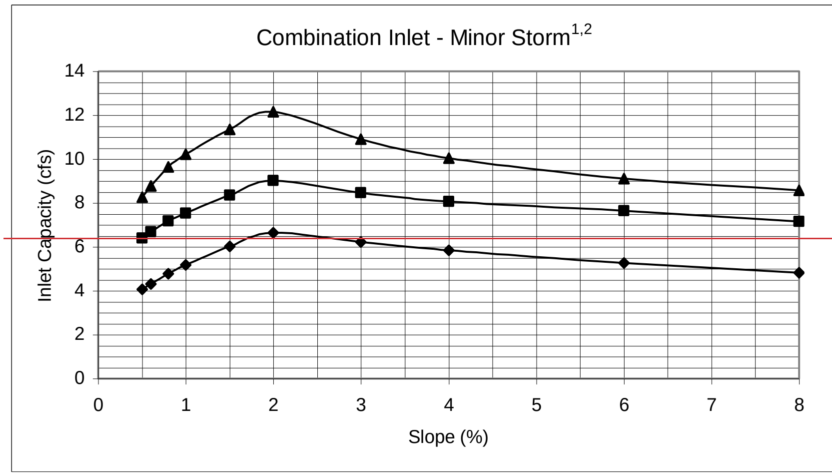
FIGURE 8-2, INLET CAPACITY CHART COMBINATION (TYPE 16) INLET

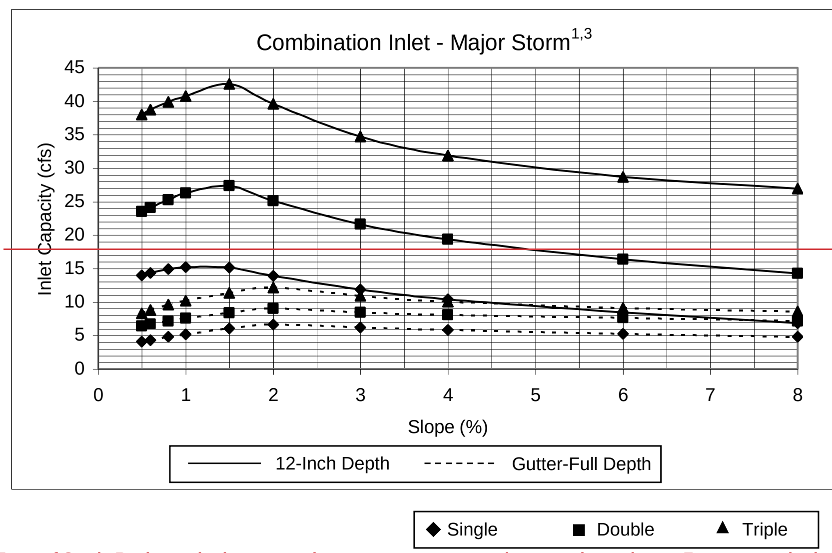
LOCAL TYPE I AND TYPE II (MULTI-FAMILY)

Street Section Data: **Street Width Flowline to Flowline = 44'**

Type of Curb and Gutter = 6" vertical

Minor Storm Maximum Spread = 18.7'





[1] The Town of Castle Rock standard street section parameters must apply to use these charts. For non-standard sections, the inlet capacity shall be calculated using the UDFCD spreadsheets (see Section 8.4).

[2] The maximum spread width is limited by the curb height based on no curb overtopping allowable during a minor storm.

[3] Calculations for the 12-inch depth curve assume a vertical wall behind the top of curb. For the gutter-full depth case, the Minor Storm Capacity Chart may be used.

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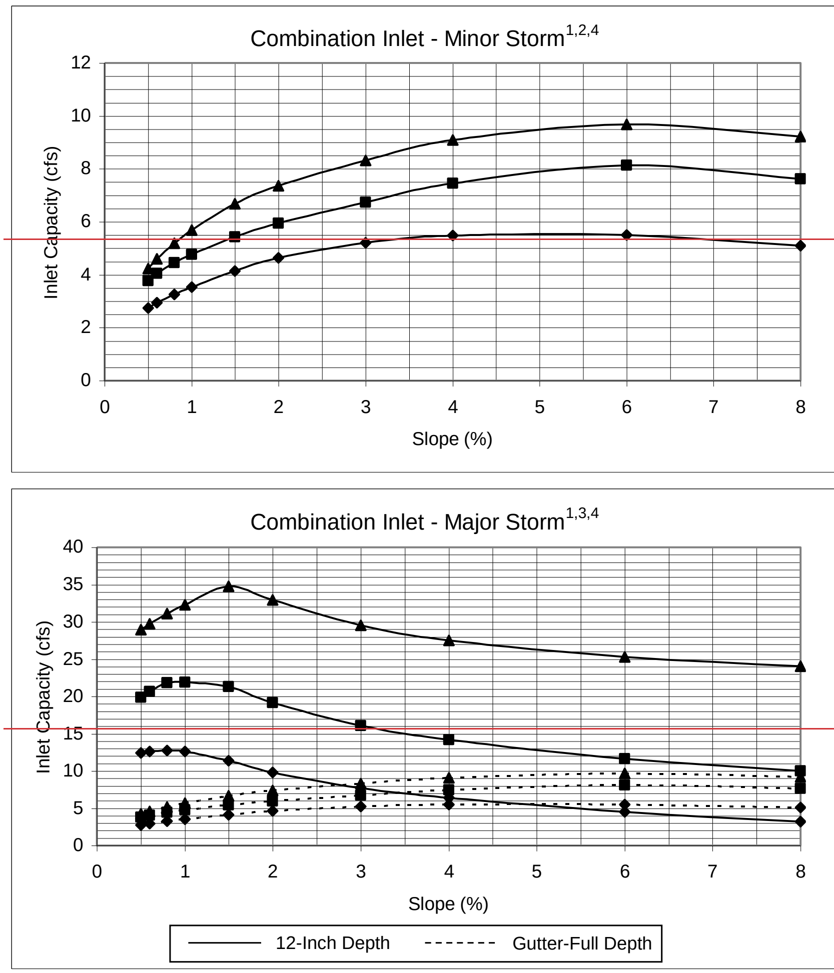
FIGURE 8-3, INLET CAPACITY CHART COMBINATION (TYPE 16) INLET
LOCAL TYPE III

Street Section Data: **Street Width Flowline to Flowline = 28'**
Type of Curb and Gutter = 4" combination
Minor Storm Maximum Spread = 13.9'



◆ Single ■ Double ▲ Triple

[1]The Town of Castle Rock standard street section parameters must apply to use these charts. For non-standard sections, the inlet capacity shall be calculated using the UDFCD spreadsheets (see Section 8.4).
[2] The maximum spread width is limited by the curb height based on no curb overtopping allowable during a minor storm.
[3]Calculations for the 12-inch depth curve assume a vertical wall behind the top of curb. For the gutter-full depth case, the Minor Storm Capacity Chart may be used.
[4]The capacity shown assumes gutter-full depth of 4.9" to the back of the attached sidewalk. If a 4" curb without an attached sidewalk is used, the street capacity shall be calculated using the UDFCD spreadsheets.

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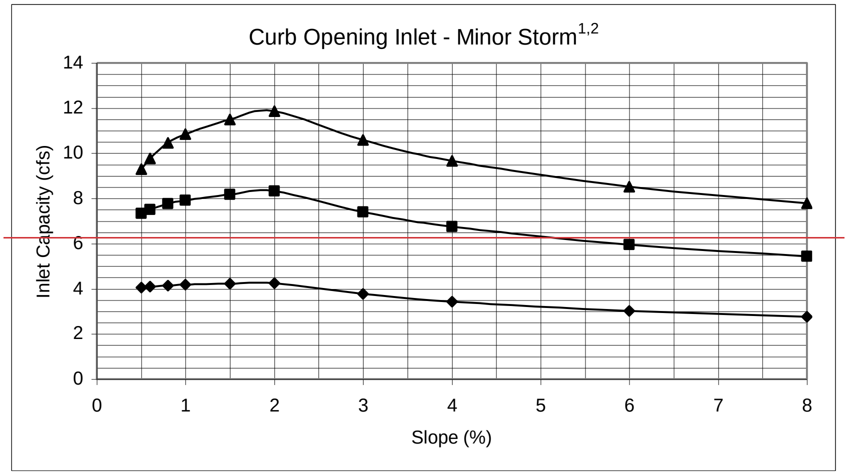
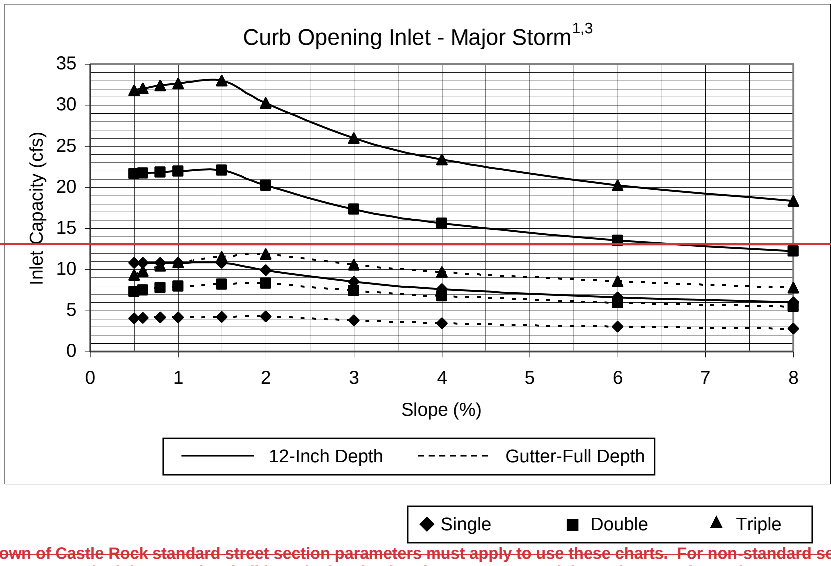
FIGURE 8-4, INLET CAPACITY CHART CURB OPENING (TYPE R) INLET
MINOR COLLECTOR

Street Section Data: Street Width Flowline to Flowline = 48'
Type of Curb and Gutter = 6" vertical
Minor Storm Maximum Spread = 18.7'





[1] The Town of Castle Rock standard street section parameters must apply to use these charts. For non-standard sections, the inlet capacity shall be calculated using the UDFCD spreadsheets (see Section 8.4).
[2] The maximum spread width is limited by the curb height based on no curb overtopping allowable during a minor storm.
[3] Calculations for the 12-inch depth curve assume a vertical wall behind the top of curb. For the gutter-full depth case, the Minor Storm Capacity Chart may be used.

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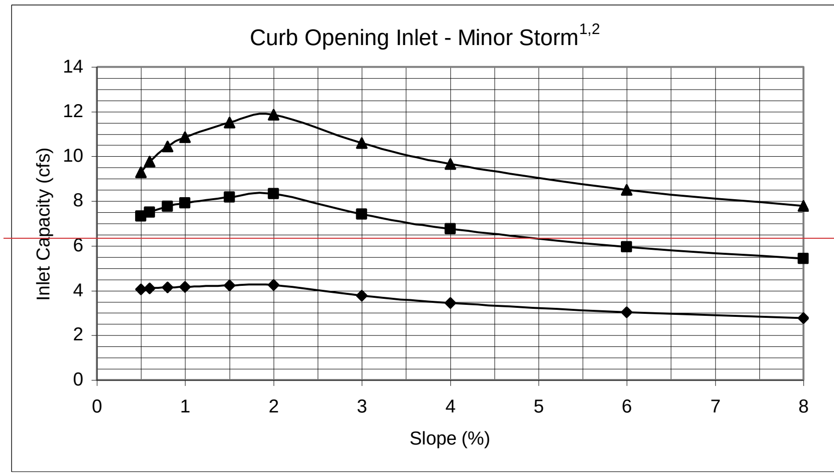
FIGURE 8-5, INLET CAPACITY CHART CURB OPENING (TYPE R) INLET

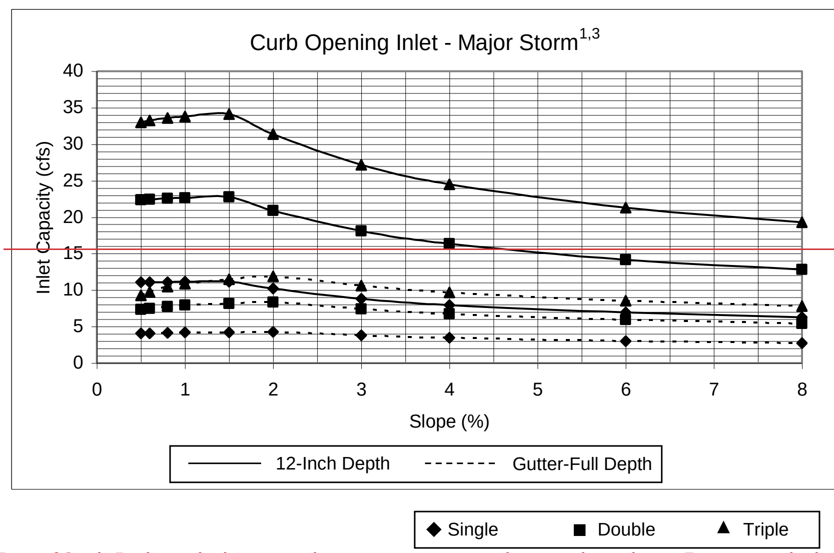
MAJOR COLLECTOR

Street Section Data: **Street Width Flowline to Flowline = 72'**

Type of Curb and Gutter = 6" vertical

Minor Storm Maximum Spread = 18.7'





[1]The Town of Castle Rock standard street section parameters must apply to use these charts. For non-standard sections, the inlet capacity shall be calculated using the UDFCD spreadsheets (see Section 8.4).
[2] The maximum spread width is limited by the curb height based on no curb overtopping allowable during a minor storm.
[3]Calculations for the 12-inch depth curve assume a vertical wall behind the top of curb. For the gutter-full depth case, the Minor Storm Capacity Chart may be used.

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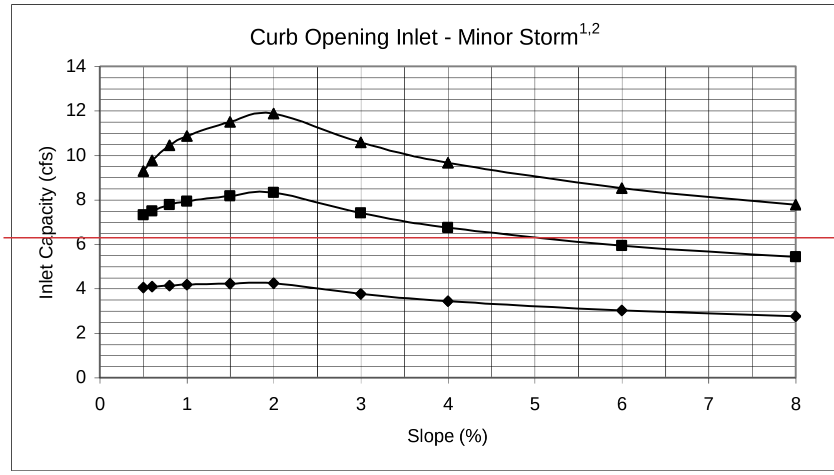
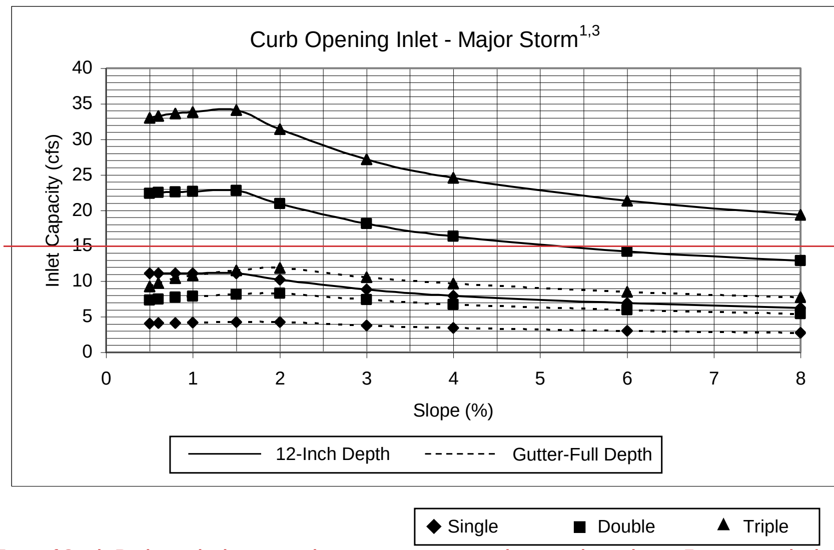
FIGURE 8-6, INLET CAPACITY CHART CURB OPENING (TYPE R) INLET
MINOR ARTERIAL

Street Section Data: **Street Width Flowline to Flowline = 74'**
Type of Curb and Gutter = 6" vertical
Minor Storm Maximum Spread = 18.7'





[1]The Town of Castle Rock standard street section parameters must apply to use these charts. For non-standard sections, the inlet capacity shall be calculated using the UDFCD spreadsheets (see Section 8.4).
[2] The maximum spread width is limited by the curb height based on no curb overtopping allowable during a minor storm.
[3]Calculations for the 12-inch depth curve assume a vertical wall behind the top of curb. For the gutter-full depth case, the Minor Storm Capacity Chart may be used.

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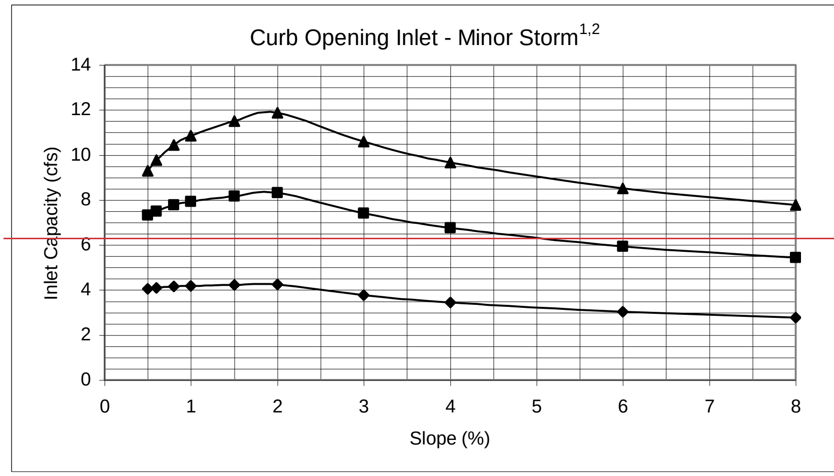
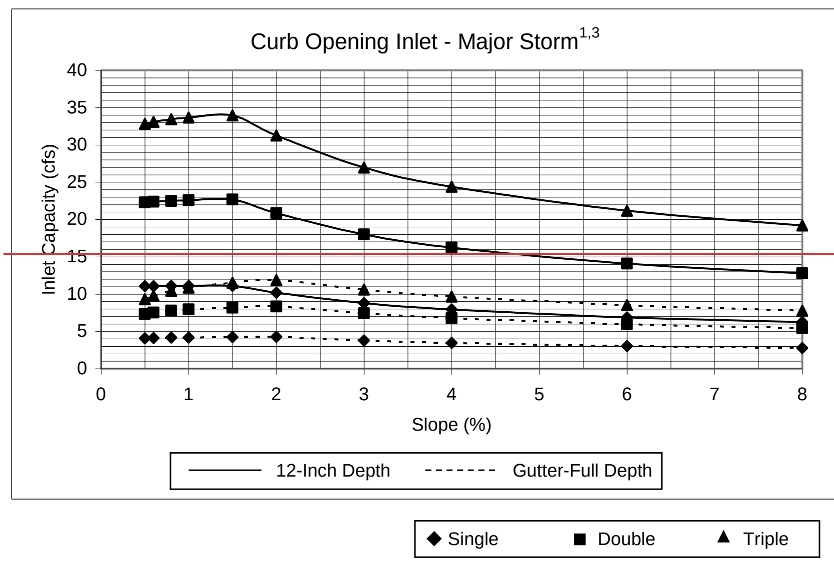
FIGURE 8-7, INLET CAPACITY CHART CURB OPENING (TYPE R) INLET
4 LANE MAJOR ARTERIAL

Street Section Data: **Street Width Flowline to Flowline = 33'**
Type of Curb and Gutter = 6" vertical
Minor Storm Maximum Spread = 18.7'



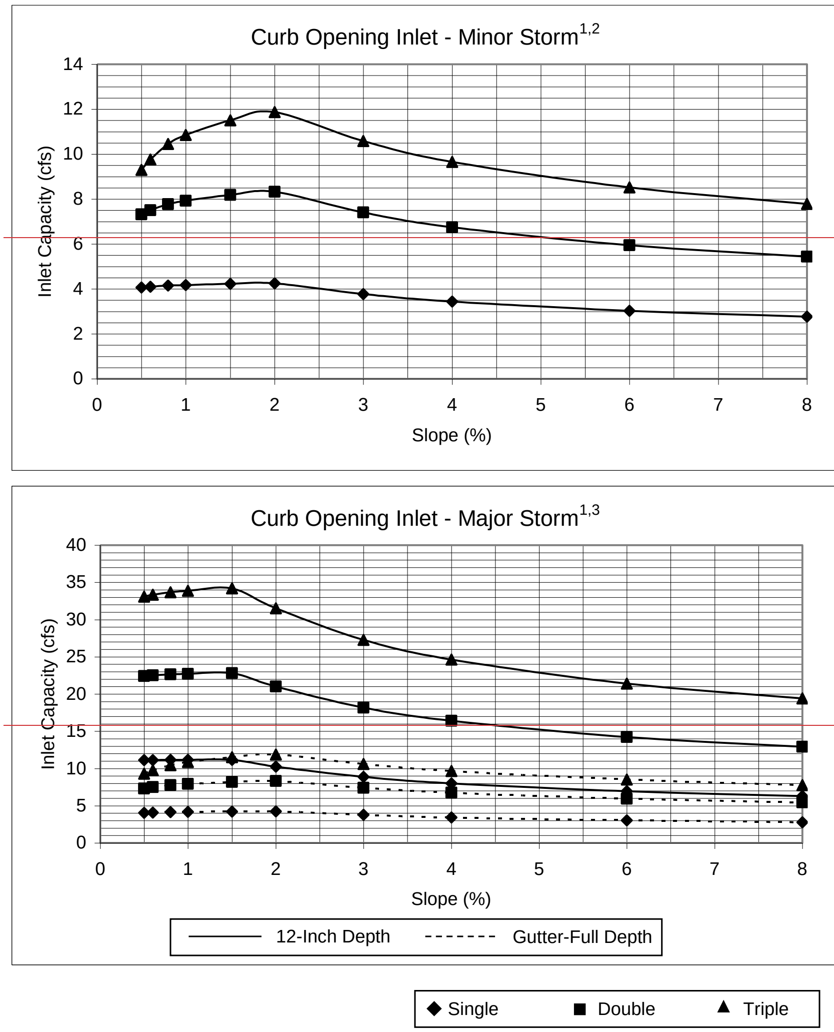


[1]The Town of Castle Rock standard street section parameters must apply to use these charts. For non-standard sections, the inlet capacity shall be calculated using the UDFCD spreadsheets (see Section 8.4).
[2] The maximum spread width is limited by the curb height based on no curb overtopping allowable during a minor storm.
[3]Calculations for the 12-inch depth curve assume a vertical wall behind the top of curb. For the gutter-full depth case, the Minor Storm Capacity Chart may be used.

FIGURE 8-8, INLET CAPACITY CHART CURB OPENING (TYPE R) INLET

6 LANE MAJOR ARTERIAL

Street Section Data: **Street Width Flowline to Flowline = 45'**
Type of Curb and Gutter = 6" vertical
Minor Storm Maximum Spread = 18.7'



[1]The Town of Castle Rock standard street section parameters must apply to use these charts. For non-standard sections, the inlet capacity shall be calculated using the UDFCD spreadsheets (see Section 8.4).
[2] The maximum spread width is limited by the curb height based on no curb overtopping allowable during a minor storm.
[3]Calculations for the 12-inch depth curve assume a vertical wall behind the top of curb. For the gutter-full depth case, the Minor Storm Capacity Chart may be used.

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FIGURE 8-1~~9~~, INLET CAPACITY CHART SUMP CONDITIONS
AREA (TYPE C) INLET

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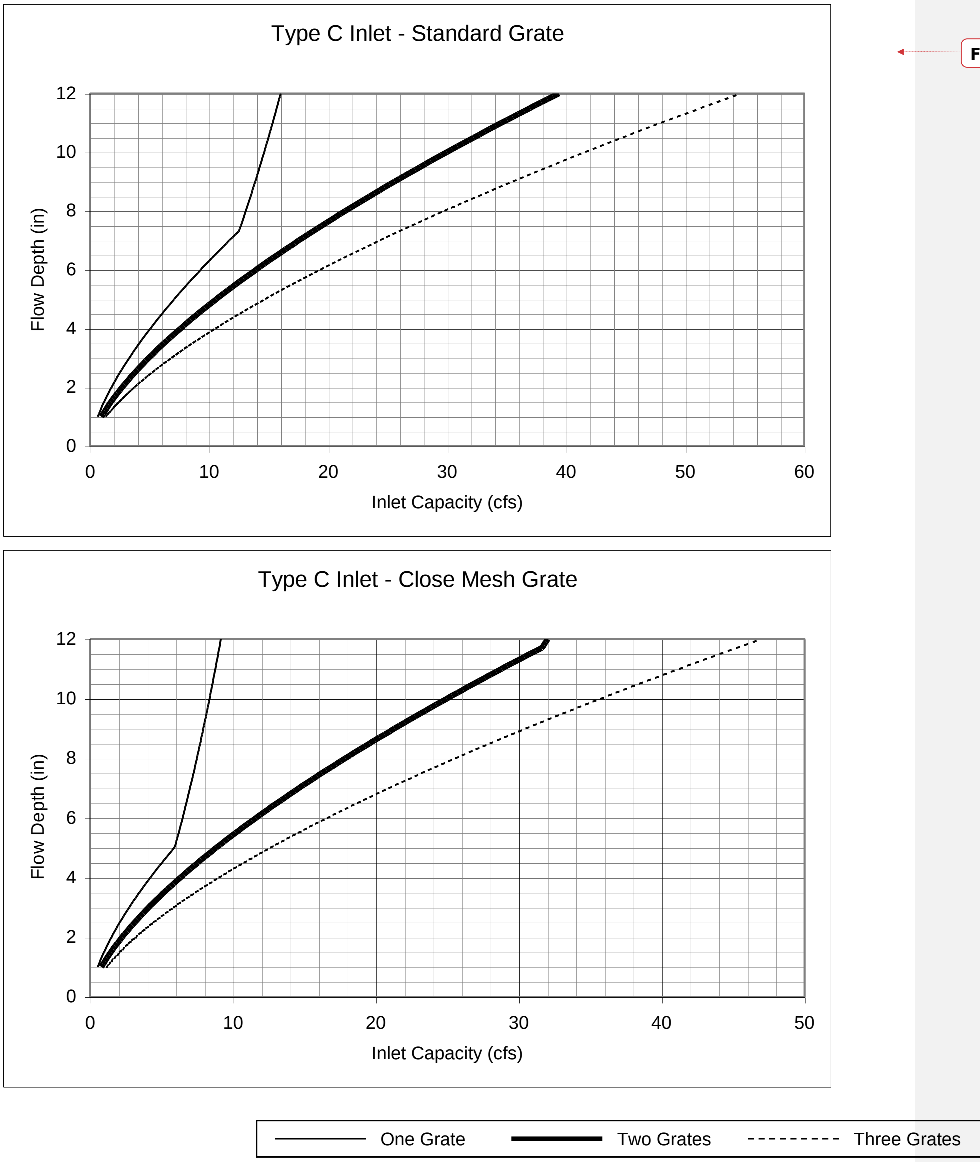
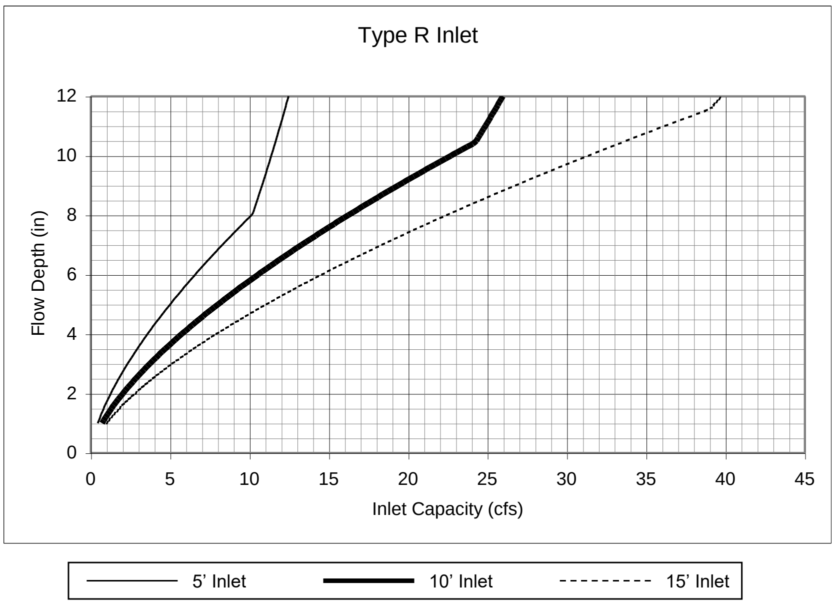


Notes:
1. **The Town of Castle Rock standard inlet parameters must apply to use these charts.**

FIGURE 8-10, INLET CAPACITY CHART SUMP CONDITIONS
CURB OPENING (TYPE R) INLET



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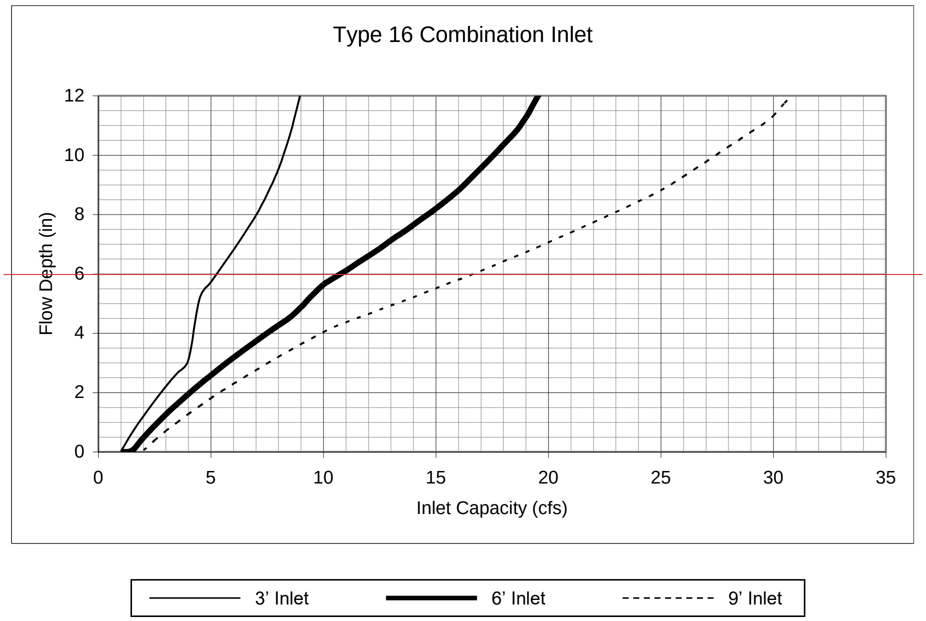
Notes:
1. The Town of Castle Rock standard inlet parameters must apply to use this chart.

FIGURE 8-11, INLET CAPACITY CHART SUMP CONDITIONS
COMBINATION (TYPE 16) INLET



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Notes:
1. The Town of Castle Rock standard inlet parameters must apply to use this chart.

9.0 Introduction

This chapter summarizes design criteria and evaluation methods for storm sewer systems in the Town of Castle Rock. The review of all planning submittals will be based on the criteria presented herein.

9.0.1 Stormwater Quality Considerations. Traditionally, urban development has relied on storm sewer systems in the upper portions of watersheds. As storm sewers pick up more drainage area, they increase in size. When the basin size exceeds 130-acres the general practice is to switch from storm sewers to open channels.

Today, with the emphasis on runoff reduction and water quality enhancement, stormwater management practices are turning to concepts that retain or create a surface drainage network extending upstream of major drainageways. To promote infiltration, attenuation and water quality enhancement, properly designed drainageways and swales can serve in place of storm sewers. When planning a new project, the use of grass swales and drainageways to reduce the extent of storm sewers must be considered. This concept, termed "Minimizing Directly Connected Impervious Areas", is discussed in more detail in Chapter 14, Stormwater Quality.

Since replacing inlets and storm sewers with grass swales and drainageways is not reasonable in all cases, storm sewers will continue to be an integral part of many drainage systems.

9.1 Design Storms for Sizing Storm Sewers

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

9.1.1 Minor Event Storm Sewer Design. 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, Street Drainage). Inlets shall be located at these points to intercept excess minor event flow and direct it to the storm sewer. The storm sewer shall be sized to convey the design storm without surcharging the storm sewer pipes. Section 9.8.2 provides additional information on hydraulic design methods for the minor storm.

9.1.2 Major Event Storm Sewer Design. There are conditions when the storm sewer system needs to be sized to convey flows greater than the minor storm runoff (and as much as the major storm runoff), including the following:

1. Locations where the street capacity for the major storm is exceeded

2. Locations where major storm flows can split off in undesirable directions (i.e., flow splits at intersections)
3. Locations where 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 designed for the major storm
5. Locations where storm sewers must convey undetained flows to a regional detention pond
~~5.~~6. Downstream of sump inlets

If a storm sewer is to be designed to carry major storm flows, the inlets to the storm sewer shall be designed accordingly. The major storm event hydraulic grade line is allowed to rise above the top of the storm sewer pipe and surcharge the system. The major storm event hydraulic grade line elevation shall be a minimum of 1-foot below the manhole lid, inlet grate or inlet curb opening elevation. In no case shall the surcharge create system velocities in excess of the maximum outlined in Section 9.8.1.

The major storm event hydraulic grade line must also be analyzed for storm sewer systems designed to convey the minor storm event runoff. Since the flow depth in the street during the major storm will typically be greater than the minor storm, inlets may intercept additional runoff and the flow in the storm sewer will be greater than during the minor storm event. Any surcharge created by conveyance of the additional runoff is subject to the limits outlined above. Section 9.8.3 provides additional information on hydraulic design methods for the major storm.

9.2 Storm Sewer Pipe Material and Size

9.2.1 Storm Sewer Pipe Material. All storm sewers located within the Town of Castle Rock public easements or in private streets shall be constructed with reinforced concrete pipe (RCP). Urban Drainage and Flood Control District has performed an extensive evaluation of the performance of various types of storm sewer pipe materials and this information is presented in the *~~UDFCD~~MHFD Update to Storm Sewer Pipe Material Technical Memorandum* dated March 1998, herein referred to as the *~~UDFCD~~MHFD Pipe Memo.* Circular pipe is the most cost effective option for reinforced concrete, but elliptical pipe may be a more appropriate option in areas where available cover is limited.

Alternate pipe materials may be considered for private storm sewers with the Town of Castle Rock approval prior to submittal of drainage reports or construction drawings for Town review. A private storm sewer system is defined as a system that conveys runoff generated by one subdivided lot or parcel. When a storm sewer system conveys runoff from two or more subdivided lots or parcels, it is considered a "public" system. The alternate pipe material that is proposed must conform to the requirements set forth in the *~~UDFCD~~MHFD Pipe Memo*, however, the Town will recognize changes in applicable standards and specifications since that document was published. For instance, AASHTO M294 – Type S – Corrugated Polyethylene Pipe is applicable for pipe diameters from

12-inches to 60-inches. Trench details, installation specifications, minimum cover or fill height limits, and construction testing requirements for alternate pipe materials shall be consistent with those recommended by the manufacturer/supplier or as determined by Town of Castle Rock.

Outlets into detention or water quality ponds and connections to the public storm sewer system must be constructed with RCP. This typically requires a change in pipe material at the privately owned structure (i.e., manhole or inlet) immediately upstream from the connection to the public storm sewer or the pond outfall.

9.2.2 Minimum Pipe Size. The minimum allowable pipe size for storm sewers located within Town Rights-of-Way and public easements is presented in Table 9-1:

TABLE 9-1
MINIMUM STORM SEWER PIPE DIAMETERS

Type	Pipe Diameter
Main Trunk	18-inch
Lateral from Inlet	18-inch
Outlet from Detention Pond	18-inch

9.2.3 Driveway Culverts. See Section 11.4 of Chapter 11, Culverts and Bridges, for the Town criteria on driveway culverts.

9.3 Other Design Considerations

9.3.1 RCP Pipe Class, Fill Height, and Installation Trench. The minimum class of reinforced concrete pipe shall be Class III, however, the depth of cover, live load, and field conditions may require structurally stronger pipe. The Town of Castle Rock trench installation requirements, trench installation details, and allowable fill heights are shown on the Town of Castle Rock Standard Detail SD-5. It is the responsibility of the design engineer to develop and submit alternate trench and installation details when project specific conditions or loadings require modification to the standard installation. Alternate designs shall follow ASTM C1479.

9.3.2 Storm Sewer Joints. All storm sewer installations, within public and private roadways and public easements, shall have watertight joints. ASTM Standard C 443 covers flexible watertight joints for circular concrete sewer and culvert pipe and precast manhole sections, using rubber gaskets for sealing the joints.

9.3.3 Trash Racks. Trash/safety racks shall not be used at storm sewer outlets.

9.3.4 Conduit Outlet Structures. See Chapter 10, Conduit Outlet Structures, for discussion regarding conduit outlet structures at storm sewer outfalls.

9.4 Easements and Maintenance

9.4.1 Storm Sewer Easements. Drainage easements are required in order to ensure the proper construction and maintenance of storm sewers and related facilities. See Chapter 2 Stormwater Policy and Principles, for further discussion regarding storm sewer easements.

9.4.2 Minimum Acceptable Storm Sewer Easements. Table 9-2 presents the minimum acceptable easement requirements for storm sewer systems. The design of the storm sewer shall include the easement width that is necessary to ensure that adequate space is provided for the construction and maintenance of the facility.

TABLE 9-2
MINIMUM ACCEPTABLE STORM SEWER EASEMENT WIDTHS

Pipe Size	Easement Width
Less than 36-inch diameter	25-feet*
36-inch diameter and larger	30-feet*

*Or as required in order to meet Occupational Safety and Health Administration (OSHA) and/or construction requirements.

The pipe shall be constructed at one-third of the easement width to allow for stockpiling of material on one side of the storm sewer trench. For storm sewer systems constructed in public Right-of-Ways that are less than 10-feet from the edge of the Right-of-Way, additional drainage easement shall be provided.The minimum widths provided in Table 9-2 assume a shallow pipe depth. Deeper pipes are required to be constructed in accordance with OSHA requirements, and appropriate easements are required to allow for construction and potential future repair or replacement. When relatively large diameter pipes are proposed or when design depths are excessive, greater easement widths will be required, as determined by the Town. Easements to provide access to the storm sewer, outlet, and other appurtenances are required if not accessible from a public Right-of-Way.

9.4.3 Allowable Landscaping and Surface Treatment in Storm Sewer Easements. Although storm sewer systems are designed to have a significant service life, it is recognized that there are circumstances, which may require that the storm sewer be accessed for inspection, maintenance, repair, and/or replacement. Storm sewer easements should be designed to convey above ground flows in the event the storm sewer or inlet becomes clogged or full. It is therefore necessary to limit uses within the easement to ensure that surface conveyance redundancy and maintenance access is not impaired. Minor landscaping, including rock, shrubs etc. may be appropriate where it can be demonstrated that the function of the easement is not compromised by the presence of the materials. Pavement over a storm sewer easement is allowable, providing that the property owner assumes responsibility for replacement in the event it is necessary to remove it to access the pipe. Improvements that are not allowed on storm sewer easements include structures of any kind, retaining walls, permanent fencing, trees and others if determined by the Town to be a problem and/or costly to replace. Surface treatments on drainage easements shall be shown on the drainage plan and final development plan, and accepted by the Town.

9.5 Storm Sewer Vertical Alignment

9.5.1 Storm Sewer Alignment. The storm sewer alignment between drainage structures (inlets or manholes) shall be straight. If a change in alignment is necessary, a manhole shall be used.

9.5.2 Minimum Cover. All storm sewers shall be constructed so that a minimum cover is maintained to withstand AASHTO HS-20 loading on the pipe. The minimum cover to withstand live loading depends upon the pipe size, type and class, and soil bedding condition, but shall be not less than 18-inches at any point along the pipe when not within a roadway section. There are numerous factors that ultimately affect the depth of cover over a pipe and in most cases it is likely that the cover will have to be greater than the minimum allowed due to other design considerations and factors. Some of the other factors that affect the depth of the pipe are hydraulic grade line elevations, inlet depths, adjacent utilities or utility crossings, including water and sewer services lines along residential streets, and connections to existing storm sewer systems.

9.5.3 Cover in Roadways. The roadway subgrade, which supports the pavement section is typically plowed to a certain depth, moisture treated and compacted prior to the placement of the sub-base, base course, and surfacing. There are also instances where the subgrade material must be excavated and replaced or treated to a certain depth to mitigate swelling soils. These efforts can impact the storm sewer system if it has not been designed with adequate depth. The design engineer shall use the best information available, including pavement design or soils reports (if available) to ensure that storm sewer pipes have adequate depth. The minimum cover in roadways shall not be less than 1-foot measured from the bottom of the pavement layer to the top of the pipe at any point along the pipe.

9.5.4 Utility Clearance. For all storm sewer crossings at water or sanitary sewer lines, the appropriate agency (i.e., water and/or sanitation district) shall be contacted to determine the agency's requirements for the crossing.

Water Main Crossing Over a Storm Sewer

The Town requires a minimum vertical clearance of 18-inches between a storm sewer and a water main, above or below (all clearances are defined as outside-of-pipe to outside-of-pipe). Additional requirements may be required by the specific utility provider.

When a water main crosses over a storm sewer, regardless of vertical clearance, one full standard length section of water pipe shall be located such that both joints will be as far from the storm sewer as possible. When a water main crosses over a storm sewer with less than two feet between the outside of the water main and the outside of the storm sewer, the storm sewer shall be encased with a minimum of six inches of concrete from springline to six inches above the top of the storm sewer. The encasement shall extend along the centerline of the storm sewer for a minimum of one foot beyond the outside of the water main at each end. When less than 18 inches of vertical clearance exists between the top of the storm sewer and bottom of the water main, the water main shall be lowered or deflected under the storm sewer wherever possible to achieve a minimum vertical clearance of 18 inches and the requirements of Subsection 4.4.9.4 of the Water System Design Criteria Manual shall apply. In all cases, the Engineer shall evaluate the potential for water main freezing, and if appropriate, the design shall incorporate preventative measures that shall be reviewed and approved by Castle Rock Water.

Water Main Crossing Under a Storm Sewer

When a water main crosses under a storm sewer, regardless of vertical clearance, one full standard length section of water pipe shall be located such that both joints will be as far from the storm sewer as possible. In all cases, a minimum of 18 inches of vertical clearance shall be provided at the crossing, which may require that the water main be lowered in conformance with the Town's Standard Details. In all cases, the Engineer shall evaluate the potential for water main freezing, and if appropriate, the design shall incorporate preventative measures that shall be reviewed and approved by Castle Rock Water.

Sanitary Sewer Main Crossing a Storm Sewer

The minimum vertical clearance between a storm sewer and a sanitary sewer shall also be 18-inches. When sanitary sewer mains or force mains cross a storm sewer, regardless of vertical clearance and which pipe crosses over the other, each joint of the storm sewer within the trench width of the crossing shall be encased in a concrete collar at least six inches thick and extending at least six inches each side of each joint.   Additional requirements may be required by the specific utility provider.

9.6 Storm Sewer Horizontal Alignment

9.6.1 Storm Sewer Alignment. The storm sewer alignment between drainage structures (inlets or manholes) shall be straight. If a change of alignment is necessary, a manhole shall be used.

9.6.2 Utility Clearance. For all storm sewer pipes constructed within a utility corridor (i.e., roadway) the appropriate agency (i.e., water and sanitation district) shall be contacted to determine the agency's requirements for horizontal clearance between the utilities.

The Town requires a minimum clearance of ten-feet between a storm sewer and a water line or sanitary sewer line. The ten-feet of clearance shall occur from the outer diameter of the storm sewer pipe to the outer diameter of the water or sewer pipe. The design engineer shall give careful consideration to the required horizontal clearance and the potential impacts to the existing utility construction trench and bedding material. The required horizontal clearance may be reduced, for clearance between a storm sewer and sanitary sewer, at the approval of the Town, if the vertical elevations of the pipes provide adequate clearance to prevent impacts to the existing and proposed construction trench.

9.7 Manholes

9.7.1 Required Locations. Manholes are required along straight segments of pipe in order to provide maintenance access. Manholes are also required whenever there is a change in size, direction, or grade of a storm sewer pipe. A manhole shall also be constructed when there is a junction of two or more sewer pipes. The maximum spacing between manholes for various pipe sizes shall be as presented in Table 9-3:

TABLE 9-3
MAXIMUM MANHOLE SPACING

Pipe Diameter	Maximum Distance Between Manholes
18-inch to 36-inch	400 feet
Greater than 36-inch	500 feet

9.7.2 Manhole Types and Minimum Sizes. The required manhole type and size is dependent on the diameter of the largest pipe entering or exiting the manhole and the horizontal and vertical alignments of all pipes entering or exiting the manhole. Table 9-4 presents general guidance regarding acceptable manhole types and minimum diameters, based on the diameter of the storm sewer pipe.

TABLE 9-4
MANHOLE TYPES AND MINIMUM SIZES[1]

Pipe Diameter	Minimum Manhole Diameter	Acceptable Manhole Types[2]
18”	4'	Slab Base
24” – 42”	5'	Slab Base
48 ”- 54”	6’	Slab Base
60” -72”	5’ (Riser)	Box Base, Denver Type “P”
72”-78”	5’ (Riser)	Box Base, Denver Type “P”, T-Base
78”-96”	5’ (Riser)	Box Base, T-Base

Larger than 96”	5’ (Riser)	T-Base

[1]Table is based on pipes with a straight through alignment (no horizontal alignment change from the upstream to the downstream pipe) or changes in alignment accommodated in the standard design for large pipe manhole structures.
[2]Manholes can be cast-in-place or precast, but must conform to the Town of Castle Rock Standard Details.

Table 9-4 provides general guidance and in many cases it is likely that the minimum diameter or manhole size will need to be increased to account for more significant changes in pipe alignment or multiple incoming pipes. There must be a minimum of 12-inches clearance from the outside of pipes adjacent to each other and pipes shall not enter or exit a manhole through the corner of a manhole structure. This 12-inch dimension must be measured on the inside wall of the manhole. It is the responsibility of the design engineer to determine the appropriate manhole type and required manhole size to achieve adequate space between the pipes entering or exiting the manhole structure. This same analysis and dimension check must be performed when an inlet is used as a junction structure. In those cases where modifications to standard manhole construction details are required or where special junction structure designs are required, additional construction details must be developed and included in the construction drawing set.

9.7.3 Large Pipe Manhole Structures. A manhole with a large diameter or a special junction structure may be required, depending on the degree of the horizontal bend, the use of large pipes, or the presence of multiple laterals into a manhole. There are a number of different options available for these special cases:

1. Box Base Manhole. It is appropriate to use this manhole for large pipe diameters with a horizontal alignment change of less than 45 degrees. The Box Base Manhole shall be constructed per the Town of Castle Rock Standard Detail SD-6.
2. T-Base Manhole. This manhole is acceptable for 72-inch diameter pipes and larger when there is no horizontal or vertical alignment change at the structure. The T-Base manhole shall be constructed per the Town of Castle Rock Standard Detail SD-6. Horizontal or vertical alignment changes using a three piece elbow or bend in conjunction with a T-Base may be considered through the variance process for very large pipes where the base structure for a Box Base or Type P manhole would be excessively large.
3. Type “P” Manhole. This manhole is appropriate for 30 degree and 45 degree deflections (horizontal alignment changes) where the use of a box base manhole would result in excessive dimensions. The Type “P” Manhole shall be constructed per the Town of Castle Rock Standard Detail SD-10.
4. Special Junction Structures. Special junction structures may have to be designed when pipe sizes and alignment changes exceed those that can be accommodated by standard manhole types.

9.7.4 Steps and Platforms. Steps are required in all manholes exceeding 3.5-feet in height and shall be in accordance with AASHTO M 199. The Occupational Health and Safety Administration has specific standards for fixed ladders used to ascend heights exceeding 20-feet. Cages and/or landing platforms may be required to satisfy these requirements in excessively deep manhole structures. It is the design engineer's responsibility to ensure that the appropriate measures are designed and construction details are developed and included in the construction drawings, as needed to comply with the Occupational Health and Safety Administration standards. When landing platforms are proposed, consideration shall be given to the potential maintenance activities and the expected loadings on the platforms.

9.7.5 Energy Dissipation in Manholes. The Town of Castle Rock encourages the use of manholes for energy dissipation when necessary to achieve velocity requirements (provided in Section 9.8) within a storm sewer pipe.

9.7.6 Manhole Shaping. All manholes shall be constructed with fill concrete to the crown of the highest top of pipe entering or exiting the manhole. The shaping shall match the pipe section below pipe springline and consist of vertical walls above pipe springline. This shaping significantly reduces manhole losses. The appropriate loss coefficient can be determined using Figure ST-8 and Table ST-9 in Volume 1 of the ~~UDFCD~~MHFD Manual for full shaping. Town of Castle Rock Standard Detail SD-6 provides construction details for channelization in slab base and box base manholes. For excessive elevation differences between pipe inverts entering/exiting a manhole, it is the design engineer's responsibility to generate special base/channel details for the construction plans.

9.7.7 Other Design Considerations. The following design criteria shall also be met:

- The elevation of the pipe crowns shall be matched when the downstream pipe is larger than the upstream pipe. This will minimize the backwater effects on the upstream pipe.
- The invert of a manhole shall be constructed with a slope between the upstream and downstream pipes. The slope shall be the average of the upstream and downstream pipe slopes or based on a fall of 0.25-foot through the manhole, whichever is greater.
- It is critical that gutter pans, curb heads, and any other problematic locations be avoided when determining the horizontal placement of manholes.
- When there is a turn through a manhole (from the upstream to downstream pipe) greater than 45 degrees, the drop through the manhole shall be equal to ½ the diameter of the outflow pipe.
- There shall be no adverse angles between the upstream and downstream pipes at manholes.

9.8 Hydraulic Design

Once the layout of the storm sewer system is determined, the peak flows in the system must be calculated followed by a hydraulic analysis to determine pipe capacity and size.

The pipe size shall not decrease moving downstream (even if the capacity is available due to increased slope, etc.) in order to reduce clogging potential.

9.8.1 Allowable Storm Sewer Velocity and Slope. The allowable storm sewer velocity is dependent on many factors, including the type of pipe, the acceptable water level during the pipe design life, proposed flow conditions (open channel versus pressure flows), and the type and quality of construction of joints, manholes, and junctions.

1. <u>Maximum velocity.</u> In consideration of the above factors, the maximum velocity in all storm sewer pipes shall be limited to 18-fps. The maximum velocity at a storm sewer outfall shall be limited to 15-fps.
2. <u>Minimum velocity.</u> The need to maintain a self-cleaning storm sewer system is recognized as a goal to minimize the costs for maintenance of storm sewer facilities. Sediment deposits, once established, are generally difficult to remove even with pressure cleaning equipment. A minimum velocity of 2-fps is required when the storm sewer conveys runoff from frequently occurring storm events. Assuming that the pipe has been designed to near full flow, a flow depth equal to 25 percent of the pipe diameter and the corresponding flow rate shall be used to check the minimum velocity. If the pipe is not designed to flow near full, a flow depth equal to 25 percent of the design flow rate depth and the corresponding flow rate shall be used to check the minimum velocity.
3. <u>Minimum slope.</u> In general, the minimum allowable pipe slopes ensure that the minimum velocity is achieved, in those cases where the pipe is designed to flow near full. In addition, storm sewers generally are not practicably constructed at slopes less than 0.50-percent with a smooth, even invert. The minimum allowable longitudinal slope shall be 0.005 ft/ft (1/2 – percent).

9.8.2 Hydraulic Evaluation of Storm Sewers in the Minor Storm Event. In the minor storm event, inlets are placed along the roadway where the flow in the roadway exceeds the minor event capacity of the street as defined in Chapter 7, Street Drainage. These inlets intercept flow, as determined by the procedures in Chapter 8, Inlets, and convey it to a storm sewer, which must be sized to convey the intercepted flow. The following process outlines the steps taken to determine the appropriate size of storm sewer pipe for laterals and main lines.

1. <u>Step 1 Hydrology.</u> The most common method used to determine the peak flow within a storm sewer is the Rational Method. Chapter 6 Hydrology of these Criteria provides detailed information on Rational Method calculations. In order to determine the peak flow within a storm sewer at various locations along the system, the total drainage area tributary to the storm sewer must be divided into sub-basins. Typically the design point of these sub-basins is located at proposed inlet locations along the system. Determining inlet locations and/or design points for the minor event is an iterative process since the placement of an inlet depends upon the minor event capacity of the street. In order to check the capacity of the street (see Chapter 7 Street Drainage), a flow rate at the location to be checked must be calculated. Once the design points (inlet locations) have been determined, the inlet

interception shall be determined per Chapter 8 Inlets. This inlet interception flow rate is used to determine the size of pipe exiting the inlet.

For a storm drainage system, which consists of a main line with multiple laterals tributary to the main line, a time of concentration (t_c) comparison shall be completed. Form SF-3 in Chapter 6, Hydrology, is a useful tool for completing this analysis. Each lateral must be analyzed using the t_c value at the local design point or inlet from the tributary sub-basin. The storm sewer main line usually has multiple tributary laterals; therefore the t_c in the main line is equivalent to the travel time from the most remote point in the major basin to the specific point of interest. This travel time is a combination of the t_c to the inlet where the flow was intercepted and the travel time from the inlet to the specific location being analyzed.

2. Step 2 Pipe Capacity. The storm sewer system shall not be surcharged in the minor storm event. A storm sewer system is considered surcharged when the water surface elevation, or hydraulic grade line, is located at or above the top of the pipe (inside diameter). The hydraulic evaluation for storm sewer systems in the minor storm event must demonstrate that the water surface elevation does not exceed the top of the pipe while including losses through the system. Further discussion regarding these calculations can be found in Step 3.

   For the minor storm event, a storm sewer is not flowing full, therefore the sewer acts like an open channel and the hydraulic properties can be calculated using Manning's Equation. For concrete pipe, the Manning's roughness coefficient (n) to be used for all storm sewer designs and analyses shall be 0.013. Based on the flow in the pipe as determined by Step 1, Manning's Equation should be solved for pipe diameters. Once the pipe sizes are determined, then the system should be checked using the energy equation by incorporating all losses in the system. If the energy equation calculation detects any surcharging in the system, then pipe sizes should be adjusted to remove the surcharge condition. Consult Section 4.4 of the Streets/Inlets/Storm Sewers chapter in Volume 1 of the ~~UDFCD~~MHFD Manual for information on Manning's equation and storm sewer sizing calculations.

3. Step 3 Hydraulic Grade Line. For partial flow conditions, the hydraulic grade line is equal to the water surface in the pipe. Hydraulic grade line calculations must be performed to account for energy losses and to ensure that the system is not surcharged during the minor storm event. There may be some special cases where the proposed storm sewer pipe is connected to an existing storm pipe (or a detention pond). If this existing pipe is surcharged, then the proposed system will receive backwater from the downstream pipe. In this situation, the minor event hydraulic grade line must be calculated to determine the impacts on the hydraulic grade line through the upstream portions of the system. Further discussion on hydraulic grade

line calculations can be found in Section 9.8.3, Step 3. The Town will be performing independent checks using software to verify results.

9.8.3 Hydraulic Evaluation of Storm Sewers in the Major Storm Event. The storm sewer system layout determined for the minor event analysis must also be evaluated for the major storm event. If necessary, additional inlets must be placed along the roadway when the flow in the roadway exceeds the major storm event capacity of the street as defined in Chapter 7 Street Drainage. The interception rates for all of the inlets shall then be calculated for the major storm event, based on the procedures in Chapter 8 Inlets.

1. Step 1 Hydrology. As described in Section 9.8.2, typically the design points of sub-basins along a storm sewer system are located at proposed inlet locations. Determining inlet locations and/or design points is an iterative process since the placement of an inlet depends upon the minor and major event capacity of the street. In order to check the capacity of the street (see Chapter 7 Street Drainage), a flow rate at the location to be checked must be calculated. Once the design points (inlet locations) have been determined, the inlet interception shall be determined per Chapter 8 Inlets.

   As described in Section 9.8.2, a time of concentration comparison shall be completed for the major storm event using Form SF-3 from Chapter 6 Hydrology. Each lateral must be analyzed using the t_c value at the local design point or inlet from the tributary sub-basin. The storm sewer main line usually has multiple tributary laterals; therefore the t_c in the main line is equivalent to the travel time from the most remote point in the major basin to the specific point of interest. This travel time is a combination of the t_c to the inlet where the flow was intercepted and the travel time from the inlet to the specific location being analyzed.

2. Step 2 Pipe Capacity. In the major storm event it is acceptable to have a surcharge in the system. Therefore Manning's equation is not applicable for those pipes, which are under pressure flow conditions. There may be cases where the major storm event does not result in a surcharge of the system. In these pipes the capacity can be calculated using Manning's equation, as described in Section 9.8.2.

3. Step 3 Hydraulic and Energy Grade Lines. Hydraulic and energy grade line calculations for the storm sewer system shall be provided for the major storm event. The major storm energy grade line (EGL) elevation must not rise above the final grade (i.e. manhole lid, inlet grate, inlet curb opening) along the storm sewer system. The hydraulic grade line (HGL) elevation shall be a minimum of 1-foot below final grade along the storm sewer system. When a storm sewer is flowing under a pressure flow condition, the energy and hydraulic grade lines shall be calculated using the pressure-momentum theory. The capacity calculations generally proceed from the storm sewer outlet upstream, accounting for all energy losses. These losses are added to the energy grade line and accumulate to the upstream end of the storm sewer. The hydraulic grade line is then determined by subtracting the

velocity head from the energy grade line at each change in the energy grade line slope. Refer to Section 4.4 in the Streets/Inlets/Storm Sewers chapter of Volume 1 of the ~~UDFCD~~MHFD Manual as a guideline for completing hydraulic grade line and energy grade line calculations. The procedure described in the ~~UDFCD~~MHFD Manual is based on the FHWA HEC-22 publication. All of the losses through a storm sewer system (at bends, junctions, transitions, entrances, and exits) shall be based upon coefficients recommended in the ~~UDFCD~~MHFD Manual.

9.8.4 Computer Programs/Equivalent Software. It is recommended that a computer program be used for the design or as a calculation "check" of a storm sewer system. NeoUDSewer is the software created to supplement the ~~UDFCD~~MHFD Manual and is an approved computer program for storm sewer analysis in the Town. NeoUDSewer can calculate rainfall and runoff using the Rational Method and then size a circular storm sewer based on Manning's equation. Example 6.13 in the Streets/Inlets/Storm Sewers chapter of the ~~UDFCD~~MHFD Manual is an example of sample project input and the resulting output from NeoUDSewer.

If an alternate computer program (i.e., StormCAD) is used, a calibration model based on Example 6.13 in the ~~UDFCD~~MHFD Manual must be completed and provided to the Town. This calibration model is generated by completing an analysis of Example 6.13 with the alternate computer model. The results of this alternate model must be comparable to the results from the NeoUDSewer analysis. It is not necessary to calibrate the hydrologic analysis as shown in Example 6.13; rather, the design engineer may input the peak flow directly to obtain a comparison of the resulting hydraulic and energy grade lines through the example system. The goal of this model calibration is to verify that the loss coefficients and other system assumptions used in the alternate computer program are equivalent to the methodology applied by NeoUDSewer, which is accepted by the Town. A summary table of all inputs must be included with the analysis.

10.0 Introduction

This section addresses the design of culvert outlets, which are typically oriented in-line with the flow in a drainageway, and storm sewer outlets, which are typically oriented perpendicular to the flow in a drainage channel or detention facility. This chapter contains references to the ~~UDFCD~~MHFD Manual for design procedures applying to both of these outlet types. Outlets into forebay sedimentation traps of water quality basins are discussed in Chapter 14, Stormwater Quality.

10.0.1 Design Considerations. Conduit outlet structures are necessary to dissipate energy at culvert and storm sewer outlets and to provide a transition from the conduit to an open channel. A conduit outlet structure is comprised of an end section or headwall and wingwalls, safety rails (if required), and a riprap or concrete structure to dissipate flow energy at the exit of the conduit.

Occasionally, other hydraulic controls are located at culvert outlets. These hydraulic controls can include drop structures, which are discussed in Chapter 12, Open Channel Design.

10.1 General Layout Information

10.1.1 Inlet and Outlet Configuration. All conduits 54-inches in diameter and larger within the Town shall be designed with headwalls and wingwalls. Conduits 48-inches in diameter and smaller may use headwalls and wingwalls or flared end sections at the inlet and outlet. Detailed grading plans showing proposed contours, spot elevations, and outlet erosion protection shall be included in the construction drawings at all conduit inlets and outlets.

10.1.2 Safety Rails. Conduit headwalls and wingwalls shall be provided with guardrails, handrails, or fencing in conformance with local building codes and roadway design safety requirements. Handrails shall be required in areas frequented by pedestrians or bicycles. The height of the handrail shall be 42-inches for pedestrian walkways or open areas and 54-inches for bicycle traffic. Acceptable materials include, but are not limited to, galvanized or painted steel, and aluminum.

10.1.3 Flared End Sections. Flared end sections shall not protrude from the embankment. Flared end sections require joint fasteners and toe walls at the outlet. Toe walls shall extend from the top of the vertical portion at the end of the flared end section to at least 3-feet below the invert. The width of the wall shall be as necessary to extend a 2:1 slope from the flared end section invert at the edge of the end section to the top of the wall (this slope shall be protected with riprap). See Figure 10-1 for an acceptable toe wall configuration.

A minimum of three joints, including the joint connecting the last pipe segment to the flared end section, shall be mechanically locked with joint fasteners as shown in Figure 10-2. Joint fasteners shall be constructed consistent with the details provided in CDOT Standard Plan No. M-603-10.

10.1.4 Culvert Elevations Relative to Drainageways. In general, in-line culvert inlet and outlet elevations are to match drainageway invert elevations upstream and downstream. Outlets shall be provided with erosion protection per Section 10.2.

Storm sewer outlets shall be set with their inverts 1- to 2- feet (2-feet for wetland channels) above the natural channel bottom and provided with erosion protection per Section 10.2. The drop is to reduce backwater affects in the storm sewer due to sedimentation.

In either case, if the existing drainageway has experienced degradation and the channel is incised, restoration improvements may raise the channel bottom back to its former elevation. The design engineer shall determine the appropriate outlet elevations considering, at a minimum, the condition and stability of the existing channel and any potential stabilization or grade control improvements that would change the longitudinal grade or elevations along the channel. To ensure that outlets and energy dissipation improvements function properly, inlet and outlet elevations shall be set based on field survey information, rather than topographic mapping generated from aerial photography.

10.2 Conduit Outlet Erosion Protection

10.2.1 Types of Erosion Protection. Erosion protection in the form of riprap or concrete basins is required at the outlet of conduits to control scour. Erosion protection shall be designed for conduit outlets in accordance with Table 10-1. These are general guidelines only and are meant to supplement the ~~UDFCD~~MHFD Manual. Other outlet erosion protection options, including many specialized types of concrete outlet structures, are available and may be used if approved by the Town. These types of structures are listed in Section 3.5 of the Hydraulic Structures chapter in Volume 2 of the ~~UDFCD~~MHFD Manual.

TABLE 10-1
EROSION PROTECTION AT CONDUIT OUTLETS

Erosion Protection Guidelines	~~UDFCD~~MHFD Manual Section	Use For	Do Not Use For
1. Riprap Lining (Section 10.3.1)	Section 7.0 of Major Drainage, Volume 1	• Receiving channel on same line and grade • Storm sewer and culvert outlets • Velocities from 0-15 fps • High tailwater • Fish passage	• Velocities above 15 fps • Wetland channels
2. Low Tailwater Stilling Basin (Section 10.3.2)	Section 3.4 of Hydraulic Structures,	• Storm sewer and culvert outlets • Velocities from 0-15	• Velocities above 15 fps • Confined

	Volume 2	fps • Low tailwater	receiving area • Major drainage areas where standing water is unacceptable
3. Drop Structures	Section 2.0 of Hydraulic Structures, Volume 2	• Wetland channels • Low rise box culverts or small diameter pipes where plugging is possible	• Confined receiving area • Fish passage

Final design criteria is available in the ~~UDFCD~~MHFD Manuals

10.2.2 Selecting Type of Erosion Protection. Riprap protection downstream of culverts is considered for most situations where moderate outlet hydraulics govern. It is highly recommended that the designer use a low tailwater basin when a storm sewer enters a drainageway at an approximate right angle, and drop structures or riprap lining for in-line culvert outlets on major drainageways. The Town strongly suggests drop structures or riprap lining for in-line culvert outlets on major drainageways.

Steep, high velocity conduits may be modified by providing a drop in a manhole and designing a larger diameter, flatter slope pipe from the manhole to the channel. This technique may also be used to reduce outlet velocities and the corresponding extents of riprap erosion protection.

In general, concrete structures are large, uncharacteristic of the natural environment, and require special safety and maintenance considerations. Concrete structures will not be approved in areas that are intended to complement the natural environment. If exit velocities are extremely high and turbulence at a conduit outlet is expected to be severe, and if space is especially limited, there are cases where a concrete stilling basin structure may be appropriate.

10.3 Design Criteria for Culvert/Storm Sewer Outlet Erosion Protection

10.3.1 Riprap Lining. The procedure for designing riprap for culvert outlet erosion protection is provided in Section 7.0 of the Major Drainage Chapter of Volume 1 of the ~~UDFCD~~MHFD Manual. The riprap protection is suggested for outlet Froude numbers up to 2.5 where the outlet of the conduit slope is parallel with the channel gradient and the conduit outlet invert is flush with the riprap channel protection. An additional thickness of riprap just downstream from the outlet is required to ensure protection from extreme flow conditions that might result in rock movement in this region. Protection is required under the conduit barrel and an end slope is provided to accommodate degradation of the downstream channel.

10.3.2 Low Tailwater Riprap Basins. The majority of storm sewer pipes in the Town discharge into open drainageways, where the receiving channel may have little or no flow when the conduit is discharging. Uncontrolled pipe velocities create erosion problems downstream of the outlet and in the channel. By providing a low tailwater basin at the end of a storm sewer conduit or culvert, the kinetic energy of the discharge is dissipated under controlled conditions without causing scour at the channel bottom.

Low tailwater is defined as being equal to or less than 1/3 of the storm sewer diameter/height. Design criteria for low tailwater riprap basins for circular and rectangular pipe are provided in Section 3.4 of the Hydraulic Structures Chapter of Volume 2 of the ~~UDFCD~~MHFD Manual.

FIGURE 10-1
CONCEPTUAL TOEWALL DETAIL

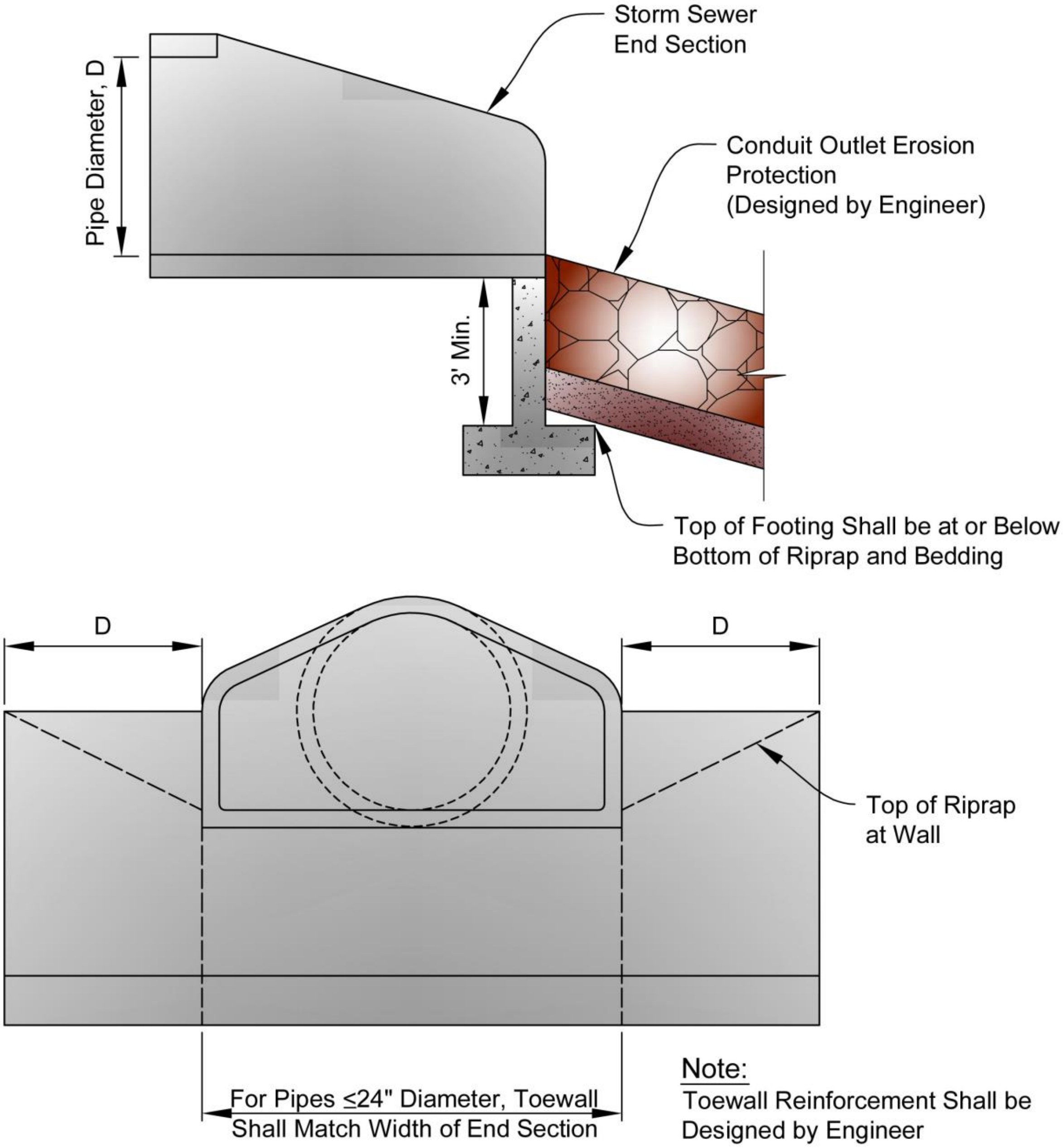
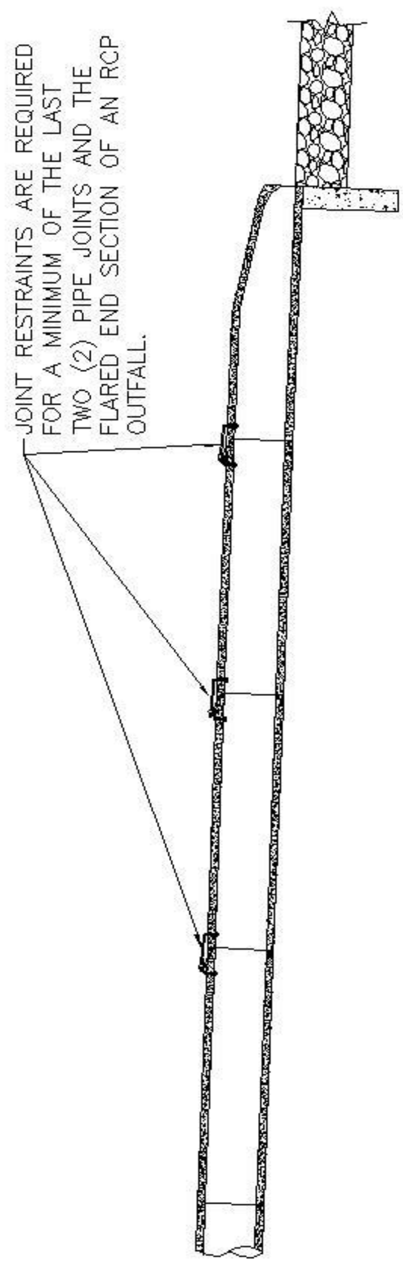


FIGURE 10-2
PIPE OUTFALL JOINT RESTRAINT REQUIREMENTS



11.0 Introduction

This section addresses design criteria for culverts and bridges as they relate to drainageways in the Town. Generally, a culvert is a conduit for the passage of surface drainage water under a highway, railroad, canal, or other embankment; a bridge is a structure carrying a pathway, roadway, or railway over a waterway. Further discussions and descriptions of both of these structure types are included in the following sections.

11.1 General Design Information

11.1.1 Design Criteria. The procedures and basic data to be used for the design and hydraulic evaluation of culverts shall be consistent with the Culverts Chapter of Volume 2 of the ~~UDFCD~~MHFD Manual, except as modified herein. The reader is also referred to the many texts covering the subject for additional information, including Hydraulic Design of Highway Culverts, Hydraulic Design Series No. 5 (FHWA 1985).

Bridges are typically designed to cross the waterway with minimal disturbance to the flow. However, for practical and economic reasons, abutment encroachments and piers are often located within the waterway. Consequently, the bridge structure can cause adverse hydraulic effects and scour potential that must be evaluated and addressed as part of each design. The design of a bridge is very specific to site conditions and numerous factors must be considered.

There are many acceptable manuals that are available and should be used in bridge hydraulic studies and river stability analysis. The Bridges Section 4.0 in the Hydraulic Structures chapter of Volume 2 of the ~~UDFCD~~MHFD Manual shall be consulted for basic criteria and information regarding other publications and resources. Some excellent references include the CDOT Drainage Design Manual, FHWA - Highways in the River Environment, FHWA - Evaluating Scour at Bridges, FHWA - The Design of Encroachments on Flood Plains using Risk Analysis, and FHWA - Stream Stability at Highway Structures.

11.1.2 Design Flows. Culverts and bridges shall be designed for future fully developed basin conditions as outlined in Chapter 6, Hydrology. The design flows shall be consistent with the design flows of the drainageway in which the improvement is being made. Specific requirements for culverts and bridges are contained in their respective sections.

11.1.3 Permitting and Regulations. Designers of stream crossings must be cognizant of relevant local, State, and Federal laws and permit requirements. Permits for construction activities in navigable waters are under the jurisdiction of the U.S. Army Corps of Engineers. Applications for Federal permits may require environmental impact assessments under the National Environmental Policy Act of 1969. In Colorado provisions of Senate Bill 40 need to be addressed on any stream crossing. A Section 404 permit from the U.S. Army Corps of Engineers, required for the discharge of dredged or fill material in waters of the United States, is an example of an additional permit.

The Town requires a Floodplain Development Permit for any stream crossing constructed in a designated floodplain. Refer to Chapter 5, Floodplain Management for information regarding construction of improvements in floodplains.

11.1.4 Aesthetics and Safety. The appearance and safety of structures, including headwalls and wingwalls, are important considerations for the Town's acceptance of the design. Structure geometry, materials, and the texture, patterning, and color of structure surfaces shall be selected to blend with the adjacent landscape and provide an attractive appearance.

The safety of the public, especially in areas of recreational use, shall be considered when selecting the appropriate structure and handrail treatment for a given area.   Consideration of structure geometry, materials, and texture, patterning, and color of structure surfaces should be given in selection to blend with the adjacent landscape and arrive at attractive appearance.

11.1.5 Easement, Ownership and Maintenance Requirements. Culverts and bridges constructed in the Town are generally within the public right-of-way for the roadway or a combination of easements and Right-of-Way. In some cases they may be constructed in private roadway easements. Additional easement or right-of-way beyond the normal roadway right-of-way or easement width may be required to facilitate the construction, operation and/or maintenance of the structure. Design plans for the structure shall include the proposed easement and/or right-of-way limits. Maintenance issues and access shall be considered in the structure design, and appropriate measures should be included to facilitate proper maintenance (i.e., access road if necessary, etc.).

11.1.6 Trail Coordination. Culverts and bridges often provide an opportunity for trails to cross roadways with a grade separation, avoiding conflicts between pedestrians and vehicles. Advance coordination with the Castle Rock Parks and Recreation Department is recommended to determine if the proposed culvert or bridge location has been identified as a potential location for a separated grade trail crossing. If the location is determined by the Town to be compatible from a planning standpoint, and the crossing is physically possible, final design requirements for trail width, vertical clearance, surfacing, and lighting and safety improvements, shall be coordinated with the Town of Castle Rock Parks and Recreation Department. The low flow channel adjacent to the trail bench shall pass as much flow as practicable, considering the duration of the flooding, inconvenience to the public, and available alternate routes. Connections of the trail to the roadway grade should be considered.

11.2 Culvert and Bridge Sizing Criteria

11.2.1 Culvert and Bridge Sizing Factors. The sizing of a culvert or bridge is dependent upon several factors including whether the drainageway is major or minor, the street drainage classification (i.e., Type A, Type B, or Type C), the allowable street overtopping, and the allowable headwater. No overtopping is allowed for any street classification at major drainageway crossings. For minor drainageways, the allowable street overtopping for the various street classifications is identified in Table 11-1.

TABLE 11-1
ALLOWABLE BRIDGE AND CULVERT OVERTOPPING
FOR MINOR DRAINAGEWAYS

Drainage Classification	10-Yr. Storm Event Runoff	Major Storm Event Runoff
Type A (Local, Minor Collector)	No overtopping allowed	Overtopping at crown governed by maximum depth of 12-inches at gutter flowline[1]
Type B (Major Collector)	No overtopping allowed	Overtopping at crown governed by maximum depth of 12-inches at gutter flowline[1]
Type C (Arterial)	No overtopping allowed	No overtopping allowed
Type C (Arterial by Functional Classification)	No overtopping allowed	No overtopping allowed

Note: No Overtopping Allowed for Major Drainageways
[1] See Chapter 7, Street Drainage, for further discussion regarding allowable flow depth in the street based on Drainage Classification.

Functional classification identifies the type of transportation service provided by a facility. Facilities providing a high level of mobility have a high functional classification such as a freeway or an arterial. Facilities providing a high level of accessibility have a low functional classification such as a local street. For example, a two-lane low volume roadway may provide high mobility between areas of low-density land use and could have an arterial functional classification.

Actual overtopping depth at the street crown will depend on the width of street and cross slope. No overtopping is allowed if a street has a raised median. Any variance from the table above will have to be considered and approved by the Town.

These criteria are considered the minimum design standard and may be modified where other factors are considered more important. For example, the designer shall consider flooding of adjacent structures or private property, excessive channel velocities, availability of alternate routes, and other factors pertinent to a specific site.

11.2.2 Sizing Procedure for Type A and B Streets When Overtopping is Allowed. The following procedure shall be used:

1. Using the future developed condition 100-year runoff, the allowable flow over the street shall be determined based on the allowable overtopping depth and the roadway profile, treating the street crossing as a broad-crested weir.
2. The culvert is then sized for the difference between the 100-year runoff and the allowable flow over the street using the allowable overtopping elevation as the maximum headwater elevation.
3. If the resulting culvert is smaller than that required to pass the 10-year storm runoff without overtopping, the culvert size shall be increased to pass the 10-year storm runoff.

11.2.3 Headwater Considerations. For all Type A and B roads, the maximum headwater to depth ratio for the 100-year design flows will be 1.5 times the culvert or bridge opening height. For a culvert through a Type C road, the maximum headwater to depth ratio for the 100-year design flows will be 1.2 times the culvert opening height. For a bridge on a Type C road, freeboard shall be applied to the water surface for the recommended design frequency. Freeboard requirements shall be considered on an individual basis due to the numerous factors or conditions that must be considered in any bridge installation. The profile grade of the bridge and roadway, the potential for debris accumulation, and predicted sedimentation are just a few of the factors that must be considered when developing freeboard requirements. Chapter 10 of the CDOT Drainage Design Manual and other publications should be consulted for discussion and guidance regarding freeboard.

11.3 Culvert Design Standards

11.3.1 Construction Material. Culverts designed and built in the Town shall be made of reinforced concrete in round or elliptical cross-sections or reinforced concrete in box or arch shapes that are either cast-in-place or supplied in precast sections. In rural areas or low-volume roadways, corrugated metal pipe culverts in round or arch cross sections may be accepted. All corrugated metal pipe must be aluminized steel or aluminum pipe.

11.3.2 Minimum Pipe Size. The minimum pipe size for a cross culvert within a public Right-of-Way shall be 24-inches in diameter for a round culvert, or shall have a minimum cross sectional area of 3.3 ft^2 for arch or elliptical shapes. Box culverts shall be as tall as physically possible, but shall not have less than a four-foot high inside dimension.

11.3.3 Culvert Sizing and Design. Culvert design involves an iterative approach. Two references are particularly helpful in the design of culverts. The Culverts chapter of Volume 2 of the ~~UDFCD~~MHFD Manual provides design aids and guidance taken from the FHWA (1985) Hydraulic Design Series No. 5, Hydraulic Design of

Highway Culverts. The FHWA circular explains inlet and outlet control and the procedure for designing culverts.

11.3.4 Capacity Curves. There are many charts, tables, and curves for the computation of culvert hydraulic capacity. To assist in the review of the culvert design computations and to obtain uniformity of analysis, the Capacity Charts and Nomographs provided in the Culverts chapter of Volume 2 of the ~~UDFCD~~MHFD Manual shall be used for determining culvert capacity.

The procedures for using the capacity charts and nomographs are provided in the Culverts chapter of Volume 2 of the ~~UDFCD~~MHFD Manual. Care must be exercised in the use of these nomographs as certain design elements are built into the nomographs, such as roughness coefficients and entrance coefficients. Selection of the appropriate entrance coefficients shall be based on the information presented in Table CU-1 in the Culverts chapter of Volume 2 of the ~~UDFCD~~MHFD Manual or in Table 12 of Hydraulic Design of Highway Culverts, (FHWA 1985). When non-standard design elements are utilized, the designer should return to the reference Hydraulic Design of Highway Culverts, (FHWA 1985) for information on treating special cases.

11.3.5 Design Forms. Standard Form CU-8 in the Culverts chapter of Volume 2 of the *~~UDFCD~~MHFD Manual* or other versions of this form shall be used to present and document the culvert design process when spreadsheets or computer programs are not used for culvert sizing and design. Form CU-8 or the equivalent must be included in the drainage report when used to document the culvert design.

11.3.6 UD-Culvert Spreadsheet. The ~~UDFCD~~MHFD has prepared a spreadsheet to aid with the calculations for the more common culvert designs. The spreadsheet applications utilize the FHWA nomographs. FHWA's HY-8 Culvert Analysis program is another computer application used to design culverts. Other computer programs or software, which are based on the methodologies presented in Hydraulic Design of Highway Culverts, (FHWA 1985), may also be used for culvert design. The UD-Culvert Spreadsheet and the FHWA's HY-8 Culvert Analysis programs are available on the ~~UDFCD~~MHFD web site, ~~udfcd~~MHFD.org.

11.3.7 Velocity Considerations. In design of culverts, both the minimum and maximum velocities must be considered.

A minimum flow velocity of two-feet per second is required when the culvert conveys runoff from frequently occurring storm events. Assuming that the culvert has been designed to flow near full, a flow depth equal to 25 percent of the culvert diameter or height and the corresponding flow rate shall be used to check the minimum velocity. If the culvert is operating under inlet control and not flowing full, a flow depth equal to 25 percent of the design flow depth and the corresponding flow rate shall be used to check the minimum velocity. The intent of this requirement is to reduce the potential for sediment accumulation in the culvert. The culvert slope must be equal to or greater than the slope required to achieve the minimum velocity. The slope should be checked for each design, and if the proper minimum velocity is not achieved, the pipe diameter may be decreased, the slope steepened, a smoother pipe used, or a combination of these may be used.

The velocity in the culvert during the 100-year event shall be kept as close as feasible to the 100-year velocity in the drainageway, but shall not exceed 15-fps within the culvert pipe and at the culvert outlet.

11.3.8 Structural Design. As a minimum, all culverts shall be designed to withstand an HS-20 loading in accordance with the design procedures of AASHTO, "Standard Specifications for Highway Bridges," and with the pipe manufacturer's recommendation. It is the engineer's responsibility to determine if a culvert installation needs to be designed to withstand a loading other than HS-20.

11.3.9 Alignment. The alignment of the culvert with respect to the natural channel is very important for proper hydraulic performance. Culverts may pass beneath the roadway normal to the centerline or they may pass at an angle (skewed). Culverts shall be aligned with the natural channel. This reduces inlet and outlet transition problems.

Where the natural channel alignment would result in an exceptionally long culvert, modification of the natural channel alignment may be necessary. Modifications to the channel alignment or profile affect the natural stability of the channel and proposed modifications shall be thoroughly investigated. In many cases where the channel alignment is modified, grade control or drop structures are needed to achieve stable channel slopes upstream or downstream of the culvert. Although the economic factors are important, the hydraulic effectiveness of the culvert and channel stability must be given major consideration. Improper culvert alignment and poorly designed outlet protection may cause erosion to adjacent properties, increased instability of the natural channel and sedimentation of the culvert.

11.3.10 Minimum Cover. The vertical alignment of roadways relative to the natural existing channel profile may define the maximum culvert diameter/height that can be used. Low vertical clearance may require the use of elliptical or arched culverts, or the use of a multiple-barrel culvert system. All culverts shall have a minimum of 1.0-foot of cover from the subgrade elevation to the outside of the top of the pipe. A variance will be required for culverts with less than 1.0-foot of cover. When analyzing the minimum cover over a culvert, consideration should be given to potential treatment of the subgrade for mitigation of swelling soils, the placement of other utilities, live loading conditions, and other factors that may affect the pipe cover.

11.3.11 Multiple-Barrel Culverts. If the available fill height limits the size of culvert necessary to convey the flood flow, multiple culverts can be used. The number of separate culvert barrels shall be kept to a minimum to minimize clogging potential and maintenance costs. If each barrel of a multiple-barrel culvert is of the same type and size and constructed such that all hydraulic parameters are equal, the total flow shall be assumed to be equally divided among each of the barrels.

11.3.12 Trash Racks. Designs that include trash racks or grates on culvert inlets will be reviewed on a case-by-case basis when there is sufficient justification for considering the use of a trash rack or grate. Alternatives to limit access or catch debris well upstream of the culvert inlet should be thoroughly investigated prior to considering improvements on the culvert inlet. Trash racks or grates to limit access will not be allowed on culvert or pipe outlets. See the Culverts chapter in Volume 2 of the ~~UDFCD~~MHFD Manual for additional discussion and requirements regarding these structures.

11.3.13 Inlets and Outlets. Culvert inlets will require erosion protection where stable channel velocities are exceeded. If needed, riprap erosion protection shall be designed according to the procedures outlined in the Major Drainage chapter in Volume 1 of the ~~UDFCD~~MHFD Manual. In addition, culvert outlets are discussed in Chapter 10 Conduit Outlet Structures of these Criteria.

11.4 Driveway Culverts

11.4.1 Applicable Criteria. The requirements in this section apply to new more rural residential subdivisions where the roadside ditch has substantial depth. Urban roadside swales, used to incorporate the Minimizing Directly Connected Impervious Area concept into a development, are treated in a different manner. See Chapter 14 Stormwater Quality for design guidelines and criteria for the urban swale/driveway interface.

11.4.2 Construction Material. Within the Town Right-of-Way, driveway culverts shall be constructed from concrete (RCP) or corrugated metal (CMP/CMPA).

11.4.3 Minimum Size. Driveway culverts for new developments or subdivisions shall be sized to pass the 5-year ditch flow capacity without overtopping the driveway. The minimum size for driveway culverts shall be 15-inches in diameter for round pipe or shall have a minimum cross sectional area of 1.2-square feet for arch or elliptical shapes.

11.4.4 Minimum Cover. Driveway culverts shall be provided with the minimum cover recommended by the pipe structural design requirements, or 1-foot, whichever is greater.

11.4.5 Culvert End Treatments. All driveway culverts shall be provided with end treatments on the upstream and downstream ends of the culvert to protect and help maintain the integrity of the culvert opening. Headwalls and/or wingwalls and flared end sections are acceptable end treatments.

11.4.6 Minimum Slope. A minimum slope shall be provided to achieve the minimum velocities outlined in Section 11.3.7.

11.4.7 Design and Construction of Driveway Culverts. Additional information must be included in the drainage report and on the construction drawings for new subdivisions, where the use of roadside ditches and driveway culverts is proposed. Driveway culverts shall be sized for each lot in the subdivision drainage report, based on the tributary area at the downstream lot line. The construction drawings shall include information regarding sizes, materials, locations, lengths, grades, and end treatments for all driveway culverts. Typical driveway crossing/culvert details shall be included in the construction drawings. In general, typical roadside ditch sections don't have adequate depth to accommodate driveway culvert installations, which meet the criteria outlined in this section. The construction drawings must address the roadside ditch section in detail to ensure that adequate depth is provided to accommodate the driveway culverts, including minimum cover, and considering overtopping of the driveway when the culvert capacity is exceeded.

11.5 Bridges Design Criteria

11.5.1 General. As presented in Section 11.1.1, the design of a bridge is very specific to site conditions and numerous factors must be considered. A partial list of these factors includes location and skew, structural type selection, water surface profiles and required freeboard, floodplain management and permitting, scour considerations, deck drainage, and environmental permitting. The consideration of these factors requires that every bridge project be a unique design with variable criteria. Additional information regarding the design of bridges can be found in the Town's Regulations.

11.6 Low Water Crossings/Pedestrian Bridges

11.6.1 General. The crossings for pedestrian use can vary greatly from small low-use crossings to regional trail crossings. The crossings can have impacts on the floodplain, wetlands, and habitat. For those reasons, the Town of Castle Rock will treat pedestrian and low water crossings on an individual basis, with criteria set upon submittal of a request for the crossing.

Consideration shall be given to floodplain impacts, debris accumulation and passage, structural design, tethering of the structure or potential blockage of other conveyance structures, clearances to water levels and structural members, maintenance responsibility and cost, and construction and replacement cost of the structure. Additional information regarding the design of low water crossings and pedestrian bridges can be found in the Town's Regulations.

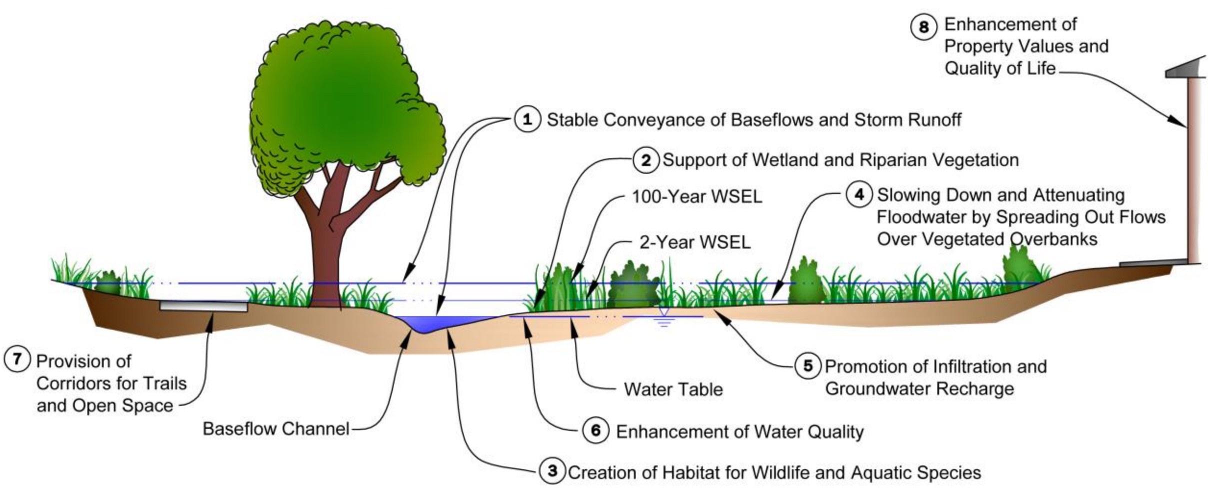
12.0 Introduction

This chapter summarizes the analysis and design methodology for drainageway improvements within the Town. Definitions are provided for minor and major drainageways and design considerations for the preservation and stabilization of both drainageway classifications.

12.0.1 Functions of Drainageways. Healthy streams and floodplains provide a number of important functions and benefits. These are summarized below and illustrated in Figure 12-1.

1. Stable conveyance of baseflow and storm runoff.
2. Support of riparian and wetland vegetation.
3. Creation of habitat for wildlife and aquatic species.
4. Slowing down and attenuating floodwater by spreading out flows over vegetated overbanks.
5. Promotion of infiltration and groundwater recharge.
6. Enhancement of water quality.
7. Provision of corridors for trails and open space.
8. Enhancement of property values and quality of life.

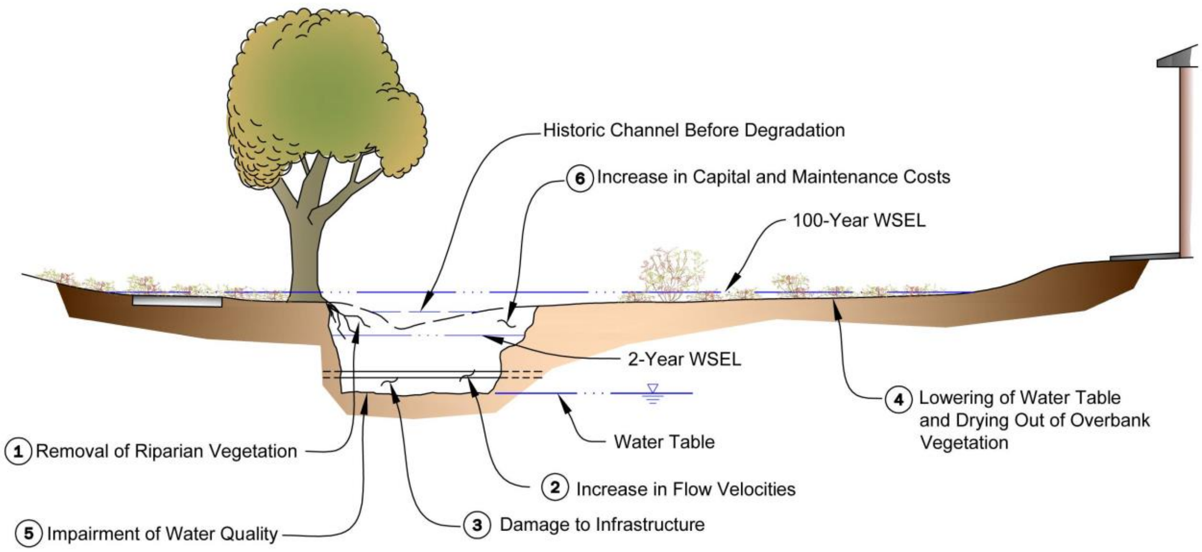
FIGURE 12-1
FUNCTIONS AND BENEFITS OF HEALTHY STREAMS



Natural stream systems are dynamic, responding to changes in flow, vegetation, geometry, and sediment supply that are imposed in developing urban environments. As a result, natural streams often face threats that can degrade the functions and values highlighted above.

12.0.2 Drainageway Degradation. Urbanization typically increases the frequency, duration, volume, and peak flow of stormwater runoff and, by stabilizing the ground with pavement and landscaping and installing water quality ponds, can decrease the supply of watershed sediment. Urban drainageways tend to degrade and incise as the streams seek a new condition of equilibrium, producing a number of negative impacts to riparian environments and adjacent properties. These are illustrated in Figure 12-2 and described below.

FIGURE 12-2
IMPACTS OF STREAM DEGRADATION



1. Removal of Riparian Vegetation. Erosion typically strips natural vegetation from the bed and banks of drainageways. This disrupts habitat for aquatic and terrestrial species and leaves the channel exposed to further erosion damage.

2. Increase in Flow Velocities. An incised channel concentrates runoff and increases flow velocities. It is not unusual for channel velocities to more than double during high runoff in an incised condition, leading to further channel erosion.

3. Damage to Infrastructure. Channel erosion can threaten utility lines, bridge abutments, and other infrastructure. Utility pipelines that were originally constructed several feet below the bed of a creek often become exposed as the bed of a channel lowers. Damage to the utility lines can result as the force of that water and debris come to bear against the line. Channel degradation can expose the foundations of bridge abutments and piers, leading to increased risk of undermining and scour failure during flood events. Erosion and lateral movement of channel banks can cause significant damage to properties adjacent to drainageways, especially if structures are located close to the top of the bank.

4. Lowering of Water Table and Drying-out of Overbank Vegetation. In many cases, lowering of the channel thalweg and baseflow elevation leads to a corresponding lowering of the local water table. Besides the loss of storage volume, lowering the water table can "dry-out" the overbanks and can effect a transition from wetland and riparian species to weedy and upland species. This can have a striking effect on the ecology of overbank areas.

5. Impairment of Water Quality. The sediment associated with the erosion of an incised channel can lead to water quality impairment in downstream receiving waters. One mile of channel incision five-feet deep and fifteen-feet wide produces almost 15,000-cubic yards of sediment that could be deposited in downstream lakes and stream reaches. Along the Front Range of Colorado, these sediments contain phosphorus, a nutrient that can lead to accelerated eutrophication of lakes and reservoirs. Also, channel incision impairs the "cleansing" function that natural floodplain overbanks can provide through settling, vegetative filtering, wetland treatment processes, and infiltration.

6. Increase in Capital and Maintenance Costs. Typical stabilization projects to repair eroded drainageways require significant capital investment; the more erosion, generally the higher the cost.

12.0.3 Vision for Drainageways. Drainageway modification is intended to reflect a natural stream character, attained by preserving and restoring existing natural drainageways and, when necessary, creating new drainageways with natural features. Natural planform and cross-sectional geometry, riparian vegetation, and natural grade control features are to be emulated wherever possible.

The vision is to go beyond just stabilizing a channel against erosion (which technically could be accomplished by lining the channel with concrete), and to implement *enhanced* stream stabilization. Enhanced stream stabilization has the goal of creating natural streams and well-vegetated floodplains that are physically and biologically healthy, with all of the attributes shown in Figure 12-1. This goal is just as important as improving the water quality of runoff flowing off a development site and into a receiving stream.

12.0.4 Definition of Major and Minor Drainageways. Criteria are presented for major drainageways and minor drainageways. Major drainageways consist of streams draining watershed areas greater than 130-acres. Major drainageways are intended to be preserved or, if degraded, to be restored to a natural condition, but not to be relocated or replaced with a pipe.

The remaining drainageway network, whether existing or constructed, are considered minor drainageways. In general, minor drainageways may be reconstructed, relocated, or replaced with a storm sewer in combination with flood conveyance in the street network. However, the Town encourages the creation of vegetated surface channels wherever possible in the minor drainageway network.

12.0.5 Jurisdictional Streams. Streams designated by the Corps of Engineers as jurisdictional under Section 404 of the Clean Water Act are subject to specific protections established during the 404 permit process. The 404 permit may impose limits on the amount of disturbance of existing wetland and riparian vegetation, may require disturbed areas to be mitigated, and may influence the character of proposed stream improvements.

In addition, any 404 jurisdictional streams upstream of regional or subregional water quality facilities require protection in the form of on-site measures to reduce directly connected impervious area. Chapter 14, Stormwater Quality, describes these minimum on-site measures.

12.0.6 Governing Criteria. All open channel design criteria shall be in accordance with the Major Drainage Section in Volume 1 of the ~~UDFCD~~MHFD Manual except as modified herein. The ~~UDFCD~~MHFD Manual provides useful information for planning and designing open channel improvements and is referenced often in this chapter. The criteria described herein and in the ~~UDFCD~~MHFD Manual represent minimum standards. Drainageway improvements will be reviewed on a case-by-case basis and in many instances, site-specific design or evaluation techniques will be required.

The criteria described herein and in Natural Channels in Volume 1 of the ~~UDFCD~~MHFD Manual shall be used for major drainageways (certain features of Composite Channels and Bioengineered Channels have been incorporated into the Natural Channel criteria). Natural Channels, Composite Channels, or Grass-lined Channels shall be used for minor drainageways. The use of riprap-lined or concrete-lined channels is generally discouraged, but they will be considered for minor drainageways on a case-by-case basis.

12.1 Drainageway Preservation and Stabilization

12.1.1 Preservation of Natural Drainageways. Natural drainageways and floodplains shall be preserved wherever possible. Initial site planning documents shall accurately identify all existing drainageways, floodplains, and other site features that may be considered to have a high resource value. The features that are proposed to be left in place and preserved or restored shall be clearly shown on the initial site planning documents. Areas shown to be protected will be subject to the review and acceptance of the Town.

Although a development project can preserve additional areas, drainageways that have one or more of the following features or characteristics, generally defined as major drainageways, shall be protected and preserved.

- Presence of protected habitat for threatened and endangered or other protected species.
- Presence of jurisdictional wetlands.
- Presence of riparian vegetation such as cottonwood or willow trees, shrub willows, and wetland or transitional grasses.

- Presence of baseflows.
- Upstream watershed area greater than 130-acres.
- Presence of bedrock outcroppings or unique landforms.
- Presence of historic, cultural, or archeological resources.

To properly identify whether or not the features listed above exist and need to be protected, information submitted in the initial planning documents shall include studies or reports regarding threatened and endangered species, wetland surveys, photographs of the drainageways, etc.

By respecting natural, historic drainage patterns in early planning, drainageways and floodplains can be preserved that provide adequate capacity during storm events, that are stable, cost-effective and of high environmental value, and that offer multiple use benefits to surrounding urban areas.

12.1.2 **Stabilization of Natural Drainageways**. Because the increased runoff from urbanization typically leads to channel erosion (with all the associated impacts described in Section 12.0.2), it is not acceptable to simply “leave a stream alone”, even when preserving drainageways as discussed in Section 12.1.1. Detention facilities do not fully mitigate impacts to the drainageways, as the adverse impacts are also related to increased runoff volumes and frequency of runoff events. Therefore, natural drainageways shall be stabilized using one of the three approaches described below:

1. Preserving Streams Not Yet Impacted. Drainageways that have not yet experienced degradation from increased urban runoff or other forms of erosion shall be preserved by implementing the following improvements:

    - Grade control structures to limit degradation in the low flow channel, stabilize any existing headcutting and to establish a flatter equilibrium slope than may have existed previously.
    - Bank stabilization at select locations where existing instability or the potential for future instability is evident.
    - The planting of supplemental vegetation to provide for the transition to species suited for “wetter” urban hydrology. Additional moisture can sustain wetland and riparian vegetation. These grasses, sedges and rushes, shrubs, and trees can help to stabilize the channel and provide a diverse habitat for wildlife.

2. Restoring Impacted Streams. Drainageways that have already experienced significant erosion and downcutting are to be addressed differently than streams that are not degraded. Restoration of these types of drainageways require the following improvements:

    - Eroded, incised channels, if possible, shall not be stabilized in a manner that retains the incised geometry with steep side banks, but shall be restored by raising the channel invert up to its historic condition and encouraging high flows to spread out, avoiding deep, concentrated flood flows within the channel.

- Grade control structures to raise the channel invert and to establish a flatter equilibrium slope.
- Utilization of vegetated overbank benches adjacent to the base flow channel to allow high flows to spread out and dissipate energy (shown in Figure 12-1).
- Bank stabilization at select locations where existing instability exists or there is potential for future instability.

These elements are discussed further in Section 12.2. The goal of preservation or restoration improvements is to avoid disturbing existing drainageways more than what is necessary to provide a stable, sustainable stream system. However, the greater the extent of existing degradation, the more work and disturbance will be required.

3. Constructing New Natural Drainageways. Where it can be demonstrated that it is not feasible or practicable to preserve a natural drainageway (generally for minor drainageways that do not exhibit the characteristics described in Section 12.1.1), or if surface channels are desired in areas where no existing drainageways are evident, construction of a new natural drainageway may be accepted. It is the intent of the Town that such constructed channels be designed to emulate natural drainageways with all of the attributes shown in Figure 12-1.

12.1.3 Design Considerations. Section 2 of the Major Drainage section in Volume 1 of the ~~UDFCD~~MHFD Manual provides a thorough discussion of drainageway planning considerations. The designer is referred to this section for guidance on urban effects, route considerations, and drainageway layout within a site.

12.1.4 Master Planning. Major Drainageway Planning Studies commonly referred to as master plans, have been developed for many of the watersheds in the urbanized parts of the Town. These studies typically provide standard channel cross-sections and details to depict the selected channel type and/or improvements for the specific reaches of the drainageway. The master plans shall be used as a basis, where appropriate, for general stabilization concepts, but will be subject to re-evaluation with regard to the standards presented in this chapter.

12.1.5 Design Flows. The design flow for open channel improvements shall be the discharge for the 100-year event assuming a fully urbanized watershed. Future developed conditions shall be based on the estimated imperviousness of the upstream watershed, or actual imperviousness if the basin is fully developed. In addition to the 100-year event, the design must also consider baseflows and frequent storm events, including the two-year flow and any other events the designer judges may produce a critical design condition. The 1.5-year to two-year discharge is commonly referred to as the “bankfull” or “channel forming” discharge for natural streams and is considered to have morphologic significance because it typically represents the breakpoint between the processes of channel formation and floodplain formation (FISRWG, 2001).

Design flow rates have been calculated in master planning documents. Prior to the use of these, or other published flow rates, a check should be made to verify that the assumptions used in the determination of the flow rates are valid. If design flow rates are not available, the design engineer shall be responsible for providing the appropriate analysis to determine the design flow rate. The final design flow rate shall be approved by the Town.

12.1.6 Permitting and Regulations. Major drainage planning and design along existing natural channels are multi-jurisdictional processes, and therefore, must comply with regulations and requirements ranging from local criteria and regulations to Federal laws. Discussions with the relevant permitting authorities should be held early in the design process and throughout construction to ensure that all permitting and regulatory requirements are being met.

1. Town Floodplain Development Permit. A Floodplain Development Permit is required for all activities proposed within the 100-year floodplain. Refer to Chapter 5, Floodplain Management, for additional discussion regarding floodplain regulations and permit requirements.

2. USACE Section 404 Wetlands Permit. Construction along existing drainageways may require a Section 404 permit from the US Army Corps of Engineers. The US Army Corps of Engineers should always be contacted early in the design process to determine if the activities will require a 404 permit. Figure MD-4 of the ~~UDFCD~~MHFD Manual provides guidance regarding 404 permitting.

3. Threatened and Endangered Species Act. Construction of improvements along drainageways may also be subject to the Federal Threatened and Endangered Species Act.

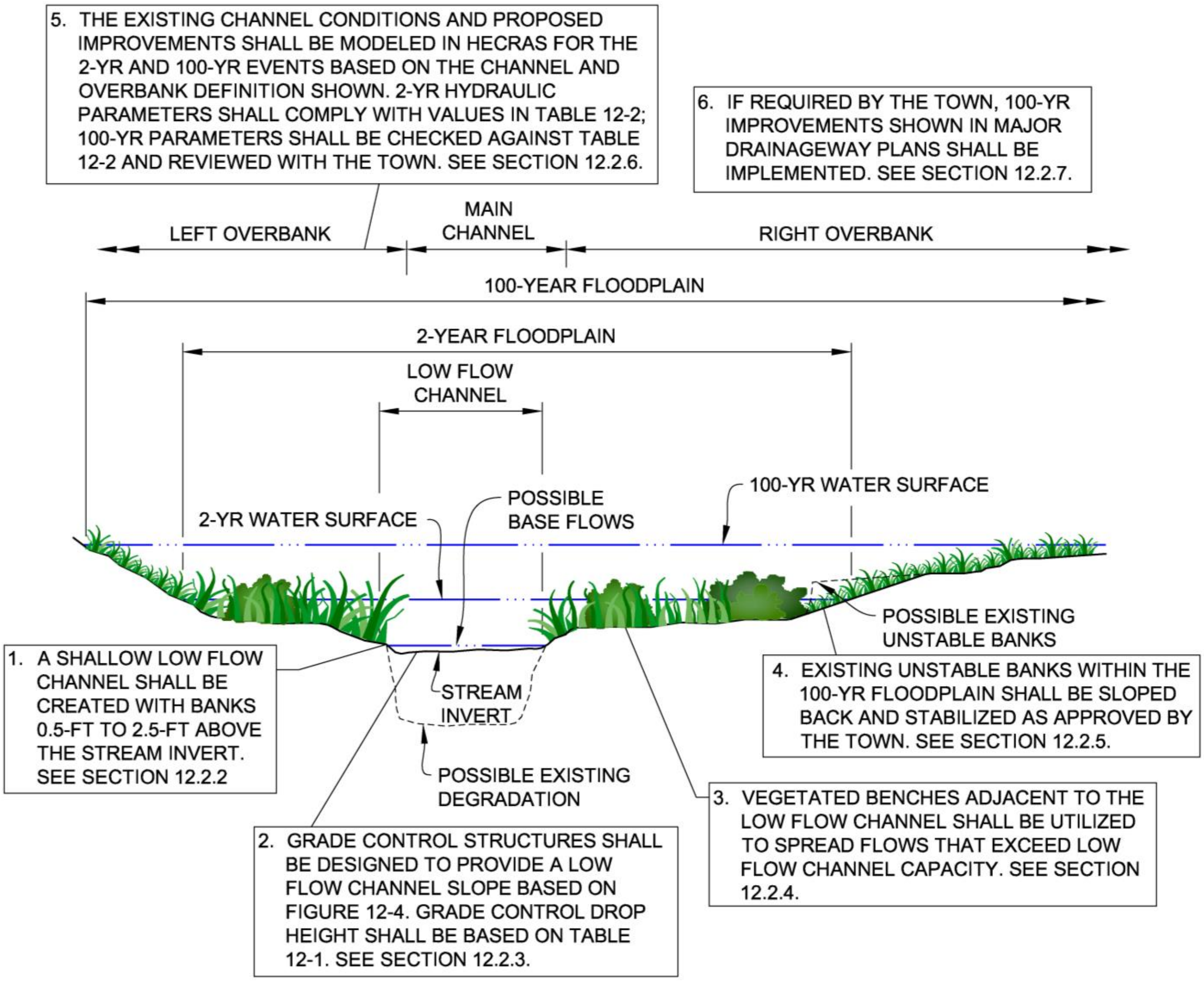
12.2 Design Criteria for Major Drainageways

12.2.1 Natural Channel Approach. Figure 12-3 illustrates six design elements associated with major drainageway design, summarized below.

1. Create shallow base flow channel.
2. Establish longitudinal slope using grade control structures.
3. Utilize vegetated benches to convey overbank flow.
4. Slope back and stabilize eroding banks.
5. Analyze floodplain hydraulics.
6. Undertake major drainageway plan improvements if required by Town.

FIGURE 12-3

DESIGN ELEMENTS ASSOCIATED WITH MAJOR DRAINAGEWAY STABILIZATION



These six steps are discussed in the following sections and comprise the recommended design approach for preserving, restoring, or constructing natural, healthy drainageways. Designers shall address these six elements and submit their proposed approach for drainageway stabilization to the Town for review and approval.

12.2.2 Create Shallow Base Flow Channel. One of the primary design tasks is to preserve or establish a base flow channel that is appropriately sized in relation to the adjacent overbank geometry. In general, shallow baseflow channels with adjacent, well-vegetated overbank benches function best to spread out and dissipate the energy associated with flood flows. The top of baseflow channel banks shall be established in the range of 0.5-feet to 2.5-feet above the channel invert. This may require filling degraded, incised channels, excavating overbank benches adjacent to the base flow channel, or some combination of the two. Usually, filling a degraded channel is the option that results in the least disturbance to existing floodplain vegetation.

Sometimes, it may be difficult to raise up the invert of a degraded channel. Existing storm sewer outfalls may have been installed near the bottom of the incised channel and constrain how much the channel bed can be raised. It may be necessary to remove the downstream end of low storm sewer outfalls and reconstruct them at a higher elevation. Raising the invert may cause a rise in a critical floodplain elevation if the regulatory floodplain was based on the degraded channel condition (it is recommended that floodplains be determined for restored, not degraded channel conditions, as discussed in Section 12.2.6). There may be a need for compensatory excavation in another portion of the floodplain of offset any rise in the floodplain caused by filling in the eroded base flow channel.

The width of the base flow channel shall approximate the existing base flow channel width in the design reach or in stable reference reaches upstream or downstream, as approved by the Town. It is normal that a baseflow channel exhibit a degree of meandering and sinuosity in natural channels. Constructed channels shall feature a meander pattern typical of natural channels.

Besides indicating width, depth and sideslope information for the base flow channel, the designer shall estimate the capacity of the baseflow channel as a percentage of the 100-year event. Typically, the brimful capacity of the base flow channel will be less than 1.0-percent of the 100-year discharge for large streams systems such as Cherry Creek upstream of the reservoir and up to approximately three to four percent of the 100-year flow for drainageways just over 130 acres.

The base flow channel is typically unvegetated if a constant baseflow or frequent ephemeral flow is present, or vegetated with riparian or wetland species if baseflows are less frequent.

12.2.3 Establish Longitudinal Slope Using Grade Control Structures. If the expected long-term equilibrium slope of the baseflow channel is less than the longitudinal slope of the adjacent overbanks, grade control structures are required to enable the baseflow channel to adopt a “stairstep” profile without exceeding the baseflow channel depths discussed above. The maximum drop height of grade control structures shall conform to Table 12-1. The design of grade control structures is covered further in Section 12.4.

TABLE 12-1
GRADE CONTROL DROP HEIGHT CRITERIA

Capacity of Grade Control Structure	Maximum Drop Height (feet)
Less than 2-year future discharge	1.5
Between 2-year and 100-year	2.5
100-year and greater	4.0

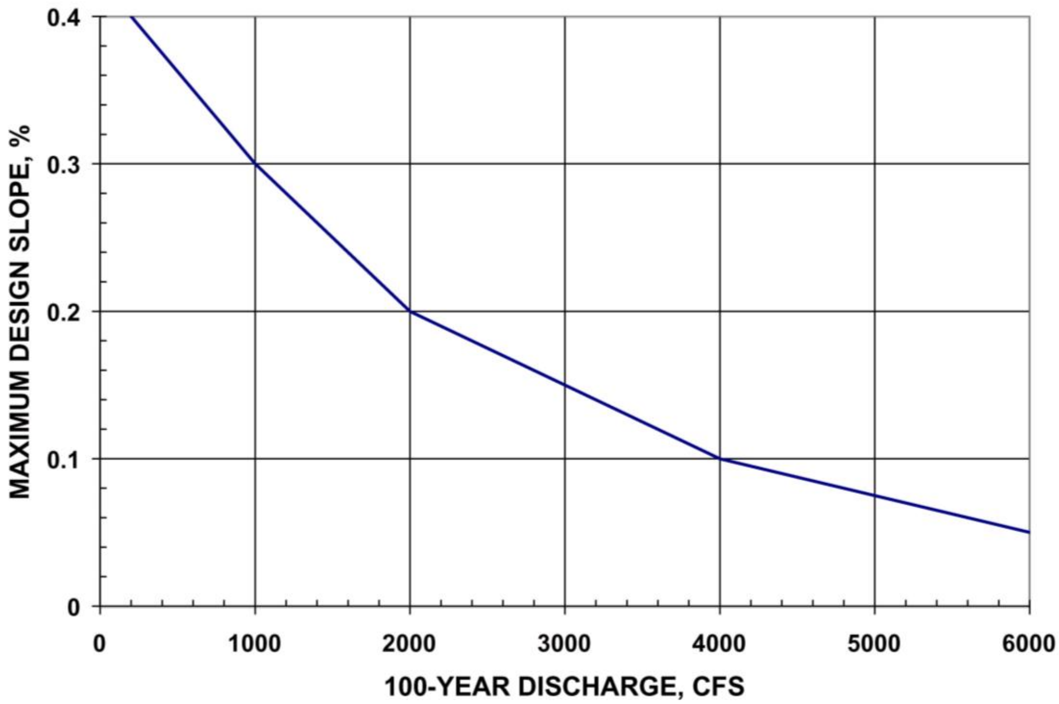
An examination of natural streams in the Denver metropolitan area reveals a typical range of stable, long-term equilibrium slopes for various urban watershed sizes and flow rates. This information was used to develop the envelop curve illustrated in Figure 12-4. Unless otherwise approved by the Town, grade control structures shall be laid out assuming the baseflow channel slope shown in Figure 12-4. The specified slope shall extend from the crest elevation of a downstream grade control structure to the downstream invert of the stilling basin for the next grade control structure upstream.

It is possible that channels may exhibit a steeper slope for periods of time, especially if a drainageway is subject to a high sediment load. This may lead to a partial or complete burying of grade control structures as channels aggrade from the design slope based on Figure 12-4. However, if slopes flatten over time in response to lower sediment loads, as is usually the case, this approach reduces the likelihood that drops will be undermined in the future. The designer shall be cognizant of the effects on the channel of steeper equilibrium slopes in the near term. Designers are encouraged to estimate equilibrium slopes using the following methods.

1. Reference Reach Concept. This is a qualitative fluvial geomorphology method that correlates equilibrium longitudinal slopes from similar drainageways that have undergone adjustments in channel slope in response to urban development. Reference reaches have similar geomorphic characteristics as project reach such as watershed size, watershed imperviousness, soil type, sediment loading, etc. In addition, the reference reach must be in equilibrium conditions and not unduly influenced by unstable upstream conditions (i.e., high sediment loads from eroding tributary). Reference reach evaluations should only be done by a designer that has expertise in geomorphology and river mechanics.

2. Sediment Transport Evaluation. This is a quantitative methodology that looks at the balance between sediment supply and transport capacity. This method is most applicable in alluvial sand bed channels such as Cherry Creek that have high sediment loads. Results are very sensitive to the assumptions used for sediment supply. An approximate methodology is provided in the "Design Guidelines and Criteria for Channels and Hydraulic Structures on Sandy Soil" (~~UDFCD~~MHFD, June 1981). Several computer models also exist that model sediment transport such as HEC-6, SAM, and GSTARS. This method should only be used by design engineers that have significant experience and expertise in geomorphology and river mechanics.

FIGURE 12-4
BASE FLOW CHANNEL SLOPE CRITERIA



12.2.4 Utilize Vegetated Benches to Convey Overbank Flow. Overbank areas adjacent to the baseflow channel are ideally wide, flat, well-vegetated, and not excessively steep with respect to longitudinal slope. Generally, the wider, the flatter, and the more vegetation, the better.

For existing natural channels, vegetated benches often exist just above the tops of the eroded base flow channel. Raising the invert of degraded channels as discussed in Section 12.2.2 usually establishes a favorable overbank geometry. If necessary, benches can be excavated adjacent to the baseflow channel, especially if impacts to existing vegetation are minimal.

It may be necessary to re-establish or supplement vegetation on the overbanks to build up a sturdy, durable cover to help retard flood flows and resist erosion.

12.2.5 Slope Back and Stabilize Eroding Banks. Steep unstable banks existing within the 100-year floodplain shall be sloped back and stabilized as approved by the Town. Designers shall indicate on a plan-view topographic map the location, height and existing slope of any unvegetated, steep, or otherwise unstable banks within the 100-year floodplain, along with the proposed approach for stabilizing the banks.

The engineer shall consider the existing bank conditions and angle of attack, the estimated potential for future erosion, and the proximity of infrastructure that could be impacted by the bank erosion as a basis for determining the appropriate method for bank stabilization. Othmaualer channel characteristics such as channel geometry, longitudinal slope, existing vegetation, underlying soils, available right-of-way and expected flow conditions shall be considered and analyzed with respect to the various potential improvements.

Unstable banks shall be protected using one of the following approaches.

1. Sloping Back Banks. Steep, unstable banks shall be sloped back to a flatter slope and revegetated. Slopes of 4 to 1 are desirable; any slopes up to 3 to 1 require approval of the Town and need to be blanketed in accordance with the Town's Temporary, Erosion, and Sediment Control (TESC) program. If the toe of these banks are subject to frequent inundation of runoff, riprap bank protection or bioengineered bank protection (described below) shall be used up to a height approved by the Town (normally up to the two-year elevation).

2. Riprap Bank Protection. Riprap bank protection is widely used in the Town to stabilize channel banks along the outside of existing channel bends and along steep banks that cannot be graded back at a 4:1 slope due to right-of-way constraints, or where overbank grades are too steep. The riprap may extend all the way up to the top of the bank or, with the Town's approval, part way up the bank to an approved elevation. Riprap bank protection shall be designed in accordance with the riprap-lined channel section of the Major Drainage Section in Volume 1 of the ~~UDFCD~~MHFD Manual. All riprap bank protection shall consist of soil riprap that is buried with six-inches of topsoil and revegetated.

3. Bioengineered Bank Protection. Experience is growing in the Colorado Front Range with the application of bioengineering techniques to protect channel banks. Bioengineering techniques are discussed in Section 4.5 of the Major Drainage Section in Volume 2 of the ~~UDFCD~~MHFD Manual.

12.2.6 Analyze Floodplain Hydraulics. The floodplain associated with the existing, unimproved natural channel and the proposed improved condition shall be analyzed using HEC-RAS to evaluate flow conditions and velocities for at least the 2-year and 100-year flood events for the purpose of assessing drainageway stability. For constructed drainageways designed to emulate natural channels, the parameters in Table 12-2 shall be achieved for both the 2-year and the 100-year event. For existing natural channels, design conditions shall be adjusted to achieve the hydraulic conditions shown in Table 12-2 for the 2-year event. Hydraulic parameters for the 100-year event shall be compared against the values in Table 12-2 and reviewed with the Town to determine what, if any, additional improvements are required. All hydraulic modeling shall be based on the channel and overbank definition shown in Figure 12-3 and on the roughness information identified in Table 12-4 at the end of this chapter and discussed below.

TABLE 12-2

HYDRAULIC DESIGN CRITERIA FOR NATURAL CHANNELS

Design Parameter	Erosive Soils or Poor Vegetation	Erosion Resistant Soils and Vegetation
Maximum 2-year Velocity (ft/s)	3.5 ft/s	5.0 ft/s
Maximum 100-year Velocity (ft/s)	5 ft/s	7 ft/s
Froude No., 2-Year	0.5	0.7
Froude No., 100-Year	0.6	0.8
Maximum Tractive Force, 100-year	0.60 lb/sf	1.0 lb/sf

The other reason to analyze floodplain hydraulics is to accurately delineate the 100-year floodplain for the purposes of laying out a development project and setting lot and building elevations adjacent to the floodplain. It is important to keep in mind that compared to channel conditions existing at the time of development, floodplain elevations can rise over time due to the following:

- Increased baseflows and runoff from development can promote increased growth of wetland and riparian vegetation, making drainageways hydraulically rougher and leading to greater flow depths.
- Stream restoration work is intended to raise the bed of incised channels to levels that existed prior to degradation. This effort, plus modifying channel slopes to flatter or more stable grades, increases water surface elevations.
- Upstream bank erosion or watershed erosion, flatter slopes, and increased channel vegetation can lead to sediment deposition and channel aggradation, raising streambed and floodplain elevations.

All of these conditions are generally healthy and positive, since they slow flow velocities, improve stream stability, and enhance water quality through sediment trapping. For these conditions to occur over time without jeopardizing properties during floods, floodplain determinations shall account for the three conditions discussed above, and the provision for ample freeboard is highly encouraged. A minimum of two-feet of freeboard shall be provided between the 100-year base flood elevation and the lowest finished floor elevation of all structures (this includes basements). For facilities which are not structures (typically not requiring a building permit) such as roadways, utility cabinets, parks and trails improvements, etc., a minimum of two-feet of freeboard is also required. Where possible the required freeboard should be contained within the floodplain tract and/or easement.

Floodplain analyses shall be based on future-development flow rates, long-term channel roughness (considering potential increases in baseflows and riparian vegetation), and potential aggradation over time. Incised or eroded channels shall not be analyzed based on their existing geometry, but on the geometry representative of a restored Natural Channel, as described in Section 12.1 and illustrated in Figure 12-1. Otherwise, the floodplain may be inappropriately low, constraining future restoration efforts such as installing grade control structures that raise the channel bed back to earlier conditions.

12.2.7 Undertake Major Drainageway Plan Improvements if Required by Town. The previous five design elements associated with major drainageway stabilization are mandatory; undertaking further major drainageway plan improvements will be required by the Town on a case-by-case basis. Section 3.4 provides additional guidance.

12.3 Design Criteria for Minor Drainageways

12.3.1 Natural Channels. Natural drainageways are the preferred channel type for minor drainageways, as well as for major drainageways. The natural channel criteria identified for major drainageways also apply to minor drainageways. It may be more common for natural channels to be constructed “from scratch” on minor drainageways than to be preserved or restored.

12.3.2 Grass-Lined Channels. Grass-lined channels are another alternative for minor drainageways, especially where the tributary area is relatively small and base flows are not expected. Sod-forming native grasses suited to wetter conditions are recommended for grass-lined channels. If irrigated bluegrass sod is proposed, a small low-flow channel (sized for approximately 1- to 3-percent of the 100-year discharge) shall be provided and vegetated with the wetter sod-forming native grasses. Hard-lined low flow channels are not desired in grass-lined channels in the Town. Grade control structures or rock stabilization in the bottom of the channel may be necessary if the longitudinal slope exceeds the values in Table 12-3.

Design criteria for grass-lined channels are provided in Section 4.1 of the Major Drainage chapter in Volume 1 of the ~~UDFCD~~MHFD Manual. Preliminary design guidance for grass-lined channels from Table MD-2 in the Major Drainage chapter in Volume 1 of the ~~UDFCD~~MHFD Manual is reproduced below for reference:

TABLE 12-3
HYDRAULIC DESIGN CRITERIA FOR GRASS-LINED CHANNELS

Design Item	Major Drainage Section (~~UDFCD~~MHFD Manual)	Grass: Erosive Soils	Grass: Erosion Resistant Soils
Maximum 100 year velocity	3.2.1	5.0 ft/sec	7.0 ft/sec
Minimum Mannings "n" for capacity check	Table MD-3	0.035	0.035
Maximum Mannings "n" for velocity check	Table MD-3	0.03	0.03
Maximum Froude number	3.2.1	0.5	0.8
Maximum Depth – outside Low flow zone	3.2.2	5.0 ft	5.0 ft.
Maximum channel longitudinal slope	3.2.3.1	0.6%	0.6%
Maximum side slope	3.2.3.2	4H:1V	4H:1V
Maximum centerline radius for a bend[1]	3.2.4	2 x top width	2 x top width
Minimum freeboard [3]	3.2.5	2.0 ft[2]	2.0 ft[2]

[1] Use 100 ft. if top width is less than 100 ft.
[2] Freeboard criteria have been modified from Table MD-2 and apply to the lowest adjacent habitable structure's lowest floor.
[3] Add superelevation to the normal water surface to set freeboard at bends.

12.3.3 Composite Channels (Wetlands Bottom Channels). As described in Section 4.2 of the Major Drainage chapter in Volume 1 of the ~~UDFCD~~MHFD Manual, there are circumstances where the use of a composite channel may be required or preferred. Composite channels shall be designed with reference to Section 4.2 of the Major Drainage Chapter and Section 10.0 of the Structural BMP chapters in Volume 3 of the ~~UDFCD~~MHFD Manual, respectively. However, riprap bank protection will generally not be required in wetland bottom channels.

12.3.4 Bioengineered Channels. Elements of bioengineered channels as described in Section 4.5 of the Major Drainage chapter in Volume 1 of the ~~UDFCD~~MHFD Manual may be used in the design or stabilization of natural channels.

12.3.5 Riprap-Lined and Concrete-Lined Channels. The use of riprap-lined or concrete-lined channels is generally discouraged, but they will be considered for Minor Drainageways on a case-by case basis. Design criteria for concrete-lined and riprap-lined channels are provided in Section 4.3 and 4.4 of the Major Drainage chapter in Volume 1 of the ~~UDFCD~~MHFD Manual.

12.4 Grade Control Structures

Grade control structures, such as check structures or drop structures, provide for energy dissipation and are used to establish flatter equilibrium slopes and moderate flow velocities in the upstream channel reach, as discussed in Sections 12.1.2 and 12.2.3. Table 12-1 provides information on maximum drop height for grade control structures. Two general approaches shall be considered when implementing grade control structures, as discussed below.

12.4.1 100-year Drop Structures. Drop structures or grade control structures that extend across the entire waterway and convey the major or 100-year flood. These drop structures are generally limited in height to 3-to 6-feet to avoid excessive kinetic energy and to avoid the appearance of a massive structure, keeping in mind that the velocity of the falling water increases geometrically with the vertical fall distance.

Drop structure design considerations, design procedures, design details, discussion regarding various types of structures, and construction concerns are provided in Section 2.0 of the Hydraulic Structures chapter in Volume 2 of the ~~UDFCD~~MHFD Manual.

12.4.2 Low-Flow Drop Structures. Low-flow drop structures and check structures are grade control structures that extend across the low-flow channel to provide control points to limit degradation at specific locations and to establish flatter thalweg slopes as discussed in Section 12.2.3. During a major flood, portions of the flow will circumvent the check. Typically, two-year flows are contained within the protected zone, so that scour around the check structure is controlled. Low-flow drop structures are not appropriate within completely incised floodplains or very steep channels where the velocities shown in Table 12-2 can't be achieved.

The primary design flow for the check will be the discharge that completely fills the check structure at its crest (usually the two-year event). The secondary design flow is the flow that causes the worst condition for lateral overflow around the abutments of the check and back into the low flow channel below (i.e., a five-year, ten-year, or 100-year event). The goal is to have the check structure survive such an event with minimal or reasonable damage to the floodplain below. The minimum crest depth for low flow drop structures is 1.5-feet.

The best approach to analyze the hydraulics of low flow drops is to estimate unit discharges, velocities, depths, along overflow paths. The unit discharges can be estimated at the crest or critical section for the given total flow. Estimating the overflow path around the check is difficult and requires practical judgment. Slopes can be derived for the anticipated overflow route, and protective measures can be devised such as buried rock.

Seepage control is also important because piping and erosion under and around these structures can be a problem. It is advisable to provide a cutoff wall that extends laterally at least 5-to 10-feet into undisturbed bank and has a cutoff depth appropriate to the profile dimension of the check structure.

Information and design guidance for low-flow grade-control check structures are provided in Section 2.9 of the Hydraulic Structures Section in Volume 2 of the ~~UDFCD~~MHFD Manual.

12.4.3 Drop Structure Types. The Town encourages the use of drop structure types and configurations that are functional, natural looking, and blend-in with the drainageway and surrounding environment. The most common type of drop structure in the Denver metro area is the Grouted Sloping Boulder drop structure. Grouted boulders can be used to develop more unique, natural looking configurations such as a horseshoe-arch shape or stepped configurations. Other drop types that have been used in the Denver Metro area include: sheet pile drops (with concrete cap), sculpted concrete drops, and soil cement drops. The sculpted concrete drops have become more popular for aesthetic reasons, particularly in upland prairie settings. The concrete is shaped, sculpted, and colored with earth tones to emulate natural rock outcroppings. Use of the following drop structure types is preferred:

- Grouted Sloping Boulder
- Grouted Boulder in natural configurations
- Sculpted Concrete

Design guidance, detailed design criteria, and construction details have not been developed by the ~~UDFCD~~MHFD for sculpted concrete drop structures. It is the responsibility of the design engineer to develop and provide the detailed construction drawings, based on previous experience in the design of sculpted concrete drop structures or research and review of past designs that have been constructed in the Denver Metro area.

The use of soil cement and roller compacted concrete drop structures may be allowed, but only on a case-by-case basis as approved by the Town. Specifications and construction quality control needed for soil cement and roller compacted concrete are extensive and generally must be in accordance with standard specifications developed by organizations such as the Portland Cement Association.

12.5 Easements, Maintenance, and Ownership

12.5.1 Drainage Easement. Drainage easements are required in order to allow for proper maintenance and operation of open channels. Drainage easements, shall be granted to the Town for inspection and maintenance purposes, and shall be shown on the Drainage Plan, Final Plat and Final Development Plan. Drainage easements shall be kept clear of impediments to the flow. Easements must also be provided to allow access to channels for maintenance.

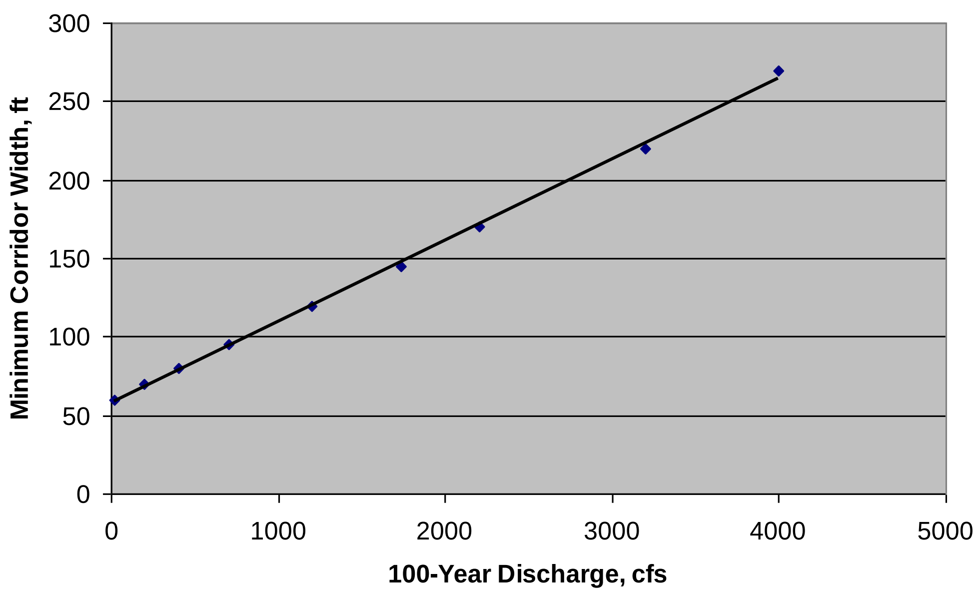
12.5.2 Drainageway Ownership. To ensure that drainageways and the associated conveyances are adequately preserved and properly maintained, all major drainageways and minor drainageways that convey flows from other properties should be placed on tracts of land owned by the Town. Easements are allowed for drainage swales between individual lots; see Section 3.5.4 for additional information.

12.5.3 Easements for Natural Drainageways. Required easement widths for natural drainageways need to provide for conveyance of design flow rates, the required freeboard, and access for maintenance. Any banks allowed to remain in place at a slope steeper than 4 to 1 shall have the easement line set back from the top of the bank to allow for some lateral movement or future grading improvements to the bank. The easement line shall be no closer than the intersection of a 4 to 1 line extending from the toe of the slope to the proposed grade at the top of the bank, plus an additional width of 15-feet for an access bench, if access is not feasible within the floodplain.

The easement widths discussed above are minimum requirements. Narrow existing channels and high flow velocities merit consideration of easements that may be wider than the existing floodplain limits. As a guideline, Figure 12-5 shows a generalized relationship of recommended easement width based on 100-year discharge. The formula for width is listed below and was developed to provide an adequate width if the channel was to be completely reconstructed according to design criteria for natural and grass channel. Proposed easement widths less than indicated in Figure 12-5 will be subject to the approval of the Town.

Minimum easement width (ft) = $0.06*Q_{100}+60$,
Where Q_{100} = 100-year discharge in cfs.

FIGURE 12-5
MINIMUM EASEMENT WIDTH FOR NATURAL DRAINAGEWAYS



12.5.4 Design for Maintenance. Open channels and swales should be designed to minimize future maintenance needs, to the extent possible, and with adequate maintenance access to ensure continuous operational capability of the drainage system. When provisions for maintenance access are being developed, consideration must be given to the potential maintenance activities and the equipment normally used to perform those activities. Designs that rely on the establishment of a vegetative cover, such as bio-engineered or grass-lined, must include a plan for establishment, including temporary or permanent irrigation of the area.

Continuous maintenance access, such as with a trail, shall be provided along the entire length of all major drainageways. The stabilized maintenance trail shall meet all Town requirements, shall have a stabilized surface at least 8-feet wide and a minimum clear width of 12-feet for a centerline radius greater than 80-feet and at least 14-feet for a centerline radius between 50-and 80-feet. The minimum centerline radius shall be 50-feet. The maximum longitudinal slope shall be ten percent. The stabilized surface does not need to be paved with concrete or asphalt, but shall be of all-weather construction and capable of carrying loads imposed by maintenance equipment. Under certain circumstances, adjacent local streets or parking lots may be acceptable in lieu of a trail.

Continuous maintenance access shall be provided along the entire length of all minor drainageways. The minimum clear width reserved for maintenance access along the channel shall be 12-feet for a centerline radius greater than 80-feet and at least 14-feet for a centerline radius between 50-and 80-feet. The minimum centerline radius shall be 50-feet. Depending on the channel size, tributary area, expected maintenance activities, and the proximity of local streets and parking areas, a continuous stabilized trail may or may not be required along minor drainageways.

12.5.5 Maintenance Responsibility. Maintenance responsibility lies with the owner of the land, except as modified by specific agreement. Maintenance responsibility shall be delineated on the Final Plat and Final Development Plan, and described in the drainage report. Maintenance of an open channel includes routine maintenance such as periodic sediment and debris removal. Channel bank erosion, damage to drop structures, low flow channel deterioration, and other channel degradation must be repaired to avoid reduced conveyance capability, unsightliness, water quality issues and ultimate failure. Maintenance operations shall be in accordance with the operations and maintenance guidelines as described in Section 4.6.

TABLE 12-4
ROUGHNESS COEFFICIENTS

Channel Type	Roughness Coefficient (n)		
	Minimum	**Typical**	**Maximum**
Natural Streams (top width at flood stage <100 feet)			
1. Streams on Plain			
a. Clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
b. Same as above, but more stones and weeds	0.030	0.035	0.040
c. Clean, winding, some pools and shoals	0.033	0.040	0.045
d. Same as above, but some weeds and stones	0.035	0.045	0.050
e. Same as above, lower stages, more ineffective slopes and sections	0.040	0.048	0.055
f. Same as c, but more stones	0.045	0.050	0.060
g. Sluggish reaches, weedy, deep pools	0.050	0.070	0.080
h. Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150
2. Mountain Streams, no vegetation in channel, banks usually steep, trees and brush along banks submerged at high stages	see Jarrett's equation*		
a. Bottom: gravels, cobbles, and few boulders			
b. Bottom: cobbles with large boulders			
Major Streams (top width at flood stage > 100 feet)			
1. Regular section with no boulders or brush	0.025		0.060
2. Irregular and rough section	0.035		0.100
Grass Areas **	**Flow Depth = 0.1-1.5 ft		Flow Depth > 3.0 ft
1. Bermuda grass, buffalo grass, Kentucky bluegrass			
a. Mowed to 2 inches	0.035		0.030
b. Length = 4 to 6 inches	0.040		0.030
2. Good Stand, any grass			
a. Length = 12 inches	0.070		0.035
b. Length = 24 inches	0.100		0.035
3. Fair Stand, any grass			
a. Length = 12 inches	0.060		0.035
b. Length = 24 inches	0.070		0.035

*Jarrett's equation: $n = 0.39\ S_f^{\ 0.38}\ R^{-0.16}$, where S_f equals friction slope and R equals the hydraulic radius.
** The n values shown for the Grassed Channel at the 0.1-1.5 ft depths represent average values for this depth range. Actual n values vary significantly within this depth range. For more information see the *Handbook of Channel Design for Soil and Water Conservation (SCS, 1954.)*

13.0 Introduction

This chapter summarizes evaluation methods and design criteria for flood control detention facilities, referencing the Storage Chapter of Volume 2 of the ~~UDFCD~~MHFD Manual for much of the background information. Criteria presented in the Storage Chapter of Volume 2 of the ~~UDFCD~~MHFD Manual shall govern except as modified or added to herein.

13.0.1 Stormwater Quality Considerations. Detention facilities are used both for attenuating peak flows during large flood events and for providing extended detention and sedimentation during small, frequent events to enhance stormwater quality. Extended detention facilities used for water quality management may be incorporated into flood control detention basins or kept separate. Extended detention and other water quality control measures are discussed in Chapter 14, Stormwater Quality, and in Volume 3 of the ~~UDFCD~~MHFD Manual.

13.1 General Requirements

13.1.1 Full-spectrum Detention shall be provided for all New Development and Redevelopment. The Town requires that full-spectrum detention including water quality capture volume and flood control detention be provided for all new development and redevelopment**.** Storage volume and release rate criteria are based on three design events, as follows:

1. Water Quality Capture Volume (WQCV) or equivalent. This is defined in Volume 3 of the ~~UDFCD~~MHFD Manual.

2. Excess Urban Runoff Volume (EURV). This is a volume that, for Type C or D soils, is about twice as large as the Water Quality Capture Volume, or slightly larger than the total two-year runoff volume, and is similar to the ten-year detention volume using the ~~UDFCD~~MHFD simplified equation. Excess Urban Runoff Volume is further explained in Section 13.1.2.

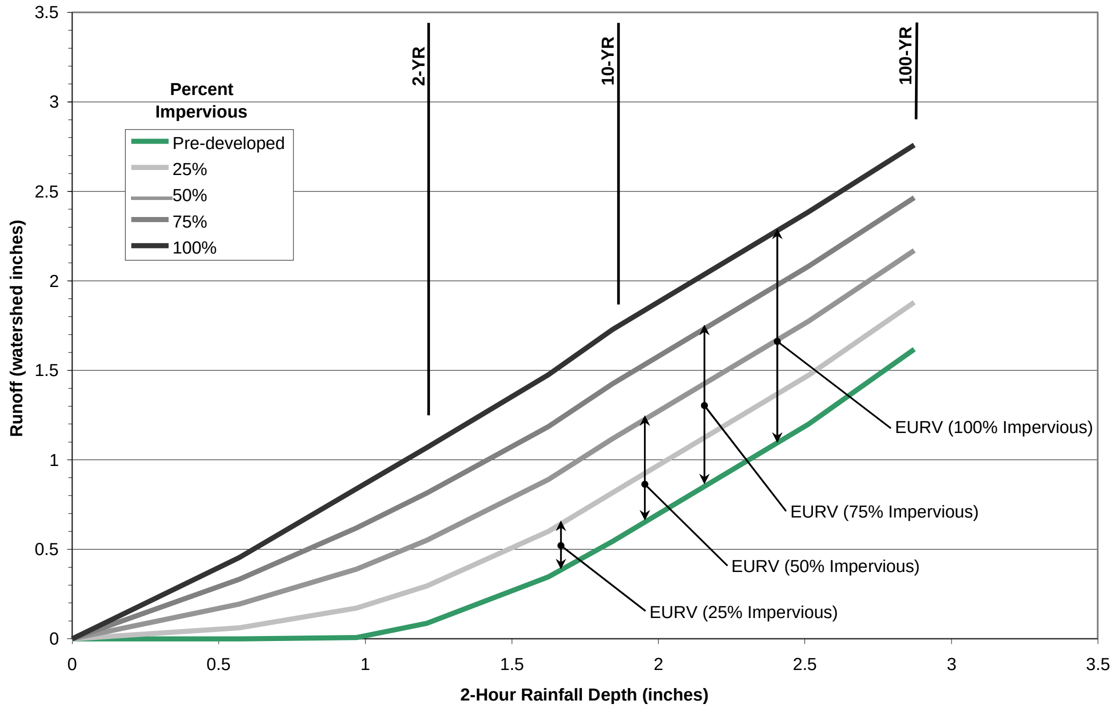
3. The 100-year event. This is outlined in the Storage Chapter in Volume 2 of the ~~UDFCD~~MHFD Manual.

Procedures for sizing detention facilities for these design events are discussed in Section 13.3 and the Storage Chapter of the ~~UDFCD~~MHFD Manual. Facilities that combine the first two events or all three events generally do not require a separate design for WQCV; the WQCV and water quality release rate are "built in" to the Excess Urban Runoff Volume design.

13.1.2 Excess Urban Runoff Volume. Excess Urban Runoff Volume is the difference between the developed and pre-developed runoff volume for the range of storms that produce runoff from pervious land surfaces (generally beyond the two-year event). Excess Urban Runoff Volume is illustrated in Figure 13-1 and is relatively constant for a given imperviousness over a wide range of storm events. Designing a detention basin to capture Excess Urban Runoff Volume and release it slowly (at a rate similar to Water Quality Capture Volume release.)

means that all the frequent storms smaller than approximately the two-year event will be reduced down to flows that are as near to zero as possible and typically less than the threshold value for erosion in most drainageways. In addition, by incorporating an outlet structure that limits 100-year runoff to the ~~UDFCD~~MHFD allowable release rate, the larger storms greater than the two-year event will be reduced down to discharges and hydrograph shapes that approximate pre-developed conditions. This reduces the likelihood that runoff hydrographs from multiple basins will combine to produce greater discharges than pre-developed conditions.

FIGURE 13-1
EXCESS URBAN RUNOFF VOLUME (EURV)
[TYPE C/D SOILS]



This detention approach, based on capturing the Excess Urban Runoff Volume and releasing it slowly, is termed “full-spectrum detention”. Full spectrum detention, will be implemented throughout the Town with the intent of reducing the flooding and stream degradation impacts associated with urban development more effectively than the former detention criteria. However, full-spectrum detention will not do away with the need to implement effective stream stabilization as identified in Chapter 12, Open Channel Design, nor change the policy regarding consideration of detention benefits discussed in Section 6.8 of Chapter 6, Hydrology.

13.1.3 Compatibility of Full-spectrum Detention Policy with Former Water Quality Capture Volume/ten-year/100-year Criteria. The Water Quality Capture Volume, Excess Urban Runoff Volume and 100-year detention volumes based on the current policy are similar in magnitude to the WQCV, ten-year and 100-year volumes associated with the former criteria (as long as WQCV is added to the ~~UDFCD~~MHFD 100-year required volume). The main difference is that the EURV described in Section 13.3 is drained at a much slower rate than the ten-year detention volume was under the former criteria. It is required that the latest UD-Detention software be utilized when designing detention facilities so as to maintain consistency with ~~UDFCD~~MHFD requirements. The software can be found on the ~~UDFCD~~MHFD website.

If master plans exist that recommend WQCV/ten-year/100-year detention facilities, the Town generally intends that these will be implemented as full-spectrum facilities; however, the final determination of detention policy will be by the Town.

There may be opportunities to convert existing ten-year/100-year detention facilities with or without Water Quality Capture Volume into full-spectrum facilities by reducing the capacity of the ten-year control orifice to an EURV release rate, and ensuring that the debris grate for the EURV orifices and the 100-year outlet and emergency spillway for the facility are adequate.

13.1.4 Definition and Requirements for New Development, Redevelopment and Constrained Redevelopment. For the purpose of Chapters 13 and 14, New Development, Redevelopment and Constrained Redevelopment shall include sites that result in land disturbance of greater than or equal to one acre, including sites less than one acre that are part of a larger common plan of development or sale or sites less than one acre in the Cherry Creek Watershed, and shall be defined as follows:

"New Development" means land disturbing activities; structural development, including construction or installation of a building or structure, creation of impervious surfaces; and land subdivision for a site that does not meet the definition of redevelopment.

"Redevelopment" includes a site that is already substantially developed with 35 percent or more of existing imperviousness; with the creation or addition of impervious area (including removal and/or replacement), to include the expansion of a building footprint or addition or replacement of a structure; structural development including construction, replacement of impervious area that is not part of a routine maintenance activity; and land disturbing activities.

"Constrained Redevelopment" includes a site that has greater than 75 percent impervious area. It must be demonstrated that it is not practicable to implement the requirements of this chapter based on an evaluation of the applicable redevelopment sites ability to install a control measure without reducing surface area covered with the structures.

A Common Plan of Development or Sale is a contiguous area where multiple separate and distinct construction activities may be taking place at different times on different schedules, but remain related. Contiguous means construction activities located in close proximity to each other (within ¼ mile).

New development and redevelopment sites shall require that full-spectrum detention be provided for the entire site in accordance with this chapter. Projects that are below the threshold for New Development are to provide detention to the extent that developed flows do not exceed the minor and major storm capacity of the downstream storm drainage system, in accordance with this criteria manual.

The site may exclude up to twenty percent, not to exceed one acre, when the design engineer has demonstrated that it is not practicable to capture runoff from portions of the site that will not drain towards control measures, and that the implementation of a separate control measure for that portion of the site is not practicable (e.g., driveway access that drains directly to street).

Constrained Redevelopment sites shall require that WQCV or equivalent and detention be provided for a minimum of fifty percent of the site, including fifty percent or more of the impervious area, treated by the control measure(s). It is not required that 100 percent of the site area be directed to control measure(s), as long as the overall removal goal is met or exceeded (e.g., providing increased removal for a smaller area). Constrained Redevelopment sites will only be approved by variance. There are three conditions that may arise for site redevelopment, depending upon whether or not detention has been provided for the existing site prior to redevelopment.

- Detention has been provided for the existing developed area. The project shall require that additional detention be provided to accommodate the altered development. Improvements to an existing detention facility may trigger the need to bring the facility up to current standards.

- Detention has not been provided for the existing developed area. Detention will be required for the full redevelopment and the existing site area that has previously been un-detained.

- Regional detention has been planned or constructed for existing developed area. Certain areas within the Town that were developed prior to Town criteria and standards may be covered under a master plan that identifies capital improvements for regional water quality and flood control. In these cases, the Town may allow cash in-lieu of on-site detention at a designated value as identified in the master plan based on the size of the project. Prior to approval of this approach it must be demonstrated that the downstream storm drainage system has capacity to support the development in accordance with this criteria manual. If the regional facility has not been constructed, temporary on-site water quality shall be required until the regional facility is constructed.

13.1.5 Exclusions from Water Quality Enhancement and Full-Spectrum Detention. The following sites are excluded from the requirements for water quality enhancement and full-spectrum detention. All exclusions shall be by variance only and shall include site name, owner name, location, completion date, site acreage, reason for exclusion, and acreage of the excluded impervious area.

1. Pavement Management Sites: Sites, or portions of sites, for the rehabilitation, maintenance, and reconstruction of roadway pavement, which includes roadway resurfacing, mill and overlay, white topping, black topping, curb and gutter replacement, concrete panel replacement, and pothole repair. The purpose of the site must be to provide additional years of service life and optimize service and safety. The site also must be limited to the repair and replacement of pavement in a manner that does not result in an increased impervious area and the infrastructure must not substantially change. The types of sites covered under this exclusion include day-to-day maintenance activities, rehabilitation, and reconstruction of pavement. "Roadways" include roads and bridges that are improved, designed or ordinarily used for vehicular travel and contiguous areas improved, designed or ordinarily used for pedestrian or bicycle traffic, drainage for the roadway, and/or parking along the roadway. Areas primarily used for parking or access to parking are not roadways.

2. Excluded Roadway Redevelopment: Redevelopment sites for existing roadways, when one of the following criteria is met:

   a) The site adds less than one acre of paved area per mile of roadway to an existing roadway, or
   b) The site does not add more than 8.25 feet of paved width at any location to the existing roadway.

3. Excluded Existing Roadway Areas: For redevelopment sites for existing roadways, only the area of the existing roadway is excluded from the requirements of a site when the site does not increase the width by two times or more, on average, of the original roadway area. The entire site is not excluded from the requirements of this chapter. The area of the site that is part of the added new roadway area must be treated.

4. Aboveground and Underground Utilities: Activities for installation or maintenance of underground utilities or infrastructure that does not permanently alter the terrain, ground cover, or drainage patterns from those present prior to the construction activity. This exclusion includes, but is not limited to, activities to install, replace, or maintain utilities under roadways or other paved areas that return the surface to the same condition.

5. Large Lot Single Family Sites: A single-family residential lot, or agricultural zoned lands, greater than or equal to 2.5 acres in size per dwelling and having a total lot impervious area of less than ten percent. A total lot imperviousness greater than ten percent is allowed when a study specific to the watershed and/or MS4 shows that expected soil and vegetation conditions are suitable for infiltration/filtration of the WQCV for a typical site and must be accepted by the Town. The maximum total lot impervious covered under this exclusion shall be twenty percent.

6. Non-Residential and Non-Commercial Infiltration Conditions: This exclusion does not apply to residential or commercial sites for buildings. This exclusion applies to sites for which post-development surface conditions do not result in concentrated stormwater flow during the 80th percentile stormwater runoff event. In addition, post-development surface conditions must not be projected to result in a surface water discharge from the 80th percentile stormwater runoff events. Specifically, the 80th percentile event must be infiltrated and not discharged as concentrated flow. For this exclusion to apply, a study specific to the site, watershed and/or MS4 must be conducted. The study must show rainfall and soil conditions present within the

Town; must include allowable slopes, surface conditions, and ratios of impervious area to pervious area; and the Town must accept such study.

7. Sites with Land Disturbance to Undeveloped Land that will Remain Undeveloped: This exclusion applies to sites with land disturbance to undeveloped land (land with no human-made structures such as buildings or pavement) that will remain undeveloped after the site.

8. Stream Stabilization Sites: Stream stabilization sites are excluded.

9. Trails: This exclusion applies to bike and pedestrian trails. Bike lanes for roadways are not included in this exclusion, unless attached to a roadway that qualifies under another exclusion in this section.

10. Oil and Gas Exploration: This exclusion applies to facilities associated with oil and gas exploration, production, processing, or treatment operations, or transmission facilities, including activities necessary to prepare a site for drilling and for the movement and placement of drilling equipment.

13.2 Regional, Sub-regional, and On-site Detention Facilities

There are three basic approaches for configuring detention facilities, as described below.

13.2.1 Regional Detention. Regional detention, as recognized by Town of Castle Rock, refers to online facilities located on a major drainageway, with an upstream watershed area generally ranging from about 130-acres to one-square mile. The definition of a major drainageway is discussed in Section 12.0.4. Figure 13-2 provides a generalized illustration of a regional detention approach.

Regional detention facilities may be constructed by a public entity such as a municipality or special district to serve several landowners in the upstream watershed. It may also be possible for a single landowner to construct a regional facility if the upstream watershed lies within the area controlled by the owner. Even if the upper part of the watershed is owned by others, it may be possible for a single landowner to construct a regional facility if the conditions below are satisfied and the Town approves the concept.

Compared to on-site facilities, regional detention facilities are typically more reliable, require less land area, and are more cost effective to construct and maintain. Regional facilities, being larger, can generally provide more favorable riparian habitat and offer greater opportunities for achieving multi-use objectives, such as combining with park and open space resources and connecting to trail systems. Because of these benefits, Town of Castle Rock requires that new development implement regional or sub-regional detention at a subdivision level in lieu of on-site detention at the time each lot is developed. For large subdivisions, the Town requires that regional or sub-regional detention be implemented by the first sub-divider rather than passing on the responsibility for detention to owners of individual filings. The Town encourages sub-regional detention to be the first option evaluated prior to regional detention. Regional detention will be approved by the Town on a case-by-case basis.

Regional detention facilities meeting the requirements below may be recognized and included in hydrologic modeling of downstream major drainageways. Sub-regional and on-site detention facilities may not be recognized in the determination of flow rates for downstream major drainageways.

The Town reserves the right to approve any proposed regional detention facilities. Generally, the following conditions shall be met:

1. Regional detention facilities shall be designed to accommodate the fully developed flows from the upstream watershed. Designing for upstream offsite areas is discussed in Section 13.3.2.

2. Regional detention facilities are required to be owned and maintained by the Town of Castle Rock or other public entity, with ownership and maintenance responsibilities clearly defined to ensure the proper function of the facility in perpetuity.

3. Drainage easements for the facility, including access from a public street, shall be provided to the Town.

4. Operations and maintenance provisions are to be included in the Phase III Drainage Report for the regional facility and accepted by the Town.

5. The creation of a jurisdictional dam shall be prohibited.

6. The facility shall be permitted under applicable environmental permits and clearances.

7. Construction of the regional facility must be coordinated with development in the upstream watershed. If the regional facility has not been constructed, temporary on-site detention (and water quality) shall be required to be provided with development projects until the regional facility is available.

8. The drainageways upstream of a regional facility shall be designed to convey fully-developed flows to the regional facility and stabilized in accordance with the criteria in Chapter 12, Open Channel Design, and in Section 14.1, Step 3.

9. If the regional facility includes Water Quality Capture Volume or equivalent, stormwater from the development sites upstream of the regional facility shall not discharge to a water of the state or shall first drain to a control measure prior to discharging to a water of the state to the levels identified in Section 14.4.5.

13.2.2 Sub-regional Detention. Sub-regional detention, as defined by the Town of Castle Rock, refers to facilities located upstream of a major drainageway (having a drainage area less than 130 acres) and serving more than one lot. The definition of a major drainageway is discussed in Section 12.0.4. Figure 13-3 illustrates a typical sub-regional detention approach.

Like regional facilities, sub-regional detention facilities may be constructed by a public entity such as a municipality or special district to serve several landowners in the upstream watershed or by a single landowner. It may be possible for a single landowner to construct a sub-regional facility if the upper part of the watershed is owned by others if the conditions identified below are achieved and the Town approves the placement. Unlike regional detention, sub-regional and onsite detention facilities may not be recognized in the determination of flow rates for downstream major drainageways.

In most cases, sub-regional detention is the preferred approach. Sub-regional detention offers many of the same benefits as regional facilities in comparison to on-site detention. As such, the Town of Castle Rock requires that new development implement sub-regional detention at a subdivision level in lieu of on-site detention at the time each lot is developed. The Town reserves the right to approve any sub-regional detention facilities. Generally, the conditions listed in Section 13.2.1 for regional facilities shall be adhered to for sub-regional facilities. Requirements for clearly defining ownership and maintenance responsibilities, providing adequate easements, and the other conditions listed for regional facilities are required for sub-regional detention facilities. Requirements for reducing directly connected impervious area if jurisdictional streams exist upstream of sub-regional water quality facilities also apply. These requirements are identified in Section 14.2.2.

13.2.3 On-Site Detention. On-site detention refers to facilities serving one lot, generally commercial or industrial sites draining areas less than twenty acres. The Town of Castle Rock allows on-site detention only on properties, where regional or sub-regional facilities are not able to be implemented. Figure 13-4 illustrates a typical on-site detention approach.

On-site detention facilities will not be recognized in the determination of flow rates for downstream major drainageways. On-site detention facilities may receive runoff from upstream off-site areas. Section 6.8 and Section 13.3.2 describe criteria regarding off-site flows.

<u>Integrating Detention and Site Landscaping Requirements.</u> Locating detention basins in areas reserved to meet site landscaping requirements is generally encouraged. Incorporating detention into landscaped areas generally creates detention facilities which are easy to inspect, are relatively easy to maintain, and can enhance the overall aesthetics of a site. Further discussion regarding landscaping improvements in detention facilities is provided in Section 13.5.

<u>Parking Lot Detention.</u> The Town will review parking lot detention on a case-by-case basis. Parking lot detention is acceptable on commercial and business sites and can offset some of the storage volume that needs to be provided on landscape areas. Parking lot detention shall meet the requirements of Section 13.4. The Town will review parking lot detention on a case-by-case basis.

<u>Underground Detention.</u> Underground detention is discouraged and only allowed by Variance based on merit and limited circumstances.

<u>Rooftop Detention.</u> Rooftop detention is prohibited in the Town of Castle Rock.

13.3 Detention Basin Design Criteria

13.3.1 Sizing Methodology. Three different procedures for sizing full-spectrum detention volumes are described in the Storage chapter of the ~~UDFCD~~MHFD Manual. A set of simplified equations or a design spreadsheet may be used for drainage areas up to 160 acres and a hydrograph approach is outlined for watershed areas up to one square mile. The release rate for the Excess Urban Runoff Volume shall be based on a drain time of 72 hours, as specified in the ~~UDFCD~~MHFD Manual. Control orifices shall be sized using procedures outlined in the Storage Chapter of the ~~UDFCD~~MHFD Manual and this Manual.

The Town of Castle Rock requires that the 100-year volume provided for full-spectrum detention facilities be equal to the 100-year detention volume calculated using the ~~UDFCD~~MHFD simplified equation plus 0.5 times the Water Quality Capture Volume. The ~~UDFCD~~MHFD design spreadsheet provides an option to specify that the Water Quality Capture Volume be added to the 100-year simplified equation volume. When the term “100-year volume” is used in these criteria in association with full-spectrum detention, it refers to the sum of the Water Quality Capture Volume and the ~~UDFCD~~MHFD 100-year simplified equation or the 100-year volume using the hydrograph methods described in the ~~UDFCD~~MHFD Storage Chapter.

The Water Quality Capture Volume is typically part of the Excess Urban Runoff Volume and the Excess Urban Runoff Volume is normally configured within the 100-year volume in one combined facility with one outlet structure. However, any combination of the incremental volumes, as shown in Figure 13-5, is acceptable.

13.3.2 On-site Detention and Addressing Off-Site Flows. Two approaches are generally acceptable for addressing off-site flows that must be conveyed through a site and the potential impacts to the on-site detention.

1. Separate Conveyance Systems. In this approach, off-site runoff is conveyed to a point downstream of the on-site detention pond outfall. The detention pond is sized based on the tributary area of the site. Off-site flows and the detained runoff can be conveyed in the same system downstream of the detention pond.

2. Design for Off-site Flows. An alternative method is to design the detention basin for the entire upstream watershed area, including the future development flows from off-site areas without giving any credit to off-site detention facilities. This method may be appropriate if the off-site tributary area is relatively small, but it becomes less feasible as the off-site tributary increases.

Further discussion regarding detention benefits in off-site flow analysis can be found in Section 6.8. Consideration of the benefits of detention provided in the off-site area may be considered in some cases, if there is sufficient justification. In those cases, the design engineer shall utilize detailed hydrograph methods to size the on-site detention to account for the additional volume from the off-site area and the differences in timing of the various hydrographs.

13.3.3 Multiple Small Detention Basins. Extended detention basins providing Water Quality Capture Volume, Excess Urban Runoff Volume, and 100-year detention typically function best if configured in one or a few large basins as opposed to multiple small basins with very small orifices. Therefore, the minimum number of detention installations is generally preferable. The same is not necessarily true for porous landscape and porous pavement detention, which may be configured in multiple small installations.

13.3.4 Detention Basins in Series. Locating two or more detention basins in series on an individual development site inherently leads to inefficiencies in the required storage volume of the downstream facilities and is generally discouraged, especially for the Water Quality Capture Volume and the Excess Urban Runoff Volume portion of a full-spectrum detention facility. If site runoff is detained by two or more detention facilities in sequence before leaving the site, hydrograph approaches, as described in Section 3.4 of the Storage Chapter in Volume 2 of the ~~UDFCD~~MHFD Manual, shall be used to determine the effect of sequential detention and to determine the detention capacity that is needed to reduce runoff peaks to the specified predevelopment flow rates at the end of the system.

13.3.5 Interconnected Ponds. When sequential detention ponds are located in close proximity, separated by a short culvert or pipe at a roadway crossing, or when sequential ponds have similar invert elevations, the ponds may have to be modeled as “interconnected ponds”. This situation could also occur if other downstream conditions cause variable backwater effects that influence the discharge of the detention pond outlet pipe. In these scenarios, the water surface elevation in the downstream pond can reduce the discharge rate from the upper pond and in some cases reverse flow can occur from the downstream pond into the upstream pond. The routing analysis is much more complex because the ponds are hydraulically dependent and the water surface elevations continuously vary and change the discharge characteristics. It is the responsibility of the design engineer to clearly identify interconnected ponds in the Phase III Drainage Report and to ensure that the appropriate analyses are performed and submitted when ponds are “interconnected”.

13.3.6 Excavated or Embankment Slopes. All excavated or embankment slopes from the pond bottom to the 100-year water surface elevation shall be no steeper than four (horizontal) to one (vertical). Excavated slopes above the 100-year water surface elevation and the slope on the downstream side of embankments shall be three to one or flatter. Embankments shall be provided with a top width of at least ten feet. An emergency overflow spillway shall be provided as described in Section 13.3.13. All earthen slopes shall be covered with a minimum of six inches of topsoil and revegetated. Revegetation shall follow Section 13.5, Landscaping Guidelines. Seeding and blanket shall be implemented on pond slopes. It is preferred that mulch be kept out of the pond bottom; a method such as drill seeding can be utilized to achieve this.

It is the responsibility of the design engineer to ensure that the design of any earthen embankment is based on specific recommendations of a geotechnical engineer. Refer to Section 3.3.2 for additional information regarding jurisdictional dams.

13.3.7 Freeboard Requirements*.* The minimum required freeboard for detention facilities is one foot above the computed water surface elevation when the emergency spillway is conveying the maximum design flow. Section 13.3.13 provides design information for the emergency spillway and embankment protection.

13.3.8 Low Flow Channels. All grassed-bottom detention ponds shall include a low flow channel sized to convey a minimum of one percent of the 100-year peak inflow. The low flow channel shall be constructed of concrete, concrete with boulder edges, soil-riprap, or other materials accepted by the Town and shall have a minimum depth of 0.5-feet and a minimum width of two feet. Grouted riprap shall not be used. The minimum longitudinal slope shall be 0.5-percent and this longitudinal slope should ensure that non-erosive velocities are maintained adjacent to the low flow channel when the design capacity is exceeded. The horizontal alignment of these low flow channels shall be as straight as possible to facilitate maintenance by equipment.

If accepted by the Town, an unlined low flow channel may be used. The unlined low flow channel shall be at least 1.5-feet deep below adjacent grassed benches and shall be vegetated with herbaceous wetland vegetation or riparian grasses, appropriate for the anticipated moisture conditions. The minimum longitudinal slope shall be 0.5-percent and the minimum width of the grassed bench adjacent to the low flow channel shall be twelve-feet on one or both sides where equipment can access. The maximum side slope below the bench shall be four to one and the maximum bottom width of the channel shall be twelve-feet if equipment can access one side of the channel and 24-feet if equipment can access both sides. Typical cross-sections of low flow channels are shown in Figure 13-6.

13.3.9 Bottom Slope. For grassed detention facilities, the pond bottom shall be sloped at four percent for the first 25-feet and at least one percent thereafter to drain toward the low flow channel or outlet, measured perpendicular to the low flow channel. The benches above unlined low flow channels, if approved, shall slope at least one percent toward the low flow channel.

13.3.10 Inlet Facilities. Unless otherwise accepted by the Town, runoff shall enter a detention facility via a stabilized drainageway, a 100-year drop structure, or a storm sewer with energy dissipater. Riprap rundowns are generally not accepted due to a history of erosion problems. Figures 14-8 and 14-9 illustrate concepts for incorporating sediment forebays into storm sewer outfalls entering a detention facility. Storm sewers shall enter the pond at the pond bottom.

13.3.11 Outlet Structure. Detention basin outlets shall be functional for controlling the design release rates, provided with oversized safety/debris grates to reduce the potential for debris plugging, easy to maintain, and designed with favorable aesthetics. Four example concepts of a combined outlet for full-spectrum detention are shown in Figures 14-4 through 14-7. Two figures show integral micropools (one with parallel wingwalls with a flush bar grating and the other with flared wingwalls and handrails). The other figures show an external

micropool. External micropools shall only be used if a constant baseflow exists, and only with the approval of the Town. In accordance with Colorado water law, no more than three percent and one percent of the total pond volume shall be retained at 72 and 120 hours, respectively.

Orifice sizing shall be a minimum of 2.5 inch diameter or 2-inch square. Smaller diameters will only be approved by variance. Orifice spacing may be adjusted based on the discussion in the next section if approved by the Town. A sealant must be specified behind the orifice plate to prevent leakage around the plate. All hydraulic sizing, concrete structure dimensions, reinforcing, and metalwork details for outlet structures shall be the responsibility of the design engineer.

13.3.12 Trash Racks. The minimum net open area of the trash rack protecting the Excess Urban Runoff Volume orifices and the flood control orifice shall comply with Figure 7 of ~~UDFCD~~MHFD's Volume 3, Typical Structural Control Measure Details. The safety grate criteria discussed in the Culverts section of the Volume 1 of the ~~UDFCD~~MHFD Manual, shall also apply. The trash rack protecting the orifices must extend to the bottom of the micropool so that flow can pass through the rack below the level of any floating debris and make its way through the orifices.

Control orifices are to be 2.5-inches or greater in diameter or 2-inches square, to allow for standard fabricated bar grating (with nominal openings of 1- by 4-inches) as a debris grate instead of well-screen. The use of well screens will only be approved by variance. If approved by the Town, the vertical spacing between orifices may be increased to 8-inches or 12-inches and the orifice areas increased by a factor of two (for 8-inch spacing) or three (for 12-inch spacing) to enable larger orifices and larger trash rack openings.

Bar grating may be used on parallel sloping wingwalls, either as the primary debris grate (if orifices are at least 2.5 inches in diameter) or as a course screen and safety grate in lieu of handrail. Sloping bar grating shall have a lockable hinged section at least 2-feet square to allow access to the orifice plate or well-screen. Manhole steps shall be provided on the side of the wingwall directly under the hinged opening. The bearing bars for steel bar grating shall be designed to withstand hydrostatic loading up to the spillway crest (assuming the grate is clogged and bears the full hydrostatic head), but generally not designed for larger loads (like vehicular loads) so that the hinged panels are not excessively heavy. Panels of bar grating shall be no more than 3-feet wide and all parts of the grating and support frames shall be hot-dipped galvanized. Bar grating shall be fastened down to the outlet structure.

The flood-flow orifice shall be sized to provide the allowable 100-year release rate when the 100-year detention volume is completely full. The weir crest at the top of the two-year volume shall pass the allowable 100-year release rate at a head that is at least 0.5-feet below the completely-full 100-year full-spectrum volume, maintaining control at the 100-year orifice in the design event.

13.3.13 Emergency Spillway and Embankment Protection. 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 pond outlet becomes obstructed or when a storm larger than a 100-year event occurs. Erosion protection for the embankment may be provided in the form of a buried riprap layer on the entire downstream face of the embankment or a separate emergency spillway constructed of buried riprap or concrete. In either case, the protection shall be constructed to convey the 100-year developed flow from the upstream watershed without accounting for any flow reduction within the detention basin.

The invert of the emergency spillway shall be set at the 100-year water surface elevation. A concrete wall shall be constructed at the emergency spillway crest extending at least to the bottom of the riprap and bedding layers located immediately downstream. The crest wall shall be extended at the sides up to one foot above the emergency spillway design water surface.

Riprap embankment protection shall be sized based on methodologies developed specifically for overtopping embankments. Two such methods have been documented by Colorado State University (USNRC, 1988) and by the US Department of Agriculture (ASAE, 1998) and designers are referred to these publications for a complete description of sizing methodology and application information. Figure 13-7 illustrates typical rock sizing for small (under ten feet high) embankments based on these procedures that may be used during preliminary design to get an approximate idea of rock size. Final design shall be based on the more complete procedures documented in the referenced publications. The thickness and bedding requirements shall be based on the criteria identified in the ~~UDFCD~~MHFD Manual.

The emergency spillway is also needed to control the release point and direction of the overflow. The emergency spillway and the path of the emergency overflow downstream of the spillway and embankment shall be clearly depicted on the drainage plan. Structures shall not be permitted in the path of the emergency spillway or overflow. The emergency overflow water surface shall be shown on the detention facility construction drawings.

13.3.14 Retaining Walls. The use of retaining walls within detention basins is generally discouraged due to the potential increase in long-term maintenance costs and concerns regarding the safety of the general public and maintenance personnel. All retaining walls must conform to the International Building Code (IBC). If retaining walls are proposed, footings shall be located above the Excess Urban Runoff Volume. Wall heights not exceeding thirty inches are preferred, and walls shall not be used on more than fifty percent of the pond circumference. If terracing of retaining walls is proposed, adequate horizontal separation shall be provided between adjacent walls. The horizontal separation shall ensure that each wall is loaded by the adjacent soil, based on conservative assumptions regarding the angle of repose. Separation shall consider the proposed anchoring system and equipment and space that would be needed to repair the wall in the event of a failure. The failure and repair of any wall shall not impact or affect loading on adjacent walls. In no case shall the separation be less than

one times the adjacent wall height, such that a plane extended through the bottom of adjacent walls shall not be steeper than two (horizontal) to one (vertical). The maximum ground slope between adjacent walls shall be four percent.

Walls shall not be used where live loading or additional surcharge from maintenance equipment or vehicle traffic could occur. The horizontal distance between the top of a retaining wall and any adjacent sidewalk, roadway, or structure shall be at least three times the height of the wall. The horizontal distance to any maintenance access drive not used as a sidewalk or roadway shall be at least four feet. Any future outfalls to the pond shall be designed and constructed to avoid disturbing the retaining walls when the future pipeline is connected to the outfall. Any wall exceeding a height of thirty inches requires perimeter fencing, safety railing, or guardrail depending on the location of the wall relative to roadways, parking areas, and pedestrian walkways. Any wall exceeding a height of four feet (measured from the bottom of the footing to the top of the wall) requires a Building Permit.

A Professional Engineer licensed in the State of Colorado shall perform a structural analysis and design the retaining wall for the various loading conditions the wall may encounter; including the differences in hydrostatic pressure between the front and back of the wall. The retaining wall design shall incorporate any recommendations provided in the soils report. A drain system should be considered behind the wall to ensure that hydrostatic pressures are equalized as the water level changes in the pond. The wall design and calculations shall be stamped by the professional engineer and submitted to the Town. The structural design details and requirements for the retaining wall(s) shall be included in the construction drawings.

There shall be no sheet flow or point discharge conveyed over the top of a retaining wall. Any stormwater that is tributary to the top of a retaining wall must be intercepted by an inlet or routed around the wall through a swale. The retaining wall structural design shall consider the impacts of an adjacent inlet or swale. Retaining walls shall not be used within the limits of any impermeable lining of water quality basins or detention ponds.

13.3.15 Landscaping Guidelines. Integration of detention and site landscaping requirements is encouraged as outlined in Section 13.2.3. The landscaping guidelines described in Section 13.5 shall be followed to provide a detention facility that blends with the site, is attractive, and well-vegetated. Additional landscaping requirements can also be found in the Town of Castle Rock Landscaping Regulations.

13.3.16 Easement Requirements. Drainage easements shall be provided to ensure the proper construction and maintenance of the detention basins and outlet facilities. Drainage easements shall be granted to the Town for inspection and maintenance purposes, and shall be shown on the Drainage Plan, Final Plats and Final Development Site Plan. The drainage easement shall state that the Town has the right of access on the easements for inspection and maintenance purposes. Drainage easements shall be kept clear of

obstructions to the flow and shall allow maintenance access. The minimum requirements for detention basins are as required to contain storage and Water Quality Capture Volume including freeboard, associated facilities, and adequate maintenance access around the perimeter based on the access road width criteria provided in Section 13.6. Access to the basin shall be provided in an easement.

13.3.17 Maintenance. The maintenance of detention facilities shall be performed by the property owner, or as otherwise designated by legal agreement. Maintenance operations shall be in accordance with the operations and maintenance guidelines as described in Section 4.6. Routine maintenance of detention basins shall include sediment and debris removal. Non-routine maintenance may include the repair and/or replacement of outlet structures, trickle channel, outlet pipes, channel slopes, and other related facilities. When appropriate maintenance is not provided, the Town may provide the necessary maintenance and shall assess the associated cost to the property owner. All detention basins, with or without retaining walls, shall be designed in accordance with the maintenance requirements identified in Section 13.6.

13.4 Design Standards for Parking Lot Detention

13.4.1 Easement Requirements. Easements for parking lot detention shall be provided in accordance with Chapter 3, Stormwater Management and Development. Easements shall include the area of the parking lot that is inundated by the 100-year water surface elevation, and the outlet structure and conveyance facilities.

13.4.2 Maintenance Requirements. Maintenance of parking lot detention ponds and facilities shall be provided in accordance with Chapter 3, Stormwater Management and Development. The property owner shall be required to ensure that the release structures are maintained.

13.4.3 Depth Limitation. The maximum allowable design depth above pavement surfaces for the Excess Urban Runoff Volume is three-inches and for the 100-year flood is nine-inches. However, to account for future overlays or parking lot resurfacing, the design volumes shall be attained even with an assumed two-inch overlay (translating to an allowable depth of one-inch for the Excess Urban Runoff Volume and seven-inches for the 100-year event). The Water Quality Capture Volume shall be located entirely out of (below) the pavement area, possibly in one or more landscaped parking islands or adjacent landscaping. An emergency spillway sized for the 100-year inflow peak shall be provided with a crest set at the 100-year water surface elevation and a maximum flow depth over the emergency spillway of six-inches. A minimum of one foot of freeboard is required above the 100-year emergency water surface to the first floor elevation of any adjacent structures (equivalent to 18-inches over the 100-year water surface).

13.4.4 Outlet Configuration. The outlet configuration shall be designed in accordance with criteria shown in Volume 3 of the ~~*UDFCD*~~*MHFD* *Manual*, as modified by Chapter 14 Stormwater Quality for the type of Water Quality Capture Volume facility selected for the site. Outlets for the Excess Urban Runoff Volume and 100-year events shall limit peak flows to the maximum design release rates.

13.4.5 Flood Hazard Warning. All parking lot detention areas shall have a minimum of two signs posted identifying the detention pond area. The signs shall have a minimum area of 1.5-square feet and contain the following message:

WARNING
THIS AREA IS A DETENTION POND AND
IS SUBJECT TO PERIODIC FLOODING
TO A DEPTH OF 9-INCHES OR MORE

Any suitable materials and geometry of the sign are permissible, subject to approval by the Town. The property owner shall be responsible to ensure that the sign is provided and maintained at all times.

13.5 Landscaping Guidelines

Integration of detention and site landscaping requirements is encouraged as outlined in Section 13.2.3. Additional landscaping requirements can be found in the Town of Castle Rock Landscape Regulations. Consideration to the type and quantity of landscaping materials should be given, to ensure that the capacity of the pond is maintained, and that future maintenance activities can be performed with minimal disruption of vegetated areas. The following is a list of recommendations for pond grading and landscaping:

a. A certified landscape professional is required to provide the design of detention facilities the vegetation plan, and may provide input on overall layout.

b. Create a basin with a pleasing, natural shape that is characterized by variation in the top, toe, and slopes of banks; avoid boxy, geometric patterns.

c. Grass selection and plant materials are key in softening the appearance of a detention area and blend it in with the surrounding landscaping and natural features. Species are to be suitable for the particular hydrologic conditions in the basin; with wetland or riparian species selected for the bottom areas subject to frequent and prolonged inundation. Guidelines for revegetation, along with recommended seed mixes, are provided in the ~~UDFCD~~MHFD Manual, as well as in the Town of Castle Rock Landscape Regulations.

d. Multipurpose detention facilities are encouraged with recreation activities such as passive open space areas, pedestrian paths, and active recreation areas. It is recommended that active recreation facilities be located above the two-year water surface to avoid frequent inundation.

e. To reduce the potential for clogging of debris grates, no straw mulch shall be used within the Excess Urban Runoff Volume of a detention basin. Instead, erosion control blanket shall be installed for a width of at least six-feet on either side of concrete low flow channels or up to a depth of one-foot in soil riprap or benched low flow channels. The blanket shall comply with the materials and installation requirements for erosion control blankets (straw coconut or 100 percent coconut) shown in the Town's Temporary Erosion, and Sediment Control (TESC) Manual. Additional blanket or other erosion control measures may be required by the Town. Trees shall not be planted within the Excess Urban Runoff Volume. Trees such as Cottonwood, Willow, and Aspen shall not be planted within the 100-year water surface of a detention basin to avoid nuisance spreading of root systems within the facility.

13.6 Designing for Maintenance

Detention facilities shall be designed to facilitate ongoing maintenance operations. The following provisions for maintenance shall be required:

13.6.1 Access for Sediment Removal. A stable access and working bench shall be provided so that equipment can remove accumulated sediment and debris from the detention basin and perform other necessary maintenance activities at all components of the facility. Unless otherwise approved by the Town, the horizontal distance from the working bench to the furthest point of removal for the forebay, bottom of the detention basin, or outlet structure shall be no more than 24-feet The working bench and access drive shall slope no more than 10-percent, and be at least 12-feet wide for a centerline radius greater than 80-feet and at least 14-feet wide for a centerline radius between 50- and 80-feet. The minimum centerline radius shall be 50-feet. Unless otherwise approved, the working bench and access drive shall be constructed of the following materials:

Below any permanent water surface: A reinforced concrete bottom slab at least 6-inches thick shall be provided as a working platform. The surface of the concrete shall be provided with a grooved finish to improve traction, with grooves oriented to drain water away to one or both sides. Concrete shall be placed on at least 6-inches of gravel base compacted subgrade.

Below the Excess Urban Runoff Volume water surface: The access ramp shall be reinforced concrete as specified above, or at least a twelve-inch thick layer of aggregate base course or crushed gravel over compacted subgrade.

Above the Excess Urban Runoff Volume and below the 100-year water surface: An access ramp shall be reinforced concrete as specified above or at least an 8-inch thick layer of aggregate base course or crushed gravel over compacted subgrade.

The use of reinforced turfgrass meeting applicable ~~UDFCD~~MHFD criteria, if proposed in this zone for an access drive, will be considered by the Town on a site-specific basis. If used, a system of marking the edges is required so that its location is evident to maintenance crews. Also, shrubs, trees, sprinkler heads and valve boxes shall not be located in the reinforced turfgrass area.

As stated above, any retaining walls shall be laid out in a manner that avoids access restrictions. Any handrails or fences, likewise, shall permit vehicular access. The entrance to an access drive from a roadway or parking lot shall be located so that traffic safety is not compromised.

13.6.2 Access during Operation. The outlet structure trash rack, emergency spillway and other critical structures must be accessible during storm events. A working bench shall be provided above the 100-year water surface elevation and within 20-24 feet of the farthest point of all critical structures to allow for equipment access. Access to the working bench for these critical structures shall be an all-weather surface that is also above the 100-year water elevation.

13.6.3 Other Improvements to Facilitate Maintenance. Other improvements that could facilitate maintenance operations in the future are encouraged. These could include:

a. Providing adequate room for staging the equipment involved in clean-out operations.

b. For larger, natural sites, it may be worthwhile to reserve a suitable location for disposing sediment that is cleaned out of the pond. This has to be carefully thought through, however, to make sure it is feasible to dump the material on-site, allow it to dry, then spread it and re-seed and much the area, without causing erosion problems.

c. Designing configuration and dimensions of grates to allow debris to be raked off using standard garden tools.

FIGURE 13-2
REGIONAL DETENTION APPROACH

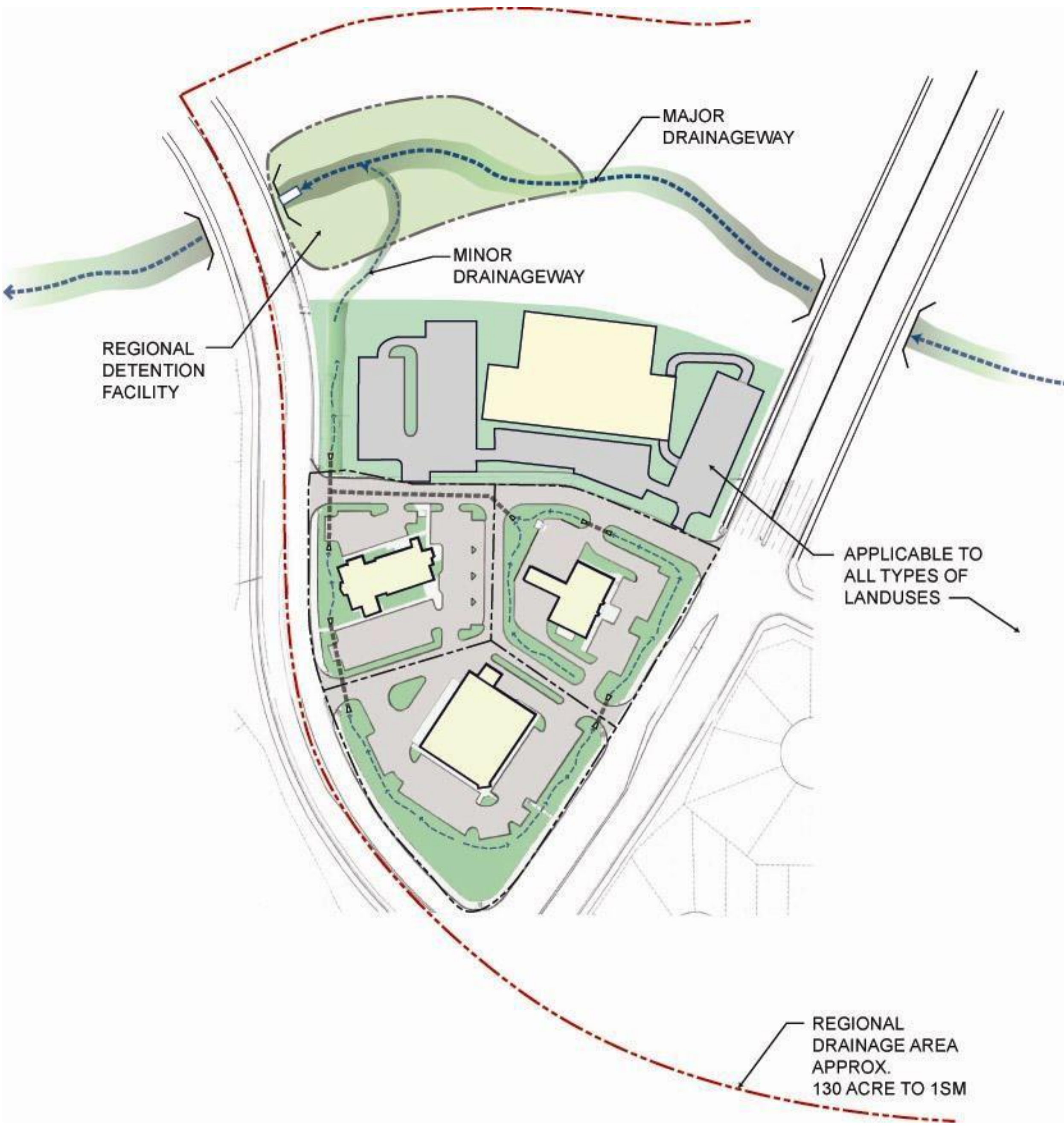


FIGURE 13-3
SUB-REGIONAL DETENTION APPROACH

FIGURE 13-4
ON-SITE DETENTION APPROACH

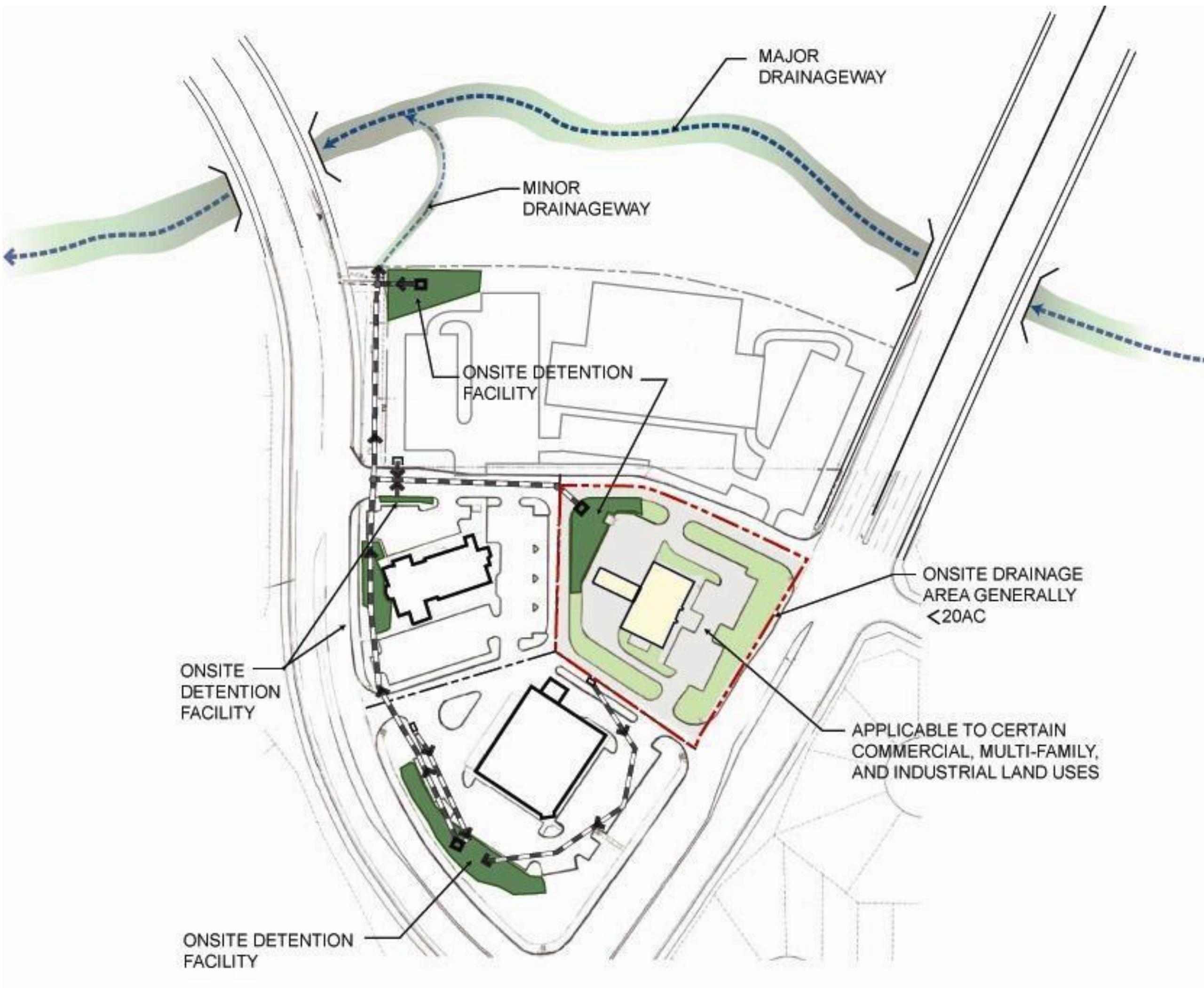


FIGURE 13-5
DESIGN OPTIONS FOR DETENTION BASINS

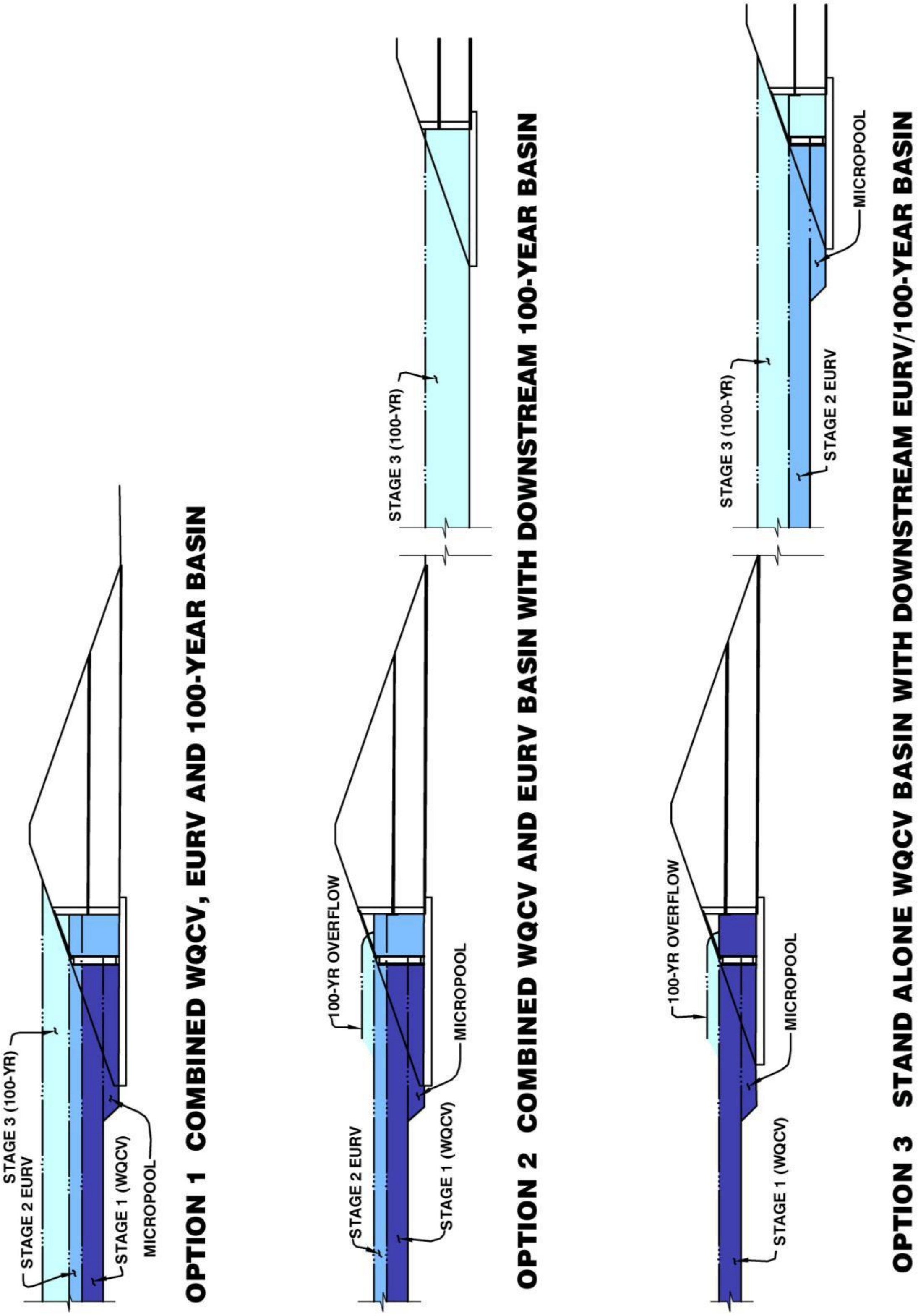


FIGURE 13-6
TYPICAL LOW FLOW CHANNEL DETAILS

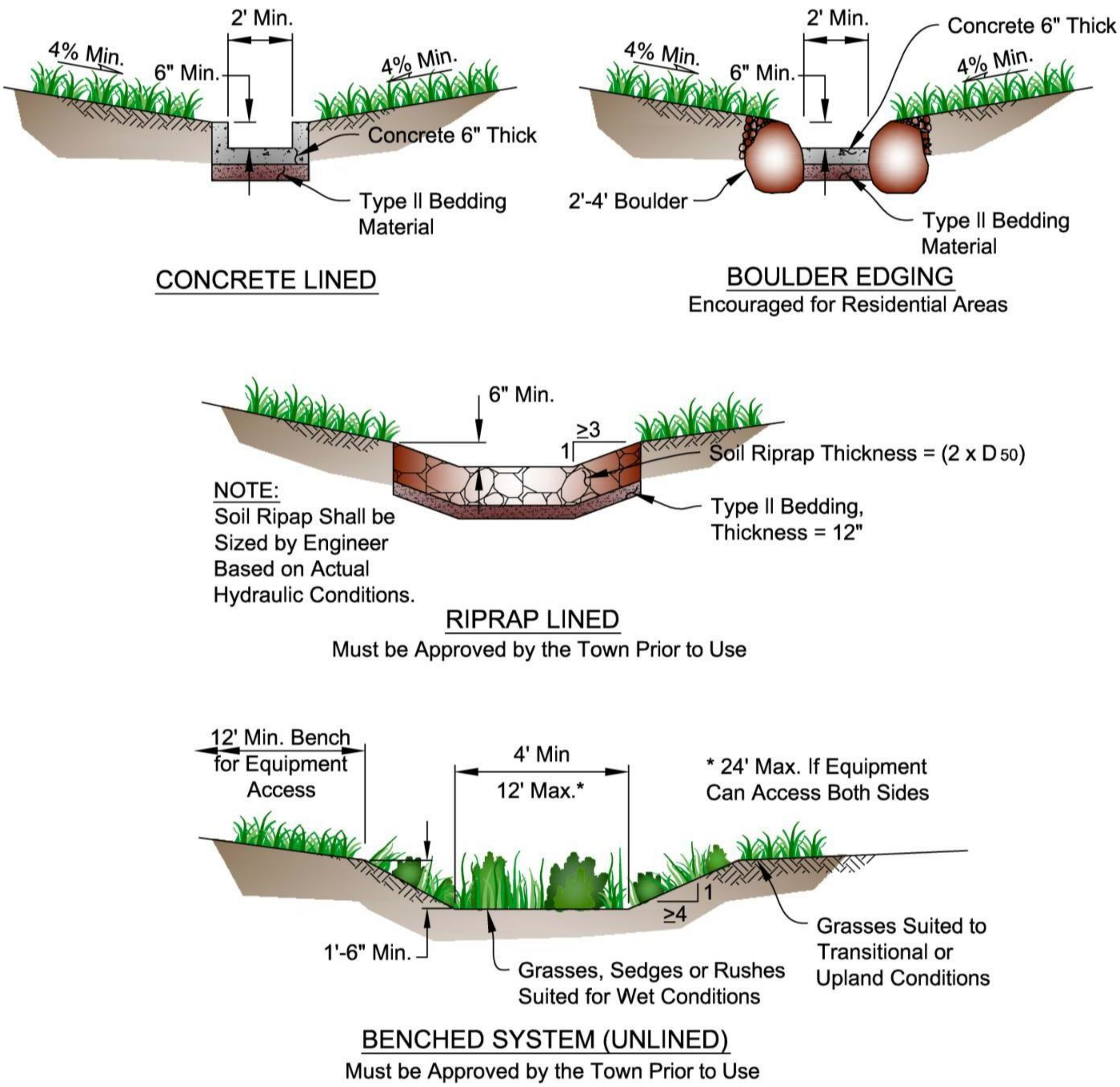
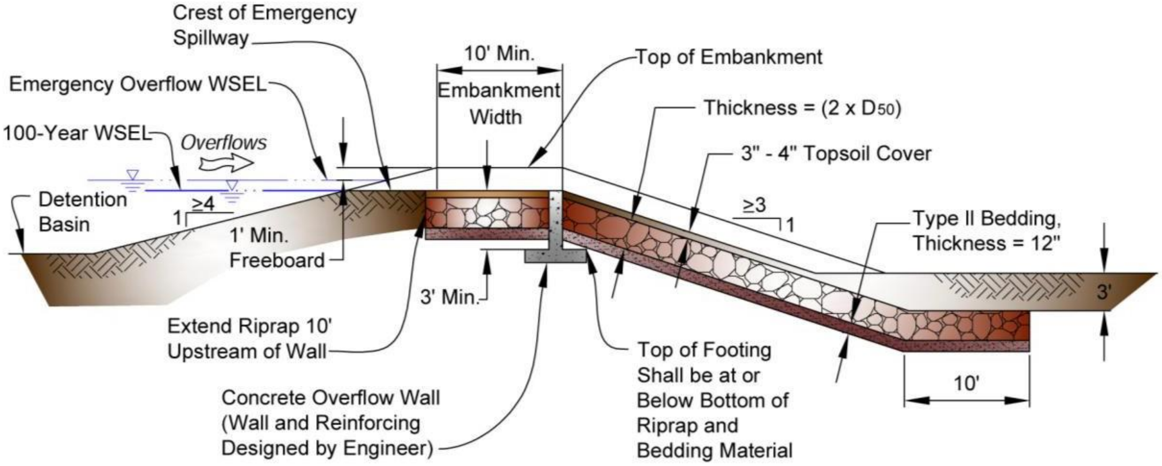
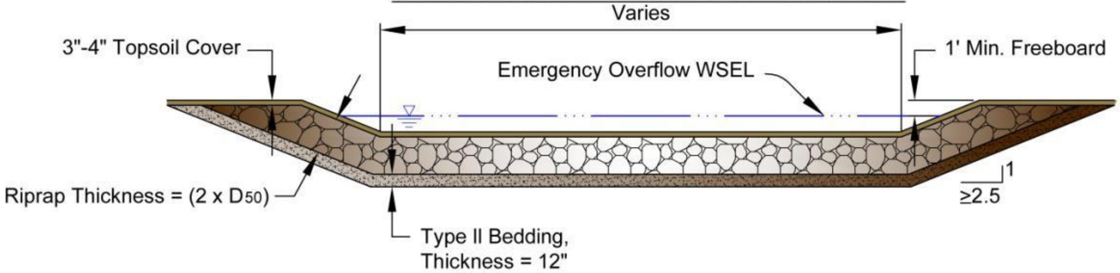


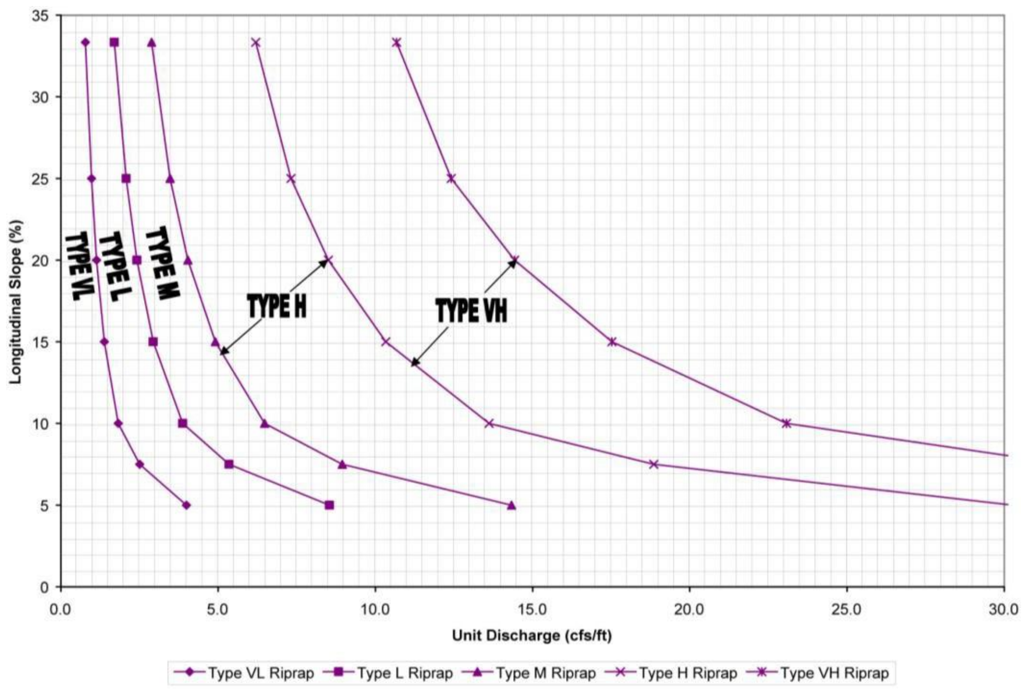
FIGURE 13-7
EMBANKMENT PROTECTION DETAILS AND ROCK SIZING CHART



EMERGENCY SPILLWAY PROFILE



SPILLWAY CHANNEL AT CREST AND DOWNSTREAM SIDE OF EMBANKMENT



14.0 Introduction

This chapter addresses requirements and design criteria related to post-construction water quality control measures (requirements for construction erosion and sediment control are addressed in the Town's Temporary Erosion, and Sediment Control (TESC) Manual). As described in Chapter 13, Storage, the Town requires that Water Quality Capture Volume be provided for all new development and redevelopment projects. In addition, other control measures are required to reduce runoff volume, stabilize drainageways, and control pollutants at their source (the four-step approach). Criteria presented in Volume 3 of the ~~UDFCD~~MHFD Manual shall govern except as modified or added to herein. Projects in the Cherry Creek Reservoir drainage basin shall design and implement post-construction water quality control measures in accordance with section 72.7 of the Cherry Creek Reservoir Control Regulation (CCR 1002-72) in addition to the requirements included in this chapter.

14.0.1 How to Use this Chapter. This chapter addresses stormwater quality planning and design. The foundation for this chapter is Volume 3 of the ~~UDFCD~~MHFD Manual and reference is made to the ~~UDFCD~~MHFD Manual for determining general control measure requirements, design features, and sizing.

In addition to referring designers to the ~~UDFCD~~MHFD Manual, the goal of this chapter is to provide additional criteria and guidance to improve the design and implementation of water quality control measures in the Town. To this end, the chapter provides the following information:

1. Four-Step Approach. Section 14.1 includes an expanded discussion of ~~UDFCD~~MHFD's four-step approach to water quality planning. This is the approach that shall be used on all new development and redevelopment projects in the Town. The four steps aim for a comprehensive approach to water quality by reducing the amount of site runoff, providing effective Water Quality Capture Volume and flood control detention, undertaking drainageway improvements to create stable, healthy streams, and implementing source controls to prevent pollutants from entering the stormwater system.

2. Regional, Sub-regional, and On-site Approaches. Section 14.2 references Chapter 13, Storage, and clearly states that the Town encourages that Water Quality Capture Volume facilities be implemented via regional or sub-regional facilities serving multiple lots as opposed to on-site facilities for each individual lot. The section also identifies specific criteria for addressing in-channel impacts associated with increased imperviousness in developments that discharge runoff into any jurisdictional drainageways (with respect to 404 permitting) upstream of regional or sub-regional water quality facilities.

3. Selection Guidance. Section 14.3 offers selection guidance for Water Quality Capture Volume facilities based on the regional, sub-regional, or on-site approach used, the character of the upstream drainageways and watershed, and the type of upstream land use. The guidance is provided to help ensure

that water quality facilities are effective and designed with consideration of the characteristics of the upstream tributary area.

4. Allowable Design Standards for Permanent Water Quality Control Measures. Section 14.4 provides minimum requirements for acceptable water quality design standards. At least one of the listed design standards must be met and documented in the design.

5. Design Criteria for the Town-Standard Control Measures. Section 14.5 provides design criteria for five types of control measures that are most commonly used in the Town. These consist of grass buffers and swales, extended detention basins, sand-filter basins, and porous landscape detention. The engineer is responsible for preparing a complete, site-specific set of design plans that provide all the construction information and detailing required to meet the criteria.

6. Design Criteria for Other Control Measures. Section 14.6 provides design criteria for control measures that are not as commonly used in the Town. These control measures include various types of porous pavement and porous pavement detention, constructed wetland basins, and retention basins. A site-specific design shall be prepared by the engineer based on information provided in Volume 3 of the ~~UDFCD~~MHFD Manual, typically in concert with appropriate specialists (in geotechnical engineering, pavement design, and structural design for porous pavement and in landscape architecture, wetlands treatment, and pond water quality for constructed wetlands and retention ponds).

7. Source Control Control Measures. Section 14.8 elaborates on the implementation of source controls on sites to reduce the likelihood that pollutants will enter the stormwater system.

14.0.2 Integrated Approach to Stormwater Quality. Stormwater quality management is a critical component of a land development plan. The design of water quality control measures must start in the early stages of the land development process and be integrated into the site and the upstream and downstream drainage network. Collaboration with professionals in fields such as site planning, landscape architecture, and geotechnical and structural engineering is recommended to create water quality control measures that function well and are safe, maintainable, and aesthetically pleasing.

14.1 Stormwater Quality Design Process

14.1.1 Four Step Process. Volume 3 of the ~~UDFCD~~MHFD Manual defines a four-step process that has become the cornerstone of the Town's approach to selecting and implementing control measures. Specific Town of Castle Rock criteria related to the four-step process are identified below.

1. Step 1: Reduce Runoff Volume to the Maximum Extent Practicable. Reducing runoff volume is accomplished by reducing the amount of pavement and roof area that is directly connected to inlets and storm sewer, while maximizing the pervious area that receives runoff from unconnected pavement or roofs. Pervious areas receiving runoff from unconnected impervious areas consist of grass buffers and swales, porous pavement, upland treatment swales, or some combination of these approaches. As long as these receiving pervious areas are stable and properly designed in accordance with Volume 3 of the ~~UDFCD~~MHFD Manual, as modified herein, they provide stormwater runoff volume reduction by dissipating the energy of the runoff, filtering the runoff through vegetation, and infiltrating stormwater runoff into the soil.

   Figure ND-1 in Volume 3 of the ~~UDFCD~~MHFD Manual can be used to estimate an effective imperviousness value based on reducing directly connected impervious area. This reduced imperviousness can result in a smaller Water Quality Capture Volume, Excess Urban Runoff Volume, and 100-year volume as described in Chapter 13, Storage. Reduced imperviousness can also result in smaller Rational Method peak flows for the five-year and smaller storms.

   Reducing directly connected impervious area (DCIA) is strongly encouraged on all new development and redevelopment projects within the Town. Site designers shall routinely look for and take advantage of opportunities to reduce directly connected impervious areas. The drainage report should contain a discussion of the efforts made to reduce DCIA. Where it can be demonstrated that additional reductions in DCIA can be achieved with minimal site revisions, the Town will recommend that the Engineer provide DCIA reductions as a part of the Town review and recommendation for approval.

   If regional water quality facilities are designed for the site, the upstream development sites require a specific minimum level of reducing directly connected impervious area. This is described further in Section 14.4.5.

   If the runoff reduction control measures are designed to infiltrate or evopotranspire sixty percent of what the calculated WQCV would be if all the impervious area for the site discharged without infiltration then no additional WQCV is required for the site. This can be achieved through the use of green infrastructure and/or low impact development principles. Runoff reduction approaches and amounts shall be substantiated in the drainage report. Supporting design information is required to justify infiltration rates and/or evapotranspiration rates. All designs must comply with state water law.

2. Step 2: Provide Water Quality Capture Volume and Flood Control Detention Via Full-Spectrum Detention. After reducing runoff volume, the remaining runoff is to be controlled through control measures that have the necessary Water Quality Capture Volume and flood detention volume. Appropriate reductions in required detention volumes may be applied for any reduction

in runoff volume from Step 1, as discussed in Chapter 13, Storage. Runoff reduction reduces the land area and costs associated with detention facilities.

Water Quality Capture Volume facilities are to be implemented in addition to 100-year flood control at a minimum of 0.5 times the WQCV plus 100-year detention volume (see Chapter 13, Storage). Water quality and flood control may be combined into a single detention facility or configured in separate facilities, as shown in Figure 13-4. Regional, sub- regional, or, in limited cases, on-site detention facilities may be used, as described in Chapter 13, Storage.

The purpose of full-spectrum detention is to control the increase in runoff rates from developed areas during frequent storm events that exacerbate stream degradation. Runoff reduction (Step 1) and full-spectrum detention (Step 2) are intended to reduce the extent and severity of degradation in drainageways downstream of developing areas. Reducing degradation helps to protect stream health and water quality while cutting down on costly stream stabilization efforts.

3. Step 3: Utilize Stream Channel Stabilization Techniques. The stream channel stabilization techniques described in Chapter 12, Open Channel Design, shall be applied to any drainageways that exist on or adjacent to the site or are constructed as part of the development. In some cases, as determined by the Town, some stabilization may be required in off-site drainageways that receive runoff from the site.

   Where regional or sub-regional detention is implemented, drainageways upstream of the facility shall be stabilized based on the increased, undetained runoff that will flow in the channels. If a regional or sub-regional facility is located within land controlled by a single development, the developer is responsible for stabilizing the drainageways based on undetained flows upstream of the detention facility to the furthest upstream outfalls that convey undetained flows. The developer is also responsible for stabilizing any drainageway reaches within its property upstream of the upstream outfalls and downstream of the regional or sub-regional detention facility, based on approved flow rates. If a regional or sub-regional facility located downstream of a developer’s property has been approved in lieu of detention within the property, the developer is responsible for stabilizing the drainageways within its area of responsibility for undetained flows and an approved plan for stabilizing the drainageways from the downstream limits of the property to the regional detention facility is required. Additional discussion of regional water quality and flood control detention is provided in Section 13.2 of Chapter 13, Storage.

   The concept of natural stream stabilization is discussed in Chapter 12, Open Channel Design. Natural stream stabilization goes beyond just stabilizing a channel against erosion (which technically could be accomplished by lining the channel with concrete), and has the goal of creating streams and floodplains that are stable, well-vegetated, and physically and biologically healthy. This goal is just as important as improving the water quality of runoff flowing off a development site and into a receiving stream.

4. Step 4: Undertake Source Control. The last step in the four step process for implementing control measures on a site is to control the potential for illicit discharges from the site. If the site has the potential for chemicals, oils, fertilizers, or other pollutants to enter the stormwater system, additional measures shall be provided. These measures may include covering of storage/handling areas, spill containment and control, and other best available technologies. In addition to structural source controls, non-structural practices applicable to site activities shall be considered and documented in the drainage report. Non-structural control measures prevent or reduce the generation of runoff or illicit discharges.

   Section 14.8 addresses requirements for source control control measures to reduce the potential for illicit discharges.

14.2 Sub-Regional, Regional, and On-site Approaches

14.2.1 General. Water Quality Capture Volume facilities, whether combined with flood control detention or standing-alone, may be implemented regionally (located on a major drainageway with a drainage area between 130-acres and one square mile), sub-regionally (serving two or more development parcels with a total drainage area less than 130-acres), or on-site (within an individual development parcel). As described in Section 13.2, the Town of Castle Rock requires that new development implement sub-regional Water Quality Capture Volume facilities and flood control detention at a subdivision level in lieu of onsite facilities at the time each lot is developed. Regional Water Quality Capture Volume facilities shall be considered on a case-by-case basis.

14.2.2 Requirements for Regional and Sub-Regional Water Quality Facilities on Waters of the State. If a regional or sub-regional water quality capture volume facility is implemented on waters of the state, the requirements of Section 14.4.4 or 14.4.5 must be met. Additionally, major drainageways and all minor drainageways upstream of the regional or sub-regional water quality facility shall be fully stabilized in accordance with Chapter 12, Open Channel Design.

14.3 Selecting Type of Water Quality Capture Volume Facility

The selection of the type of Water Quality Capture Volume facility for a project depends on a number of factors, including the following:

1. Sub-Regional, Regional, or On-site Water Quality Detention Approach. Sub-regional and regional control measures are generally larger facilities such as extended detention basins or, if hydrology is adequate to support wetlands or permanent pools, constructed wetlands basins or retention ponds. Infiltration-type control measures are not to be used for sub-regional and regional facilities, but may be considered for on-site control measures.

2. Drainage Area. Drainage area is a factor in the selection of certain control measures. For instance, infiltration-type control measures are suited for relatively small drainage areas. Also, a modified version of an extended detention basin may be considered for drainage areas less than ten acres. Drainage area defines major and minor drainageways, which in turn dictates the dividing line between sub-regional and regional facilities.

3. Type of Development. Type of development determines certain control measure choices. Infiltration-type control measures are not allowed in single-family residential land uses in the Town. Industrial and commercial land uses require source control control measures to be employed to keep chemicals and other potential pollutants out of the stormwater system.

4. Upstream Land Cover. Upstream land cover influences the selection of control measures. Infiltration-type control measures generally are only allowed if the upstream drainage area consists of pavement, roof, or fully-stabilized landscaping.

5. Hydrology. Hydrology affects the selection of control measures. Constructed wetlands basins and retention ponds shall only be used if adequate hydrology exists to support the wetlands or permanent pool.

Table 14-1, located towards the end of this chapter, comprises a selection matrix for Water Quality Capture Volume facilities based on the factors described above.

14.4 Allowable Design Standards for Permanent Water Quality Control Measures

14.4.1 WQCV Standard: The control measure(s) is designed to provide treatment and/or infiltration of the water quality capture volume and evaluation of the minimum drain time shall be based on the pollutant removal mechanism and functionality of the control measure implemented. Consideration of drain time shall include maintaining vegetation necessary for operation of the control measure (e.g., wetland vegetation).

14.4.2 Pollutant Removal Standard: The control measure(s) is designed to treat at a minimum the 80th percentile storm event. The control measure(s) shall be designed to treat stormwater runoff in a manner expected to reduce the event mean concentration of total suspended solids (TSS) to a median value of 30 mg/L or less.

14.4.3 Runoff Reduction Standard: The control measure(s) is designed to infiltrate into the ground where site geology permits or evapotranspire a quantity of water equal to sixty percent of what the calculated WQCV would be if all impervious area for the applicable development site discharged without infiltration. This base design standard can be met through practices such as green infrastructure or low impact development. “Green infrastructure” generally refers to control measures that use vegetation, soils, and natural processes or mimic natural processes to manage stormwater. Green infrastructure can be used in place of or in addition to low impact development principles.

14.4.4 Applicable Development Site Draining to a Regional WQCV Control Measure: The regional WQCV control measure must be designed to accept the drainage from the applicable development site. Stormwater from the site must not discharge to a water of the state before being discharged to the regional WQCV control measure. The regional WQCV control measure must meet the requirements of the WQCV in Section 14.4.1.

14.4.5 Applicable Development Site Draining to a Regional WQCV Facility: The regional facility is designed to accept drainage from the applicable development site. Stormwater from the site may discharge to a water of the state before being discharged to the regional WQCV facility. Before discharging to a water of the state, at least twenty percent of the upstream imperviousness of the applicable development site must be disconnected from the storm drainage system and drain through a receiving pervious area control measure comprising a footprint of at least ten percent of the upstream disconnected impervious area of the applicable development site. The control measure must be designed in accordance with the Manual. In addition, the stream channel between the discharge point of the applicable development site and the regional WQCV facility must be stabilized.

The regional WQCV facility must meet the following requirements:

1. The regional WQCV facility must be implemented, functional, and maintained following good engineering, hydrologic and pollution control practices.

2. The regional WQCV facility must be designed and maintained for 100 percent WQCV for its entire drainage area.

3. The regional WQCV facility must have capacity to accommodate the drainage from the applicable development site.

4. The regional WQCV facility must be designed and built to comply with all assumptions for the development activities planned by the permittee within its drainage area, including the imperviousness of its drainage area and the applicable development site.

5. Evaluation of the minimum drain time shall be based on the pollutant removal mechanism and functionality of the facility. Consideration of drain time shall include maintaining vegetation necessary for operation of the facility (e.g., wetland vegetation).

6. The regional WQCV facility shall include operation and maintenance guidelines.

7. The regional WQCV facility must be subject to the Town’s authority.

8. Regional Facilities must be designed and implemented with flood control or water quality as the primary use. Recreational ponds and reservoirs may not be considered Regional Facilities. Water bodies listed by name in surface water quality classifications and standards regulations (5 CCR 1002-32 through 5 CCR 1002-38) may not be considered regional facilities.

14.5 Design Criteria for Commonly Implemented Control Measures

The following sections refer to base criteria in Volume 3 of the ~~UDFCD~~MHFD Manual and provide supplementary design information and criteria.

14.5.1 Design Criteria for Grass Buffers and Swales.

1. Base Criteria. Grass buffers and grass swales shall be designed in accordance with information provided in Volume 3 of the ~~UDFCD~~MHFD Manual, as supplemented by the following criteria. These criteria pertain to shallow urban roadside swales described in Section 7.7 and to grass buffers and swales not associated with a roadway.

2. Definition of Terms. Figure 14-1 illustrates four variables that are associated with the principle of reducing directly connected impervious area. These are defined in Appendix A of the Runoff chapter of the ~~UDFCD~~MHFD Manual. The pavement and roof area that is directly connected to a curb and gutter or storm sewer is termed the directly connected impervious area. The rest of the impervious area on the site, draining to landscape or porous pavement, is termed the unconnected impervious area. The directly connected impervious area and the unconnected impervious area add up to the total impervious area. The portion of the landscape area that receives runoff from the unconnected impervious area and is wetted during the two-year storm is called the receiving pervious area. The remaining landscape area is called the separate pervious area.

3. Sizing and Design Criteria. As stated in Section 14.1.1, the objective on any urban site is to minimize directly connected impervious area and maximize receiving pervious area and to achieve the on-site requirements associated with regional and sub-regional water quality facilities on jurisdictional streams identified in Section 14.2.2. This is accomplished by laying out grass buffers and swales in proximity to roofs and pavement to receive as much impervious area runoff as possible and convey it through the site.

   It is desirable to lay out grass buffers and swales with ample flow width and relatively flat slopes to slow down flow velocities and increase contact time with the soil and vegetation, but not so flat as to create standing water. Maximum slopes shall be dictated by the criteria shown in Table 14-2. Swales exceeding the maximum slope criteria may be allowed if lined with soil riprap, subject to approval of the Town.

Table 14-2 illustrates concepts for grass swales, including an urban roadside grass swale and details for an underdrain and soil riprap lining.

TABLE 14-2
GRASS BUFFER AND SWALE DESIGN CRITERIA

	Grass Buffer	**Grass Swale**[2]	
	Max. Slope	Max. Slope	Max. 2-Year Velocity (fps)
Irrigated Bluegrass Sod[1]	25%	4.0%	4.0
Irrigated Native Turf Grass[1]	10%	2.5%	3.0
Non-Irrigated Native Turf Grass	4%	0.5%	1.0

[1] If swale slope is less than 2.0%, an underdrain is required
[2] Minimum swale slope is 0.2%

4. Determination of Receiving Pervious Area. The receiving pervious area is the wetted area of the buffers, swales, porous pavement, or upland treatment swales in the two-year storm. A quick approximation of the wetted area may be obtained by summing the buffer areas, the bottom of any trapezoidal swales, and the side slopes of swales assuming an average flow depth of a few inches. As the overall size of the receiving pervious area is finalized, a refined estimate of area may be determined by calculating average two-year flow rates for each buffer, swale, or other component, computing flow depths and top widths, and summing the wetted area of the components.

   The following guidelines apply when estimating the size of the receiving pervious area for purposes of achieving the requirements associated with regional or sub-regional water quality identified in Section 14.2.2.

   a. The size of the unconnected impervious area needs to be estimated as a percentage of upstream directly connected impervious area for each tributary or outfall draining to a jurisdictional drainageway upstream of the regional or sub-regional water quality facility.

   b. The size of the receiving pervious area needs to be estimated as a percentage of upstream unconnected impervious area for each tributary or outfall.

   c. Areas that, in the judgment of the designer, may not be fully wetted in the two-year event due to short-circuiting or other reasons, should not be included in the receiving pervious area.

   d. The unconnected impervious area and receiving pervious area shall be clearly indicated on the drainage plan and construction drawings, as well as the percentages described in a. and b. above.

5. Pavement Edge Treatment. A concrete edger is recommended in urban areas for asphalt streets and parking areas adjacent to grass buffers and swales. The formed concrete provides a neat edge adjacent to the grassed area that can be constructed at a controlled grade. The concrete edger, a concept for which is shown in Figure 14-3, can also serve to cut off the flow of water from the buffer or swale toward the pavement subgrade.

6. Reducing Wheel Rut Impacts. Because standard curb and gutter is typically not used at the edge of pavement adjoining grass buffers or swales, inadvertent tracking of vehicles onto the grassed area can be an issue. One of several options may be considered for reducing the impact of wheel rutting on grass buffers and swales adjacent to access and parking areas.

   a. *Wheel stops.* Concrete wheel stops can be used in parking lots adjacent to grass buffers or swales to keep vehicles off the grass area.

   b. *Intermittent curb*. Curb and gutter with frequent openings in the curb may be used to direct runoff to a grass buffer or swale, while still impeding inadvertent tracking off the pavement. The unit runoff rates shown for grass buffers in Volume 3 of the ~~UDFCD~~MHFD Manual shall not be exceeded through the openings in the curb. Curb ends shall be shaped or sloped to reduce impacts on snow removal equipment.

   c. *Cobble strip*. A layer of exposed rock several feet wide can reduce wheel rutting impacts to grass buffers and swales. The rock shall be large enough to resist movement during the design runoff event.

   d. *Reinforced turf*. Several feet of reinforced turf, one of the porous pavement options described in Volume 3 of the ~~UDFCD~~MHFD Manual, may be considered to reduce wheel rutting impacts to grass buffers and swales adjacent to pavement.

7. Landscaping Considerations. Dense turf grass, either bluegrass or sod-forming native grasses, shall be used for grass buffers and swales. An irrigation system is required for grass buffers and grass swales; if sod-forming native grasses are used, the irrigation system will help to establish a dense stand of turf grass and maintain it in periods of low precipitation. Erosion control blankets in accordance with the Town of Castle Rock TESC Manual shall be used during grass establishment in buffers and swales if native grasses are used. Shrub and tree plantings may be considered within grass buffers and swales, although their effect on capacity must be taken into account.

8. Underdrain Piping. Underdrain piping shall be consistent with the Town of Castle Rock standards (see design checklists on the Town of Castle Rock's website, at CRgov.com/codecentral).

9. Required Drawings. Construction drawings for grass buffers and grass swales shall include design drawings and detailed information, consistent with the example drawings and as required on the design checklist available on the Town's website (CRgov.com/codecentral).

14.5.2 Design Criteria for Extended Detention Basins.

1. Base Design Information. Extended detention basins are to be designed in accordance with the two-stage layout shown in Volume 3 of the ~~UDFCD~~MHFD Manual, as supplemented by the following criteria. This section also describes modified extended detention basin criteria for small sites.

2. Combining with Flood Detention. An extended detention basin is typically combined with Excess Urban Runoff Volume and 100-year detention, although any of the three design options shown in Figure 13-4 may be used. Criteria for Excess Urban Runoff Volume and 100-year detention are described in Chapter 13, Storage.

3. Selection Criteria. Extended detention basins may be used as a sub-regional or regional water quality detention facility or as an on-site water quality facility for those cases where a sub-regional or regional approach is not possible (see Section 13.2). Extended detention basins shall comply with the selection criteria shown in Table 14-1.

4. Basin Storage Volume. Provide extended detention storage volume equal to the applicable Water Quality Capture Volume, plus any combined volume for the Excess Urban Runoff Volume and 100-year events computed according to Volume 3 of the Storage Chapter of the ~~UDFCD~~MHFD Manual. The elevation difference between the invert of the pipe outlet at the centerline of the basin embankment and the crest of the emergency spillway shall be less than ten-feet unless otherwise approved.

5. Outlet Structure. Figures 14-4 and 14-5 show conceptual layouts of several types of outlet structures with integral micropools. Figures 14-6 and 14-7 show similar outlet structures with external micropools. External micropools shall only be used if a constant baseflow exists, and only with the approval of the Town. Outlet structures include a column of orifices to control releases from the Water Quality Capture Volume and Excess Urban Runoff Volume (sized based on the Storage Chapter of the ~~UDFCD~~MHFD Manual), a trash rack to protect the orifices, and a drop box for flood flows with a grate and control orifice. Orifice spacing may be adjusted based on the discussion Section 13.3.12, if approved by the Town.

   The flood-flow orifice shall be sized to provide the allowable 100-year release rate when the 100-year detention volume is completely full. The weir crest at the top of the Excess Urban Runoff Volume shall pass the allowable 100-year release rate at a head that is at least 0.5-feet below the completely full 100-year volume, maintaining control at the 100-year orifice in the design event.

6. Trash Rack. Trash racks shall comply with the criteria described in Section 13.3.13 of Chapter 13, Storage.

7. Scour Protection at Inflow Points. Stable protection against scour at all inflow points is required. This may consist of stable, irrigated grasses if runoff enters via sheet flow, or as described in Section 13.3.11 of Chapter 13, Storage.

8. Sediment Forebay. Forebays provide locations for debris and coarse sediment to drop out and accumulate, extending the functionality of the main portion of an extended detention basin. Forebays shall be sized based on Volume 3 of the ~~UDFCD~~MHFD Manual and designed in a similar manner as shown in the example design drawings shown on the Town of Castle Rock website. Figures 14-8 and 14-9 show concepts for sediment forebays that are integrated into the downstream outfall of storm sewer systems, one at a pipe end and one at a flared end section. The use and sizing of integral forebays at pipe outfalls shall be as approved by the Town.

9. Low Flow Channel. See Section 13.3.9 for criteria pertaining to low flow channels.

10. Micropool. Micropools are an essential part of EDB function, as they are designed in conjunction with the trashrack protecting the control orifices to reduce the potential for trashrack and orifice plugging. The trashrack is designed to extend down to the bottom of the micropool. The micropool functions to keep a midrange portion of the trashrack clear between sediment accumulating on the bottom of the pool and floatable debris accumulating on the top. Experience has shown that extended detention basins that have been constructed without micropools tend to clog at the orifices or trashrack and result in shallow flooding and boggy conditions in the bottom of the pond. Micropools may be integrated into the outlet structure or, if approved by the Town, extend upstream of the outlet structure (while maintaining a connection to the trashrack). Provisions for safety and maintenance access such as steps, ramps or a sloped perimeter bench shall be provided

11. Retaining Walls. All retaining walls shall be designed in accordance with the criteria specified in Section 13.3.15 of Chapter 13, Storage.

12. Modified Extended Detention Basin for Small Sites. On a site-specific basis, the Town may allow modified extended detention basins on small sites, as shown in Figure 14-1. Modified extended detention basins shall utilize sediment forebays integrated into pipe outfalls, as shown in Figures 14-8 and 14-9, and outlet structures with integral micropools, as shown in Figures 14-4 and 14-5. The sediment forebays may be sized according to the dimensions shown in Figures 14-8 or 14-9, or as approved by the Town. The invert of the low flow channel shall be at an

elevation at least 4-inches above the surface of the micropool, as specified for the two-stage design in the Storage Chapter of the ~~UDFCD~~MHFD Manual.

Figures 14-10 and 14-11 show representative layouts of a modified extended detention basin for a small site, if approved.

13. Designing for Maintenance. Design requirements for maintenance operations are specified in Chapter 13, Storage.

14. Landscaping Considerations. Design recommendations for vegetation in extended detention basins and for shaping and making the most of recreation opportunities are discussed in Chapter 13, Storage.

15. Design Drawings and Checklist. Construction drawings for extended detention basins shall include design drawings and detailed information, consistent with the example drawings and as required on the design checklist available on the Town's website (CRgov.com/codecentral).

14.5.3 Design Criteria for Sand Filter Basins.

1. Base Design Information. Sand filter basins are to be designed in accordance with information provided in Volume 3 of the ~~UDFCD~~MHFD Manual, as supplemented by the following criteria.

2. Combining with Flood Detention. A sand filter basin may be used as a stand-alone Water Quality Capture Volume basin, may be combined with Excess Urban Runoff Volume, or may be combined with Excess Urban Runoff Volume and 100-year detention, in accordance with Figure 13-4. Criteria for Excess Urban Runoff Volume and 100-year detention are described in Chapter 13, Storage.

3. Selection Criteria. Sand filter basins may be used as a sub-regional facility or as an on-site water quality facility for those cases where a sub-regional approach to water quality detention is not possible (see Section 13.2). Sand filter basins shall comply with the selection criteria shown in Table 14-1. Although sand filter basins with sediment forebays can handle a small amount of inflowing sediment, sand filter basins in general are not well suited for high sediment loads.

4. Basin Storage Volume. The minimum surface area of the filter media of the sand filter basin shall be actual area required to contain the Volume 3 Water Quality Capture Volume assuming a depth of 3.0-feet extending vertically upward from the bed (although the actual basin will normally provide 4 to 1 slopes or flatter around the sand bed). The bottom of the basin shall be flat for the entire area of the sand bed. If the Excess Urban Runoff Volume and 100-year volume is included, the aerial extent of the sand bed is to stay the same and the overflow drop-inlet is to be designed to control the Excess Urban Runoff Volume and 100-year outflows. The sand filter comprises the flat bottom of the basin, with stable landscaped slopes required all around.

5. Outlet Structure. Figure 14-16 shows the layout of a typical outlet structure for the three outflow conditions illustrated in Figure 13-4.

6. Underdrain Piping. Underdrain piping shall be consistent with the Town of Castle Rock standards (see design checklists on the Town of Castle Rock website).

7. Scour Protection at Inflow Points. Stable protection against scour at all inflow points is required. This may consist of stable, irrigated grasses if runoff enters via sheet flow, or as described in Section 13.3.14 of Chapter 13, Storage.

8. Sediment Forebay. Based on Table 14-1, sand filter basins serving more than an acre or that accept runoff from drainage areas that may have some non-irrigated native grasses require a sediment forebay at each inflow point. Forebays provide locations for debris and coarse sediment to drop out, extending the functionality of the main portion of a sand filter basin. Forebays shall be as shown in Figures 14-8 and 14-9 or as approved by the Town.

9. Perimeter Separation Walls. Proper construction and maintenance of sand filter basins require that the sand filter material be separated from the native material surrounding the filter. A permanent barrier must be provided for the perimeter of the sand filter material. Barrier walls may consist of concrete, plastic sheet piling, stacked block, or other methods approved by the Town. Barrier walls shall be designed by the engineer and detailed on the construction plans. The plans shall include methods for attaching or wrapping the geotextile fabric or liner, and for the surface treatment above the wall.

10. Liners. The determination whether or not an impermeable liner is required for the sand filter basin shall be based on the recommendation of a licensed geotechnical engineer. Sections 14.5.7 and 14.5.8 provide additional information and design considerations when an impermeable liner is required.

11. Retaining Walls. All retaining walls shall be designed in accordance with the criteria specified in Section 13.3.15 of Chapter 13, Storage. In addition, Section 14.5.9 provides design information regarding retaining walls and sand filter basins.

12. Designing for Maintenance. Design requirements for maintenance operations are specified in Section 13.7 of Chapter 13, Storage.

13. Landscaping Considerations. Detailed information regarding landscaping of sand filter basins and porous landscape detention basins is presented in Section 14.5.10.

14. Design Drawings and Checklist. Construction drawings for sand filter basins shall include design drawings and detailed information, consistent with the

example drawings and as required on the design checklist available on the Town's website.

15. Construction of Sand Filter Basins. Because of their high potential for clogging during the construction of the development, sand filter basins shall not be installed until the site has been stabilized with pavement and permanent landscaping. Construction control measures should remain in place until the site is permanently stabilized.

14.5.4 Design Criteria for Porous Landscape Detention.

1. Base Design Information. Porous landscape detention facilities are to be designed in accordance with information provided in Volume 3 of the ~~UDFCD~~MHFD Manual, as supplemented by the following criteria.

2. Combining with Flood Detention. Porous landscape detention may be used as a stand-alone Water Quality Capture Volume basin, may be combined with Excess Urban Runoff Volume, or may be combined with Excess Urban Runoff Volume and 100-year detention volume, in accordance with Figure 13-4. Criteria for Excess Urban Runoff Volume and 100-year detention are described in Chapter 13, Storage.

3. Selection Criteria. Porous landscape detention shall only be used as an on- site water quality facility. On-site facilities shall only be used for those cases where a sub-regional or regional approach to water quality detention is not possible (see Section 13.2). Porous landscape detention shall comply with the selection criteria shown in Figure 14-1. Porous landscape detention shall only be used in locations that receive runoff from upstream pavement, roofs, or fully stabilized landscape areas (irrigated sod or planting beds with stable mulch layer).

4. Basin Storage Volume. The minimum area of the filter media of the porous landscape detention basin shall be actual area required to contain the Volume 3 Water Quality Capture Volume assuming a maximum depth of 12-inches extending vertically upward above the bed, or to contain the Excess Urban Runoff Volume assuming a maximum depth of 2-feet extending vertically above the bed. In each case the side slopes will normally be 6 to 1 or flatter, so the actual depths will be less than assumed. For porous landscape detention basins located adjacent to paved areas, like those shown in Figures 14-12 through 14-14, the surface of the filter media shall be no more than 18-inches below the elevation of the adjacent pavement, unless otherwise approved. The bottom of the basin shall be flat for the entire area of the filter media. If the Excess Urban Runoff Volume and 100-year volumes are included, the aerial extent of the filter media stays the same and the overflow drop-inlet is designed to control the Excess Urban Runoff Volume and 100-year outflows as shown in Figure 14-13.

5. Outlet Structure. Figure 14-16 shows the layout of a typical outlet structure for the three outflow conditions illustrated in Figure 13-4. The structure receives the underdrain collection piping from the porous landscape detention and includes a drop box for flood flows with a grate and one or more control orifices.

6. Underdrain Piping. Underdrain piping shall be consistent with the Town of Castle Rock standards (see design checklists on the Town of Castle Rock website).

7. Scour Protection at Inflow Points. Stable protection against scour at all inflow points is required. This may consist of stable, irrigated grasses if runoff enters via sheet flow or other methods depicted in Figure 14-14.

8. Perimeter Separation Walls. Proper construction and maintenance of porous landscape detention facilities require that the sand filter material be separated from the native material surrounding the filter. A permanent barrier must be provided for the perimeter of the sand filter material. Barrier walls may consist of concrete, plastic sheet piling, stacked block, or other methods approved by the Town. Barrier walls shall be designed by the engineer and detailed on the construction plans. The plans shall include methods for attaching or wrapping the geotextile fabric or liner, and for the surface treatment above the wall.

   In limited cases where porous landscape detention facilities are incorporated into unconstrained, open landscape areas located away from pavement, the perimeter separation walls may be eliminated as shown in Figure 14-15, if approved by the Town.

9. Liners. The determination whether or not an impermeable liner is required for the porous landscape detention shall be based on the recommendation of a licensed geotechnical engineer. Sections 14.5.7 and 14.5.8 provide additional information and design considerations when an impermeable liner is required.

10. Retaining Walls. All retaining walls shall be designed in accordance with the criteria specified in Section 13.3.15 of Chapter 13, Storage. No retaining walls shall be used within the area of any liners, except for the buried separation walls between the sand media and the earth. In addition, Section 14.5.9 provides design information regarding retaining walls and porous landscape detention.

11. Designing for Maintenance. Design requirements for maintenance operations are specified in Section 13.7 of Chapter 13, Storage.

12. Landscaping Considerations. Detailed information regarding landscaping of sand filter basins and porous landscape detention basins is presented in Section 14.5.

13. Design Drawings and Checklist. Construction drawings for porous landscape detention shall include design drawings and detailed information, consistent with the example drawings and as required on the design checklist available on the Town's website.

14. Construction of Porous Landscape Detention. Because of their high potential for clogging during the construction of the development, porous landscape detention shall not be installed until the site has been stabilized with pavement and permanent landscaping. Construction control measures should remain in place until the site is permanently stabilized.

14.5.5 Geotextile Fabric Design Considerations. Proper specification and installation of the geotextile fabrics are significant elements in ensuring that sand filter and porous landscape detention basins function properly over an extended time period. In typical installations, a bottom layer geotextile fabric is required to provide a barrier between the underdrain gravel and the native subgrade material and a top layer geotextile is required to provide a barrier between the gravel underdrain layer and the filter media. In those cases where a geomembrane liner is required, the geomembrane liner provides the barrier between the gravel layer and the native material subgrade, but an additional geotextile fabric layer is required on each side of the liner to protect the liner. In typical installations (without a geomembrane liner) the top geotextile fabric layer must be wrapped over the buried perimeter wall and attached with a batten strip to the outlet or other structures. When a geomembrane liner is required, the geotextile fabric must be attached with the liner to perimeter walls and outlet structures with the batten strip.

The final design and specification and attachment of geotextile fabrics shall be based on the information and requirements presented on the Town example drawings and checklists, and in consultations with the Town.

14.5.6 Geomembrane Liner Design Considerations. In some cases, developing sites or parcels may have expansive soils or sensitive environmental resources that must be protected. The Town, the design engineer, or the project geotechnical engineer may require that a geomembrane liner be specified to protect structures or sensitive resources in the vicinity of proposed sand filter and porous landscape detention basins. There are a number of important design, construction, and inspection requirements and considerations that must be addressed to ensure that the geomembrane liner is properly installed and that the liner functions as intended. Some of the considerations include, but are not limited to, proper material specifications, liner pre-assembly, proper welding and testing of seams, provisions for pipe penetrations, careful subgrade preparation, liner attachment to trench walls and outlet structures, handling and protection of the liner during construction, anchoring of the liner, and the design of an underdrain system, if needed to mitigate potential impacts from a high groundwater table.

The final design of the geomembrane liner shall be based on the information and requirements presented on the Town example drawings and checklists, and in consultations with the Town and the manufacturer of the specified liner.

14.5.7 Retaining Wall Use in Sand Filter Basins and Porous Landscape Detention. In general, the use of above grade retaining walls in the design of sand filter and porous landscape detention basins is discouraged. In most cases, the buried perimeter wall is needed to separate the filter media from the adjacent native soils during construction, but the use of above grade retaining walls shall be limited. A goal of the overall site design and layout should be to minimize the depth of sand filter and porous landscape detention basins and to allow for a smooth transition into adjacent impervious or landscaped areas. Utilizing sheet or shallow channel flow to convey runoff to the facilities rather than using underground storm sewer can

also help reduce the depth between the filter media and the grade adjacent to the facility. The use of retaining walls adjacent to a sand filter or porous landscape detention basins limits the ability to easily access the filter media and other components for maintenance. In no case shall dry stack retaining walls be used below the top of the filter media or the design water surface when a geomembrane liner is required.

14.5.8 Sand Filter Basin and Porous Landscape Detention Landscaping Requirements. There are specific considerations and landscaping requirements for sand filter and porous landscape detention basins. In general, porous landscape detention basins offer more options than sand filter basins for vegetative treatments to complement and enhance the overall site landscaping.

In the design of a sand filter basin, no vegetation or mulch shall be specified in the filter media of a sand filter basin. If the design includes a forebay or sediment chamber, vegetative treatment for the forebay or sediment chamber shall be irrigated sod turf grass. Irrigated turf grass sod or shrubs maybe used on the slopes above the Water Quality Capture Volume water surface, if a geomembrane liner is not required. Irrigation systems provided to supply water to the slopes shall be located outside of the filter media.

In the design of a porous landscape detention basin, potential vegetative treatments within the filter media include a full cover of native grasses established by seeding, or “clump-type” vegetation comprised of ornamental clump grasses or small native shrubs. Spacing of plants shall be specified such that hand raking can take place between plants to remove accumulated sediment. Shredded red cedar mulch shall be specified, if mulch is desired. Rock mulch shall not be used. Shrubs with mulch or irrigated turf grass may be used on the slopes of the basin, outside of the filter media. An irrigation system shall be provided to supply adequate water to all vegetated areas within and adjacent to the porous landscape detention basin. Irrigation heads and laterals shall be located outside of the filter media.

Tree plantings adjacent to porous landscape or sand filter basin installations shall be isolated from the basin using concrete or sheet pile barriers to ensure that the root structure does not impact the filter media or underdrain system. The barriers shall be placed adjacent to the basin, outside the Water Quality Capture Volume elevation, if a geomembrane liner is required. For either type of basin, the layout of landscaping on the adjacent slopes shall allow for necessary maintenance access.

14.6 Design Criteria for Other Control Measures

The following sections refer to base criteria in Volume 3 of the ~~UDFCD~~MHFD Manual and provide supplementary design information and criteria for control measures that are not as commonly used in the Town. These control measures include constructed wetland basins, retention basins, and various types of porous pavement and porous pavement detention. At present, no example drawings or design checklists have been prepared for these control measures. Rather, a site-specific design shall be prepared by the engineer, typically in concert with appropriate specialists (in geotechnical engineering, pavement design, and structural design for porous pavement and in landscape architecture, wetlands treatment, and pond water quality for constructed wetlands and retention ponds).

14.6.1 Design Criteria for Constructed Wetlands Basins.

1. Base Design Information. Constructed wetlands basins are to be designed in accordance with information provided in Volume 3 of the ~~UDFCD~~MHFD Manual, as supplemented by the following criteria.

2. Combining with Flood Detention. A constructed wetlands basin is typically combined with the Excess Urban Runoff Volume and 100-year detention volume in accordance with Figure 13-4. Criteria for Excess Urban Runoff Volume and 100-year detention are described in Chapter 13, Storage.

3. Selection Criteria. Constructed wetlands basins may be used as a sub-regional or regional water quality detention facility where hydrology is adequate to support the wetlands and where any water rights issues have been addressed. Constructed wetlands basins are typically not used for small on-site facilities due to their requirement for adequate hydrology. Constructed wetlands basins shall comply with the selection criteria shown in Table 14-1.

4. Basin Storage Volume. Provide extended detention storage volume above the permanent wetlands water surface equal to the applicable Water Quality Capture Volume computed according to Volume 3. For combined facilities, the basin shall include the Excess Urban Runoff Volume and 100-year detention volumes based on the methods in Chapter 13, Storage.

5. Outlet Structure. The layout and sizing of the outlet structure for a constructed wetlands basin is the same as specified in Section 14.5.4 for an extended detention basin, with the wetlands water surface corresponding to the micropool water surface.

6. Scour Protection at Inflow Points. Stable protection against scour at all inflow points is required. This may consist of stable, irrigated grasses if runoff enters via sheet flow, or as described in Section 13.3.9 of Chapter 13, Storage.

7. Sediment Forebay. Forebays provide locations for debris and coarse sediment to drop out and accumulate, extending the functionality of the constructed wetlands basin. Forebays may be located upstream of the constructed wetlands basin, as long as all runoff entering the constructed wetlands basin flows through a forebay. Figures 14-8 and 14-9 show concepts for sediment forebays that are integrated into the downstream outfall of storm sewer systems, one at a pipe end and one at a flared end section. The use and sizing of integral forebays at pipe outfalls shall be as approved by the Town.

8. Retaining Walls. All retaining walls shall be designed in accordance with the criteria specified in Section 13.3.15 of Chapter 13, Storage.

9. Designing for Maintenance. Design requirements for maintenance operations are the same as specified in Section 13-7 of Chapter 13, Storage.

10. Landscaping Considerations. If there is an adequate base flow to support the wetland vegetation and provide circulation in the pools, a constructed wetlands basin can be a very attractive natural feature. Establishing proper species of emergent and riparian vegetation is key to the basin's success. A detailed landscaping plan shall be developed by the appropriate specialists and included in the construction drawing set. Recommendations for shaping and making the most of recreation opportunities are discussed in Chapter 13, Storage.

11. Design Drawings. Site-specific construction drawings for constructed wetlands basins shall be prepared in accordance with the ~~UDFCD~~MHFD Manual, the information above, and consultation with Town Staff.

14.6.2 Design Criteria for Retention Ponds.

1. Base Design Information. Retention ponds are to be designed in accordance with information provided in Volume 3 of the ~~UDFCD~~MHFD Manual, as supplemented by the following criteria.

2. Combining with Flood Detention. A retention pond is typically combined with Excess Urban Runoff Volume and 100-year detention volumes in accordance with Figure 13-4. Criteria for Excess Urban Runoff Volume and 100-year detention are described in Chapter 13, Storage.

3. Selection Criteria. Retention ponds may be used as a sub-regional or regional water quality detention facility where hydrology is adequate to support the permanent pool and where any water rights issues have been addressed. Retention ponds are typically not used for small on-site facilities due to their requirement for adequate hydrology. Retention ponds shall comply with the selection criteria shown in Table 14-1.

4. Basin Storage Volume. Provide extended detention storage volume above the permanent water surface equal to the applicable Water Quality Capture

Volume computed according to Volume 3 of the ~~UDFCD~~MHFD Manual and Chapter 13, Storage. Additional sediment storage volume above the water surface is not necessary, since sediment storage will occur under the water surface. If the Excess Urban Runoff Volume is included above the permanent pool, no specific volume requirements are necessary for the pool other than providing the littoral zone shaping and pool depths specified in Volume 3 of the ~~UDFCD~~MHFD Manual.

5. Outlet Structure. The layout and sizing of the outlet structure for a retention pond is the same as specified in Section 14.5.4 for an extended detention basin, with the permanent water surface corresponding to the micropool water surface.

6. Retaining Walls. All retaining walls shall be designed in accordance with the criteria specified in Section 13.3.14 of Chapter 13, Storage.

7. Designing for Maintenance. Design requirements for maintenance operations are the same as specified in Chapter 13, Storage.

8. Landscaping Considerations. If there is an adequate base flow to maintain the permanent pool and provide circulation, a retention pond can be an attractive natural feature. Establishing proper species of emergent and riparian vegetation along the shoreline is essential for the pond's success. A detailed landscaping plan shall be developed by the appropriate specialists and included in the construction drawing set.

9. Design Drawings. Site-specific construction drawings for retention ponds shall be prepared in accordance with the ~~UDFCD~~MHFD Manual, the information above, and consultation with Town Staff.

14.6.3 Design Criteria for Porous Pavement

1. Base Design Information. Porous pavement facilities shall be designed in accordance with information provided in Volume 3 of the ~~UDFCD~~MHFD Manual, as supplemented by the following criteria.

2. Selection Criteria. Porous pavement shall only be used in locations that receive runoff from upstream pavement, roofs, or fully stabilized landscape areas (irrigated sod or planting beds with stable mulch layer).

3. Typical Drawings. Refer to Volume 3 of the ~~UDFCD~~MHFD Manual for typical layouts of porous pavement.

4. Sizing Criteria. Sizing criteria for porous pavement used as a runoff reduction technique is shown in Volume 3 of the ~~UDFCD~~MHFD Manual.

5. Underdrain Piping. Underdrain piping requirements shall be based on information provided in Volume 3 of the ~~UDFCD~~MHFD Manual and consultation with Town Staff.

6. Liners. The determination whether or not an impermeable liner is required for the porous pavement shall be based on the recommendation of a licensed geotechnical engineer. Additional design requirements and material specifications shall be based on information provided in Volume 3 of the ~~UDFCD~~MHFD Manual and consultation with Town staff.

7. Designing for Maintenance. Access for maintenance is generally not a problem, since this control measure is located within an area of pavement.

8. Construction Phasing. Porous pavement shall not be installed until all upstream areas are fully stabilized, or barriers or filters shall be set up to protect the porous pavement from sedimentation, as approved by the Town. Site drainage shall be considered for the period of construction prior to site stabilization and installation of the porous pavement.

9. Design Drawings. Construction drawings for porous pavement shall be prepared in accordance with the ~~UDFCD~~MHFD Manual, the information above, and consultation with Town Staff.

14.6.4 Design Criteria for Porous Pavement Detention.

1. Base Design Information. Porous pavement detention facilities are to be designed in accordance with information provided in Volume 3 of the ~~UDFCD~~MHFD Manual, as supplemented by the following criteria.

2. Combining with Flood Detention. Porous pavement detention may be used as a stand-alone Water Quality Capture Volume basin, may be combined with the Excess Urban Runoff Volume, or may be combined with the Excess Urban Runoff Volume and 100-year detention volume, in accordance with Figure 13-4. If the Excess Urban Runoff Volume and 100-year volumes are not combined with the porous pavement detention, they shall be provided elsewhere on or downstream of the site.

3. Selection Criteria. Porous pavement detention shall only be used as an on-site water quality detention facility for those cases where a sub-regional or regional approach to water quality detention is not possible (see Section 13.2). Porous pavement detention shall comply with the selection criteria shown in Table 14-1. Porous pavement detention shall only be used in locations that receive runoff from upstream pavement, roofs, or fully stabilized landscape areas (irrigated sod or planting beds with stable mulch layer).

4. Typical Drawings. Refer to Volume 3 of the ~~UDFCD~~MHFD Manual for typical layouts of porous pavement detention.

5. Sizing Criteria. Porous pavement detention facilities shall be flat, with no cross slope or longitudinal slope. Sizing criteria for porous pavement that is used as a stand-alone Water Quality Capture Volume facility is shown in Volume 3 of the ~~UDFCD~~MHFD Manual. If the Excess Urban Runoff Volume and

100-year volume is included, the aerial extent of the porous pavement detention facility stays the same and the overflow drop-inlet is designed to control the Excess Urban Runoff Volume and 100-year outflows.

6. Outlet Structure. Figure 14-16 shows the layout of a typical outlet structure for the three outflow conditions illustrated in Figure 13-4. The structure receives the underdrain collection piping from the porous pavement and includes a drop box for flood flows with a grate and one or more control orifices.

7. Underdrain Piping. Underdrain piping requirements shall be based on information provided in Volume 3 of the ~~UDFCD~~MHFD Manual and consultation with Town Staff.

8. Liners. The determination whether or not an impermeable liner is required for the porous pavement detention shall be based on the recommendation of a licensed geotechnical engineer. Additional design requirements and material specifications shall be based on information provided in Volume 3 of the ~~UDFCD~~MHFD Manual and consultation with Town Staff.

9. Designing for Maintenance. Access for maintenance is generally not a problem, since this control measure is located within an area of pavement.

10. Construction Phasing. Porous pavement detention shall not be installed until all upstream areas are fully stabilized, or barriers or filters shall be set up to protect the porous pavement from sedimentation, as approved by the Town. Site drainage shall be considered for the period of construction prior to site stabilization and installation of the porous pavement.

11. Design Drawings. Construction drawings for porous pavement detention shall be prepared in accordance with the ~~UDFCD~~MHFD Manual, the information above, and consultation with Town Staff.

14.7 Operation and Maintenance

Operation and Maintenance guidelines and procedures have been developed for common types of post-construction water quality control measures. The purpose of these documents is to provide information and guidance for those entities that will be responsible for the long-term inspection and maintenance of the facility. For more information refer to Section 4.6.

14.8 Source Control Control Measures

14.8.1 General. All new development and redevelopment in the Town shall be required to provide on-site structural and/or non-structural source controls to reduce the potential for illicit discharges from the site into the stormwater management system. The term “illicit discharge” is defined in the Phase II stormwater regulations as “any discharge to a municipal separate storm sewer that is not composed entirely of stormwater, except discharges pursuant to the Colorado Discharge Permit System permit and discharges resulting from fire-fighting activities."

Illicit discharges often include wastes and wastewater which enter the stormwater system through either direct connections (e.g., non-stormwater piping either mistakenly or deliberately connected to the storm drains) or indirect connections (e.g., infiltration into the storm sewer from cracked sanitary systems, contaminants or spills carried by stormwater runoff into the stormwater system). The result is untreated discharges that contribute high levels of pollutants, including heavy metals, toxics, oil and grease, solvents, nutrients, viruses, and bacteria to waters of the state. Pollutant levels from these illicit discharges have been shown in EPA studies to be high enough to significantly degrade receiving water quality and threaten aquatic, wildlife, and human health.

The Town requires that adequate provisions be included during the site plan development process to reduce the potential for illicit discharges from the property. Volume 3 provides information on structural and nonstructural control measures and should be used as a basis for determining the appropriate source controls for the intended activities associated with the site.

14.8.2 Direct Connections. Direct connections into the public storm sewer system are prohibited, except for those storm sewer systems that are reviewed and approved by the Town as a part of the development's Phase III Drainage Report. Exceptions may be made for special cases, in which the Town may approve other flows that are acceptable to be permitted into the storm drainage system. Such cases shall be approved by a variance request, with adequate analysis and justification.

14.8.3 Indirect Connections. Illicit discharges can occur with "indirect" connections. These types of discharges occur from stormwater runoff which flows on and over the impervious area of a site. The runoff has the potential to pick-up and carry pollutants from the site into the storm drainage system. These illicit discharges occur as a result of site activities which have the potential to expose pollutants to stormwater runoff. Examples of site activities which have the potential for pollutants to be discharged and carried off in stormwater runoff include:

- Outside material storage
- Vehicle washing
- Vehicle maintenance
- Outside manufacturing
- Painting operations
- Above ground storage tanks
- Loading and unloading areas
- Fueling
- Power washing

14.8.4 Structural Source Controls. Development projects which propose outdoor uses and activities which are deemed by the Town to have the potential to create illicit discharges shall be required to provide special source control control measures. The source control control measures shall be designed to prevent the contamination of stormwater runoff from the site.

Source control control measures can include, but are not limited to:

- Permanent covering of outdoor storage areas
- Spill containment and control (secondary containment, curbing, diking, etc.)
- Proper sanitary sewer connections
- Provision of designated storage and material handling areas
- Provision of proper waste receptacles

14.8.5 Non-Structural Controls. Non-structural control measures reduce or prevent contamination of stormwater runoff by reducing pollutant generation through changes in behavior. Non-structural controls are extremely effective, as they typically prevent or eliminate the entry of pollutants into stormwater at their source. The Town encourages that all development and redevelopment require and implement non-structural controls throughout their site and within their facility operational practices. Non-structural control measures which may provide a significant benefit to water quality include:

- General good housekeeping practices (proper material storage, clean and orderly work areas)
- Preventative maintenance
- Recycling programs
- Spill prevention and response
- Employee "awareness" education and training

14.8.6 Town Requirements for Illicit Discharge. The Phase III Drainage Report shall include a discussion of the uses and activities proposed for the site that may have the potential for illicit discharges. In particular, sites with a potential for the activities listed in Section 14.8.3 shall be identified. The Phase III Drainage Report shall discuss and include design information for appropriate source controls to mitigate the potential for illicit discharges from the identified activities. The source controls designated in the Phase III Drainage Report shall be required to be shown on the Site Improvement Plan, Phase III Drainage Plan and the Construction Drawings as applicable.

14.8.7 Operation and Maintenance. Source Control facilities require periodic maintenance to ensure that they are functioning properly and serving the intended purpose of reducing the potential for illicit discharges into the stormwater system. Inspection and maintenance requirements shall be identified in the Phase III Drainage Report for all source control control measures to ensure the controls function as intended.

TABLE 14-1
SELECTION MATRIX FOR WATER QUALITY CAPTURE VOLUME FACILITIES

Type of WQCV Facility	Town Standard?	Regional, Sub-Regional or Onsite	Drainage Area	Development Type	Upstream Land Cover	Hydrology
Extended Detention Basin	Yes - Example drawings and design checklist shall be used	Regional, sub-regional, or onsite	Generally 10 to 640 acres	Single-family residential or commercial/ office/ multi-family/ industrial	Can accept native, non-irrigated grass areas or upstream natural channels	Can handle baseflows, but baseflows are not needed
Constructed Wetlands Basin	No - specialized design required	Regional or sub-regional	Generally 20 to 640 acres	Single-family residential or commercial/ office/ multi-family/ industrial	Can accept native, non-irrigated grass areas or upstream natural channels	Baseflows are required; adequate water must be available for evapotranspiration
Retention Pond	No - specialized design required	Regional or sub-regional	Generally 20 to 640 acres	Single-family residential or commercial/ office/ multi-family/ industrial	Can accept native, non-irrigated grass areas or upstream natural channels	Baseflows are required; adequate water must be available for evapotranspiration
Modified Extended Detention Basin	Yes - Example drawings and design checklist shall be used	Sub-regional or onsite	Generally less than 10 acres[1]	Single-family residential or commercial/ office/ multi-family/ industrial	Can accept limited[2] native, non-irrigated grass areas or upstream natural channels	No baseflows are expected
Sand Filter Basin with Sedimentation Basin	Yes - Example drawings and design checklist shall be used	Sub-regional or onsite	Generally 1 to 20 acres	Commercial/ office/ multi-family/ industrial	Can accept limited[2] native, non-irrigated grass areas	No baseflows are expected
Sand Filter Basin	Yes - Example drawings and design checklist shall be used	Sub-regional or onsite	Generally Less Than 10 acres	Commercial/ office/ multi-family/ industrial	Requires 100% stable land cover (pavement, irrigated turfgrass, or stable mulches)	No baseflows are expected
Porous Landscape Detention	Yes - Example drawings and design checklist shall be used	Onsite	Generally less than 1 acre	Commercial/ office/ multi-family/ industrial	Requires 100% stable land cover (pavement, irrigated turfgrass, or stable mulches)	No baseflows are expected
Porous Pavement Detention	No - specialized design required	Onsite	Generally less than 1 acre	Commercial/ office/ multi-family/ industrial	Requires 100% stable land cover (pavement, irrigated turfgrass, or stable mulches)	No baseflows are expected

[1] For drainage areas less than 1 acre, the Town may consider alternative designs that reduce structural elements associated with forebay, low flow channel and outlet structure.

[2] For upstream land cover defined as "limited native non-irrigated grass", total land cover cannot consist of more than 20% native non-irrigated grass.

FIGURE 14-1
TERMS FOR MINIMIZING DIRECTLY CONNECTED IMPERVIOUS AREA

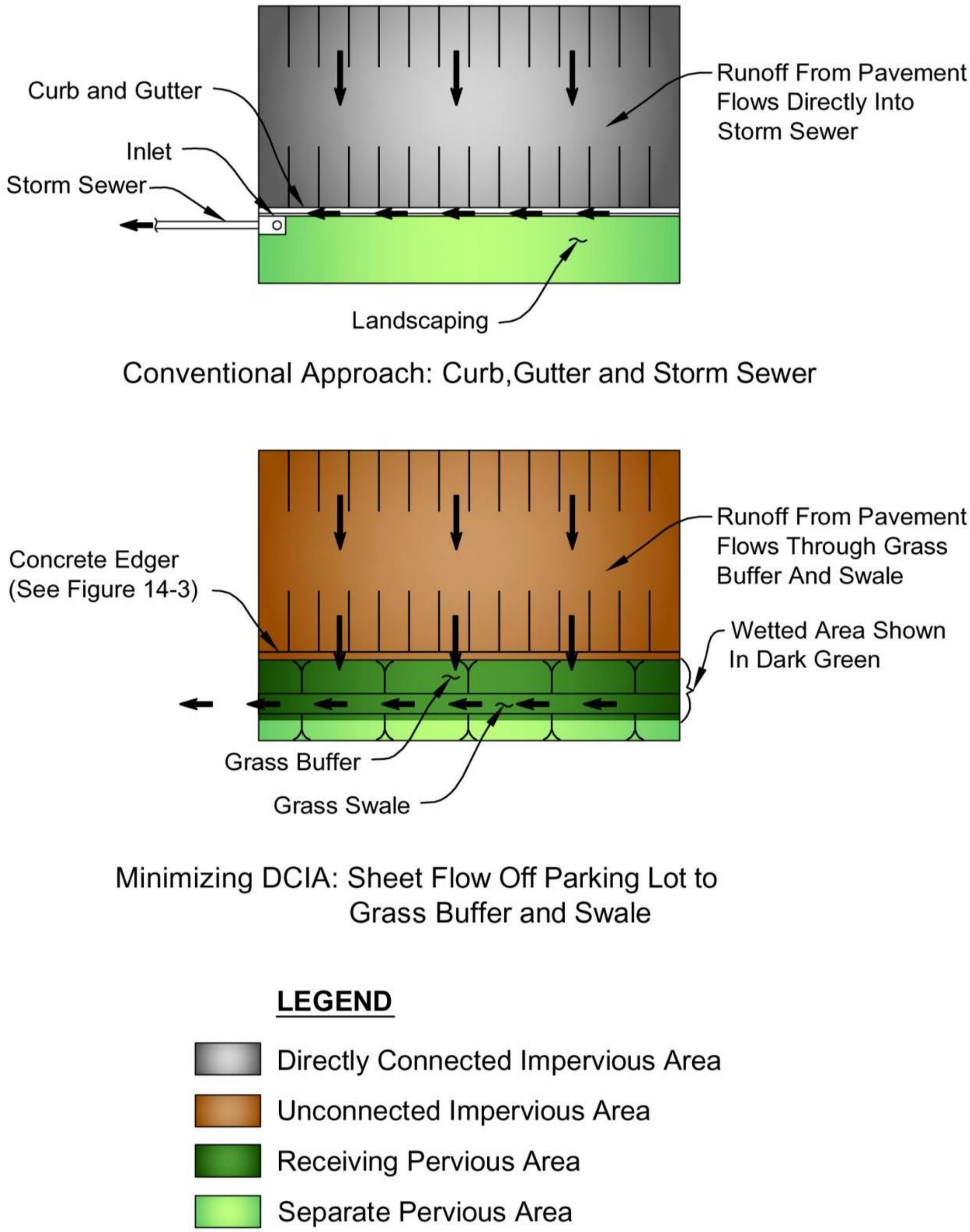


FIGURE 14-2
CONCEPTS FOR GRASS SWALES

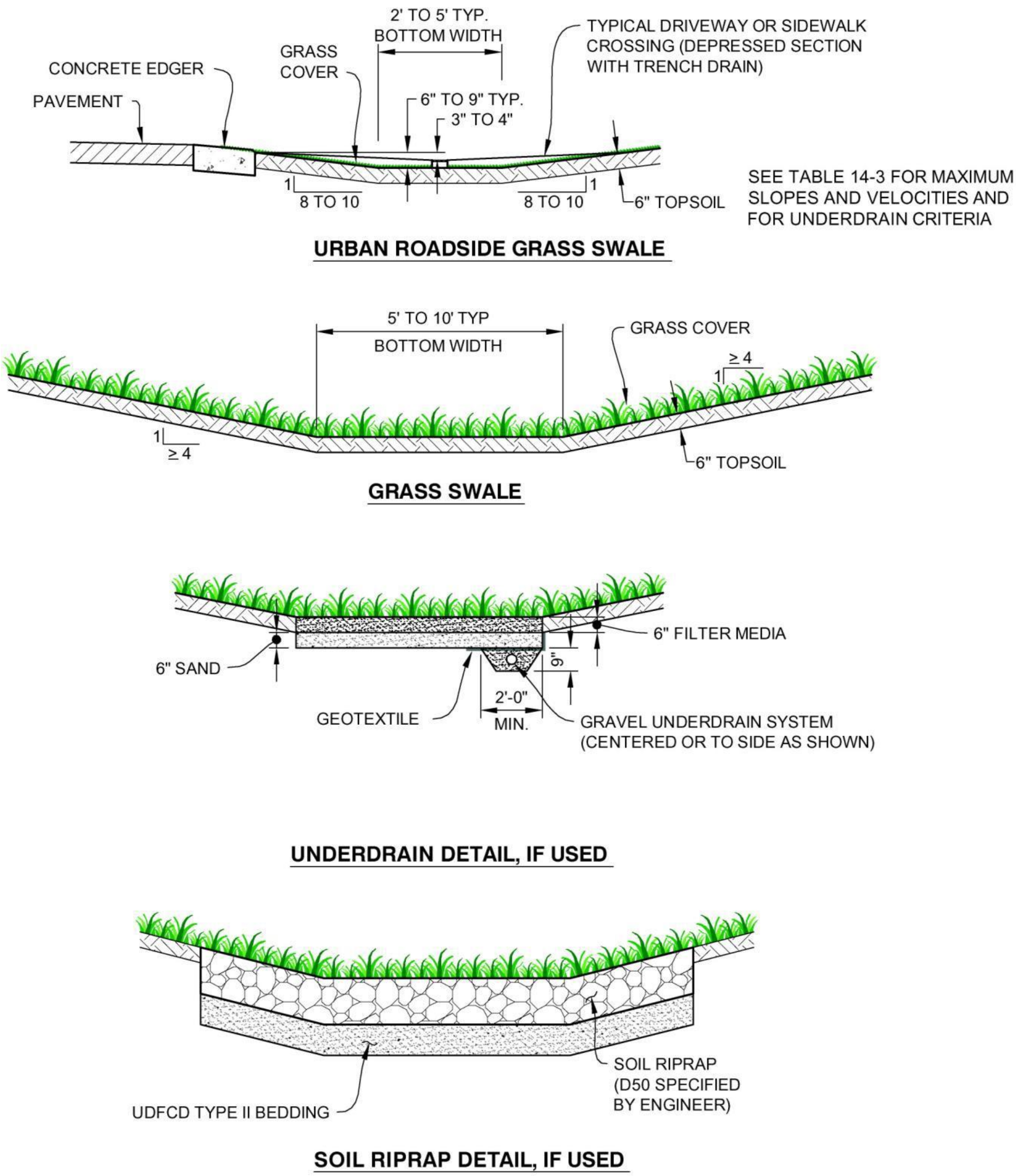


FIGURE 14-3
CONCEPT FOR CONCRETE EDGER

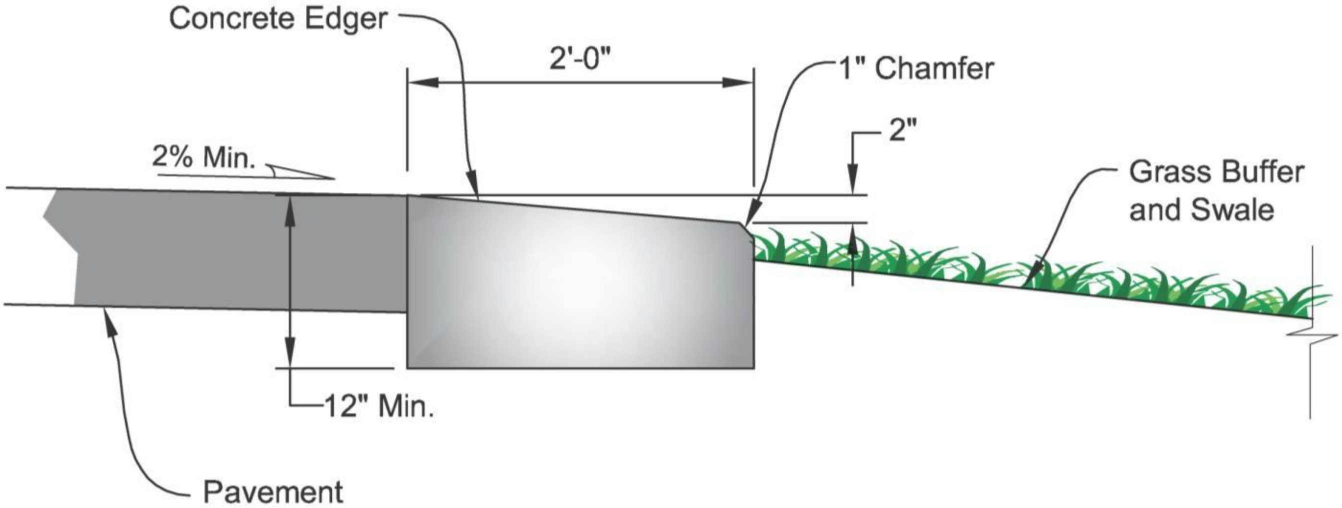
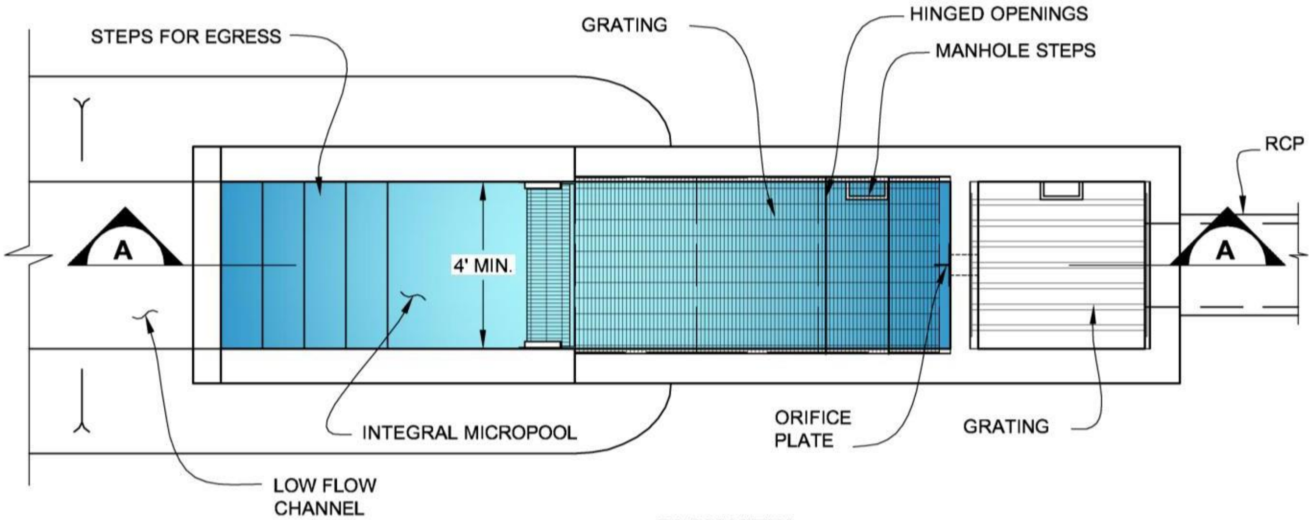
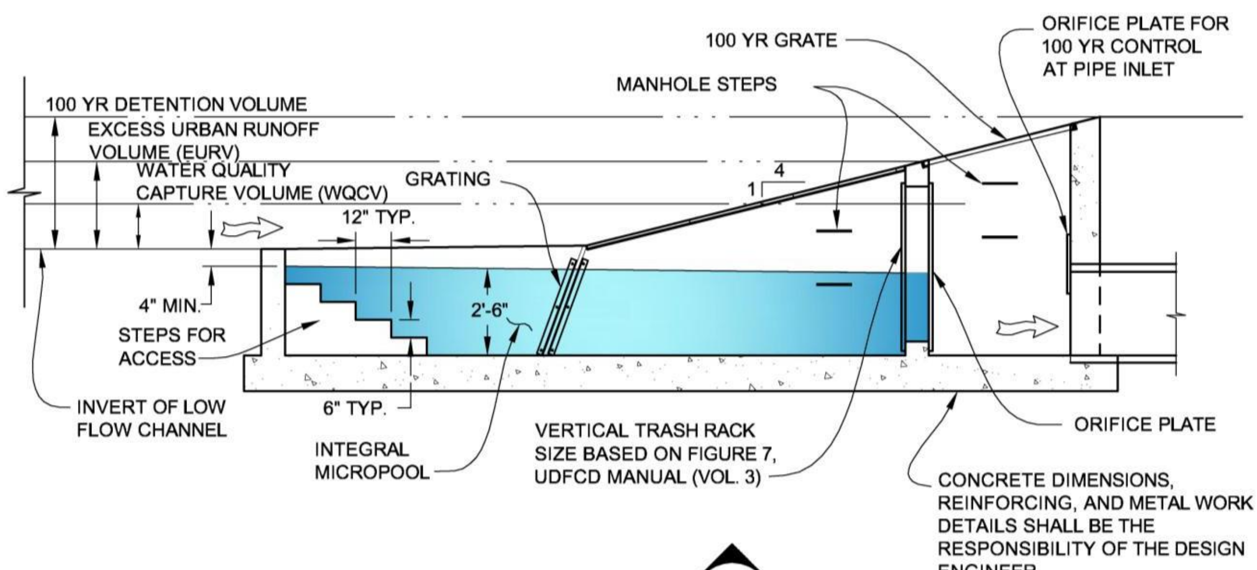


FIGURE 14-4
CONCEPT FOR OUTLET STRUCTURE WITH PARALLEL WINGWALLS AND FLUSH BAR GRATING (INTEGRAL MICROPOOL SHOWN)

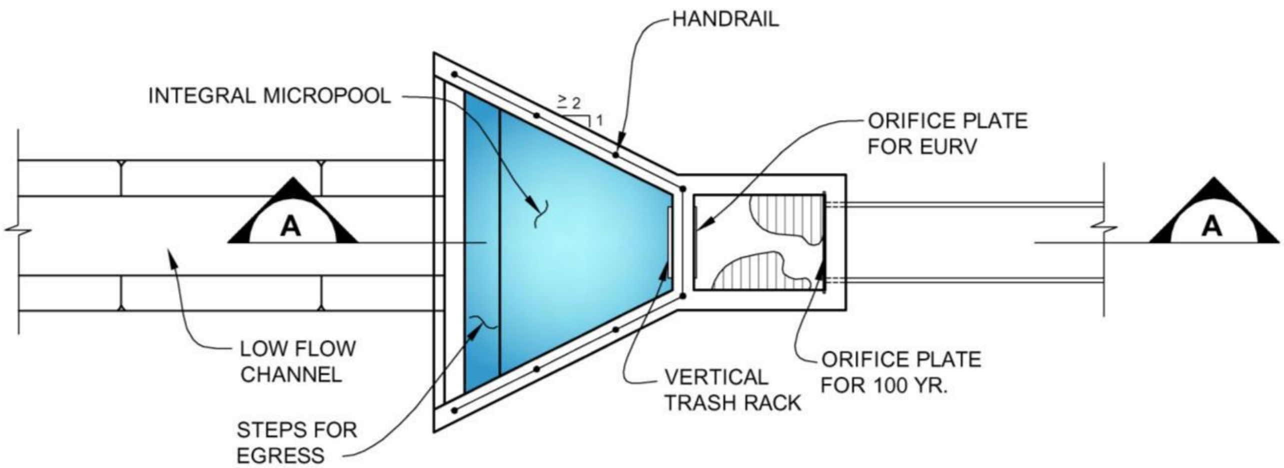


PLAN VIEW

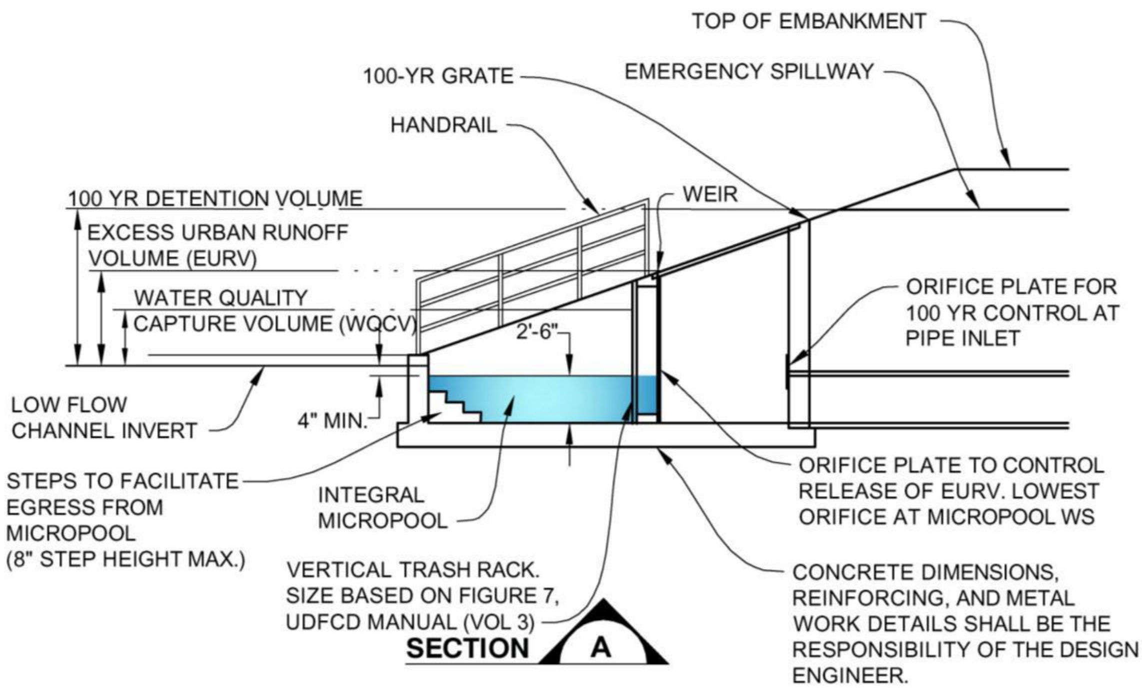


SECTION A

FIGURE 14-5
CONCEPT FOR OUTLET STRUCTURE WITH FLARED WINGWALLS AND HANDRAIL (INTEGRAL MICROPOOL SHOWN)

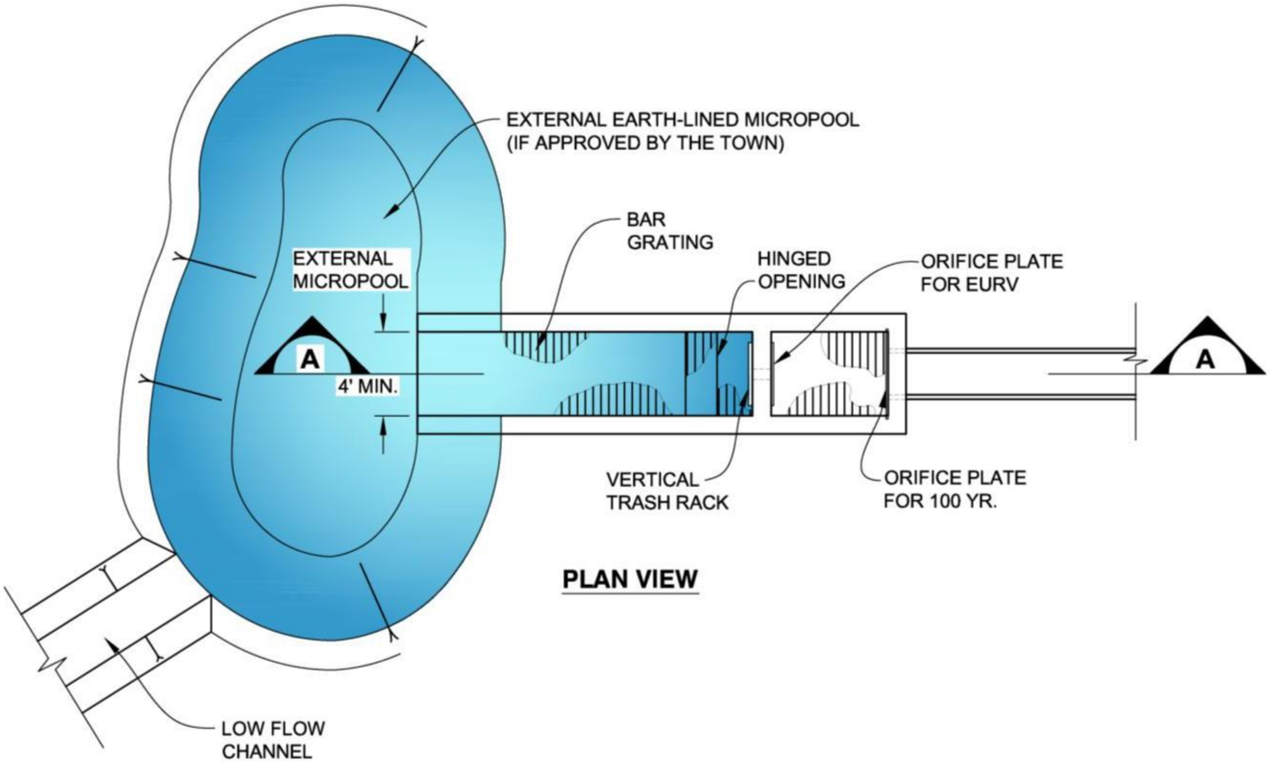


PLAN VIEW



SECTION A

FIGURE 14-6
CONCEPT FOR OUTLET STRUCTURE WITH PARALLEL WINGWALLS AND FLUSH BAR GRATING (EXTERNAL MICROPOOL SHOWN)



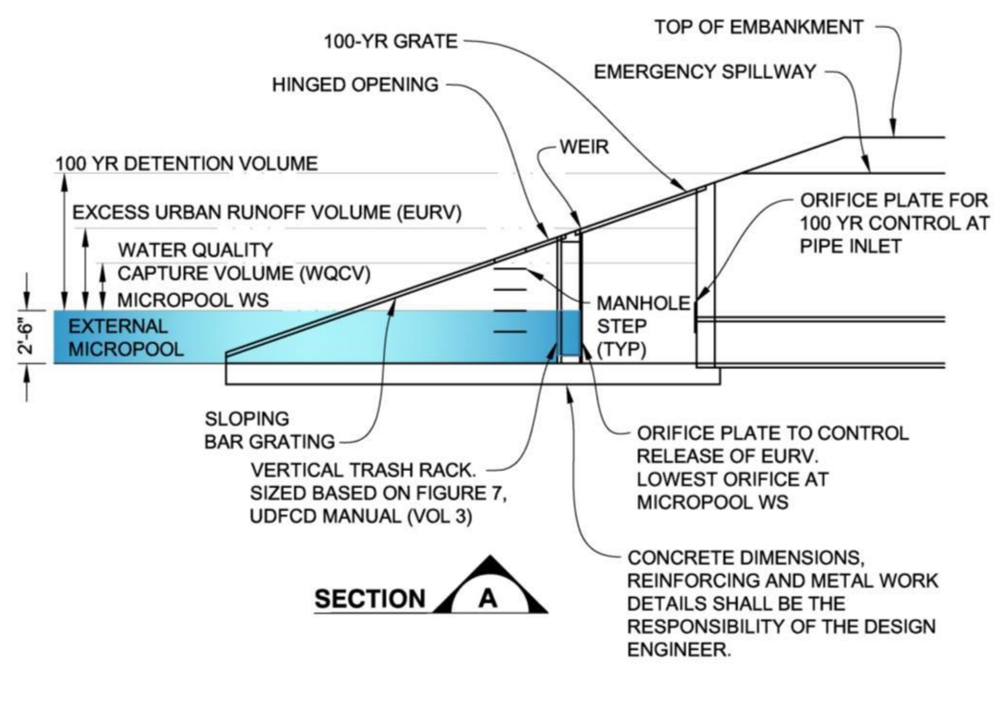
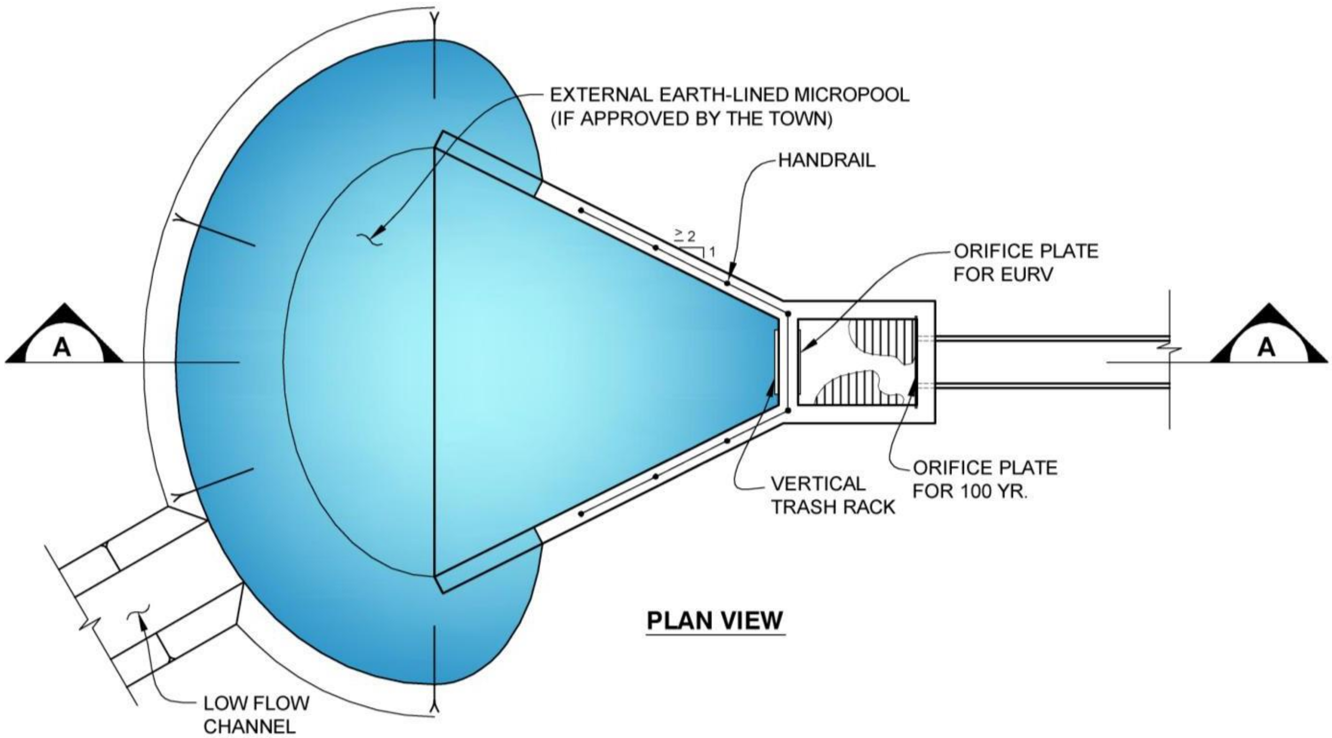


FIGURE 14-7
CONCEPT FOR OUTLET STRUCTURE WITH FLARED WINGWALLS AND HANDRAIL (EXTERNAL MICROPOOL SHOWN)



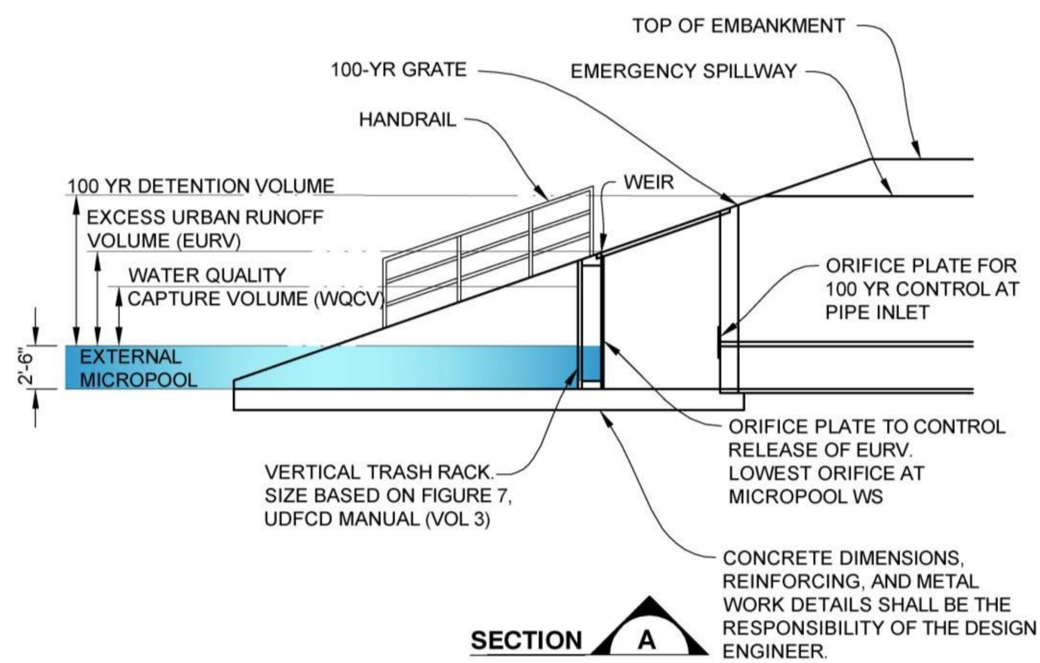
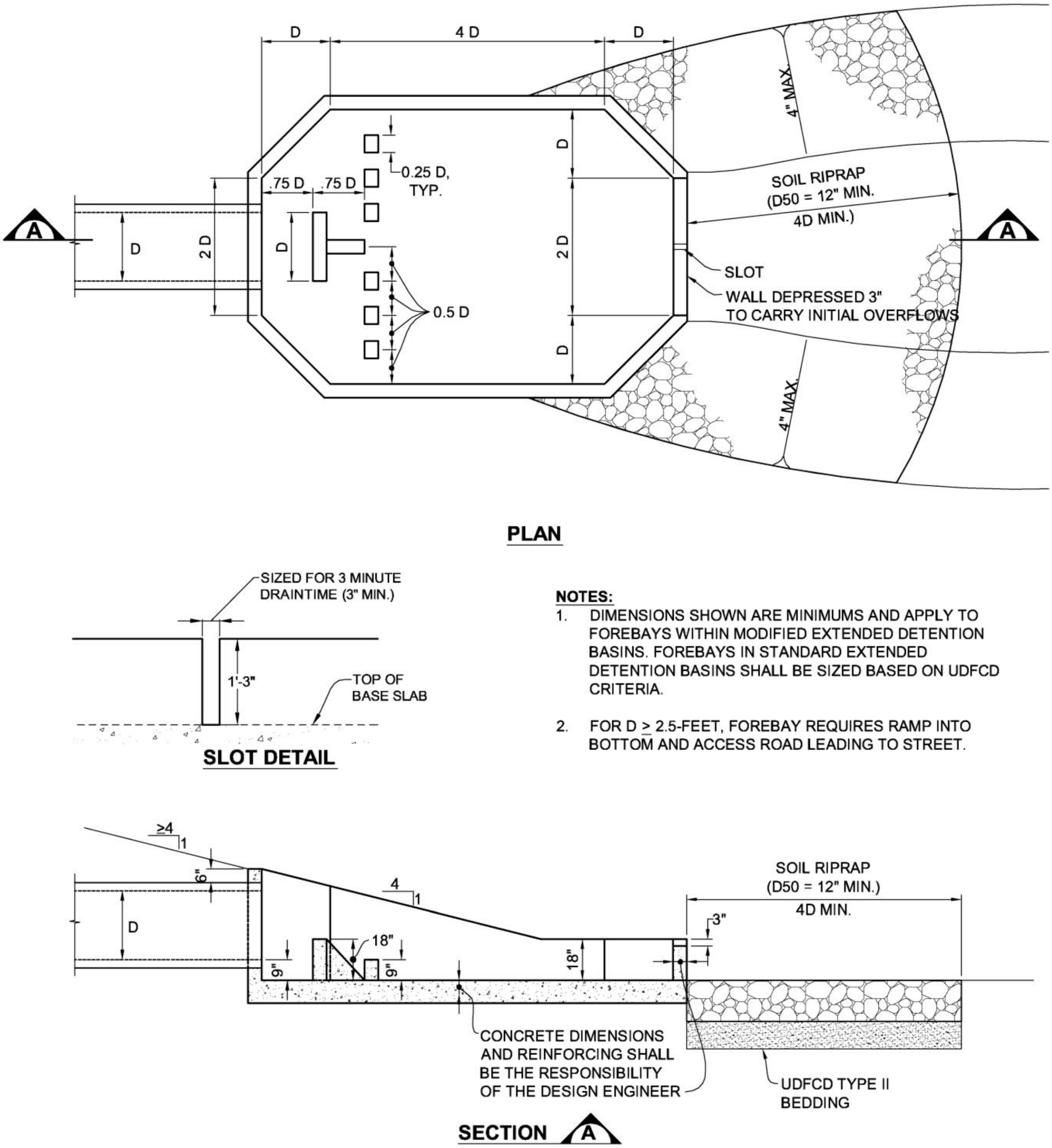


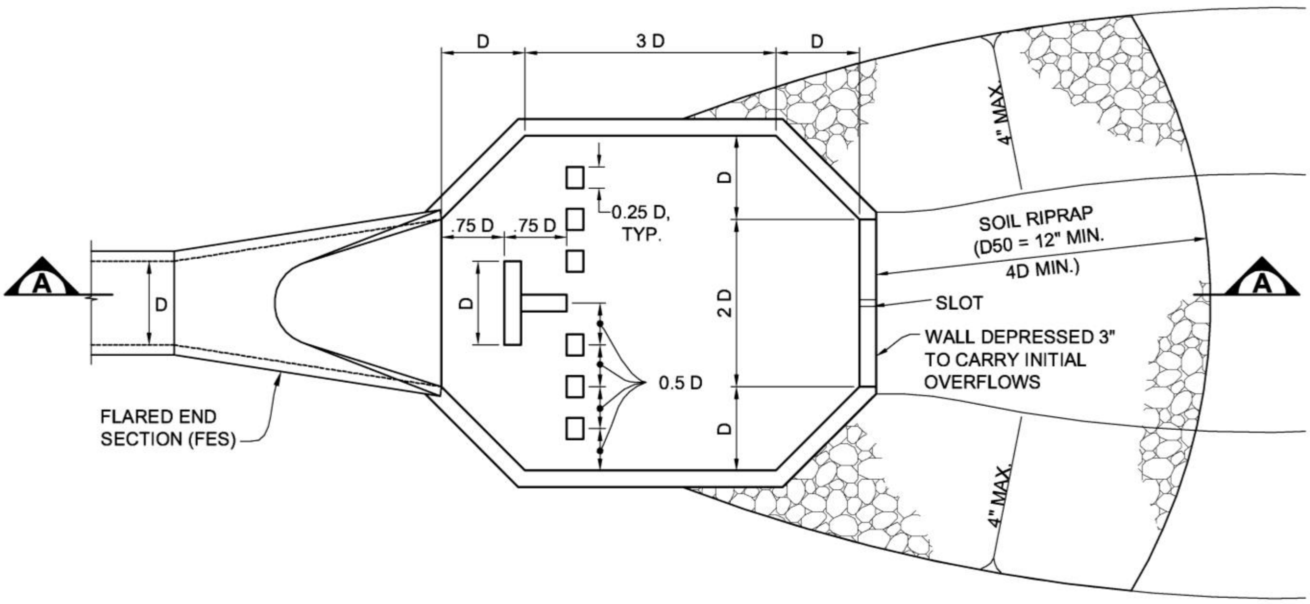
FIGURE 14-8
CONCEPT FOR INTEGRAL FOREBAY AT PIPE OUTFALL



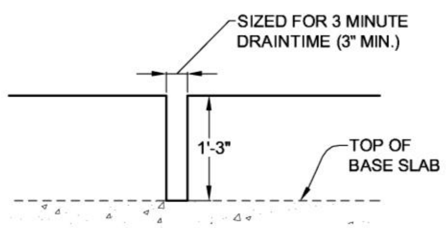
NOTES:

1. DIMENSIONS SHOWN ARE MINIMUMS AND APPLY TO FOREBAYS WITHIN MODIFIED EXTENDED DETENTION BASINS. FOREBAYS IN STANDARD EXTENDED DETENTION BASINS SHALL BE SIZED BASED ON UDFCD CRITERIA.
2. FOR D ≥ 2.5-FEET, FOREBAY REQUIRES RAMP INTO BOTTOM AND ACCESS ROAD LEADING TO STREET.

FIGURE 14-9
CONCEPT FOR INTEGRAL FOREBAY AT END SECTION



PLAN

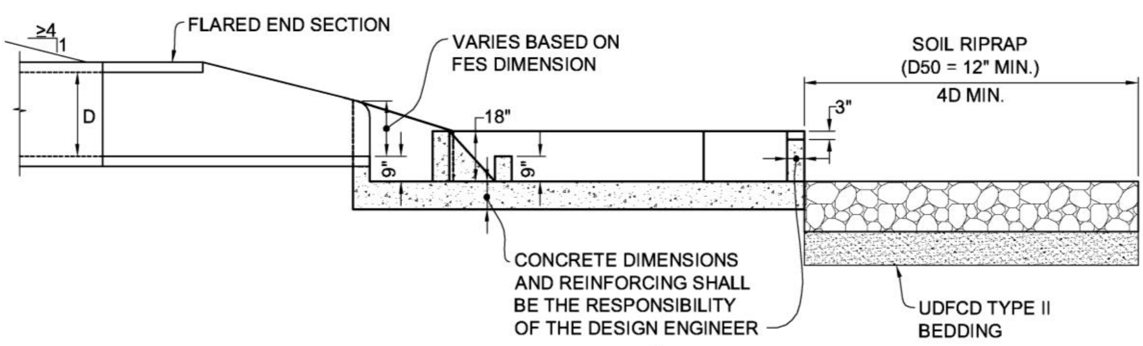


SLOT DETAIL

NOTES:

1. DIMENSIONS SHOWN ARE MINIMUMS AND APPLY TO FOREBAYS WITHIN MODIFIED EXTENDED DETENTION BASINS. FOREBAYS IN STANDARD EXTENDED DETENTION BASINS SHALL BE SIZED BASED ON UDFCD CRITERIA.

2. FOR D $\geq$ 2.5FEET, FOREBAY REQUIRES RAMP INTO BOTTOM AND ACCESS ROAD LEADING TO STREET.



SECTION A

FIGURE 14-10
CONCEPT FOR MODIFIED EXTENDED DETENTION BASIN FOR SMALL SITES
(CONCRETE LOW FLOW CHANNEL SHOWN)

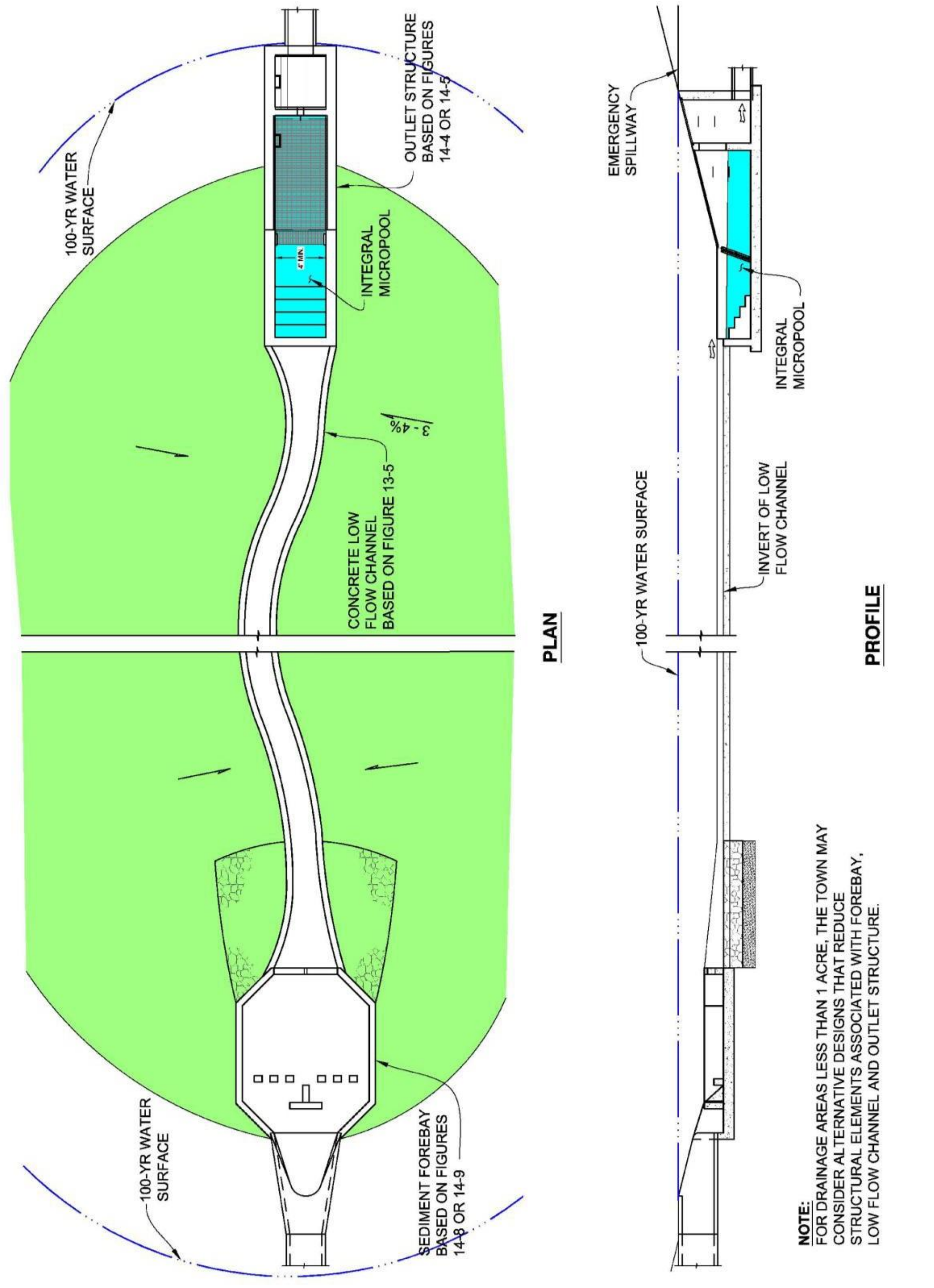


FIGURE 14-11
CONCEPT FOR MODIFIED EXTENDED DETENTION BASIN FOR SMALL SITES (BENCHED LOW FLOW CHANNEL SHOWN)

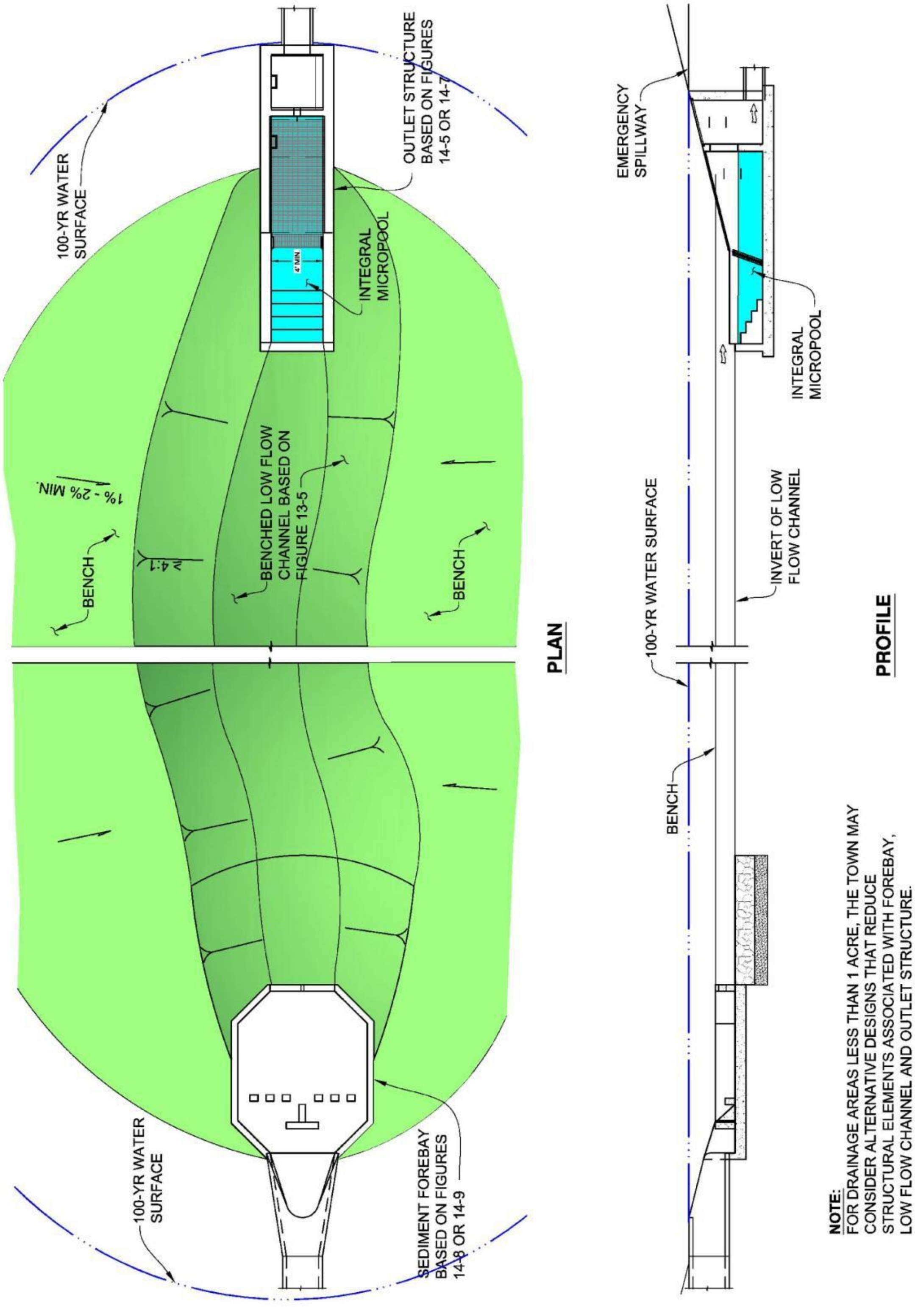
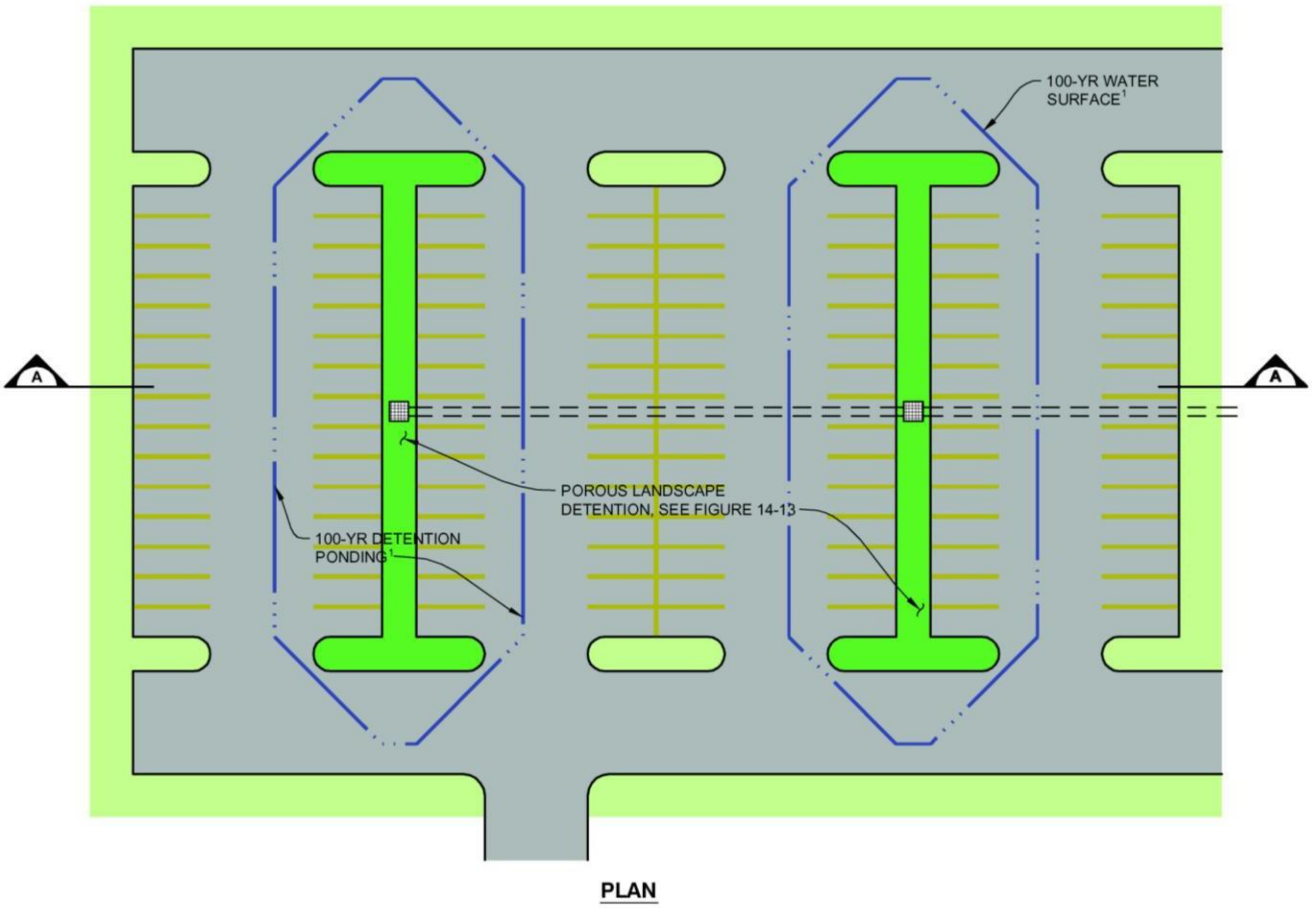
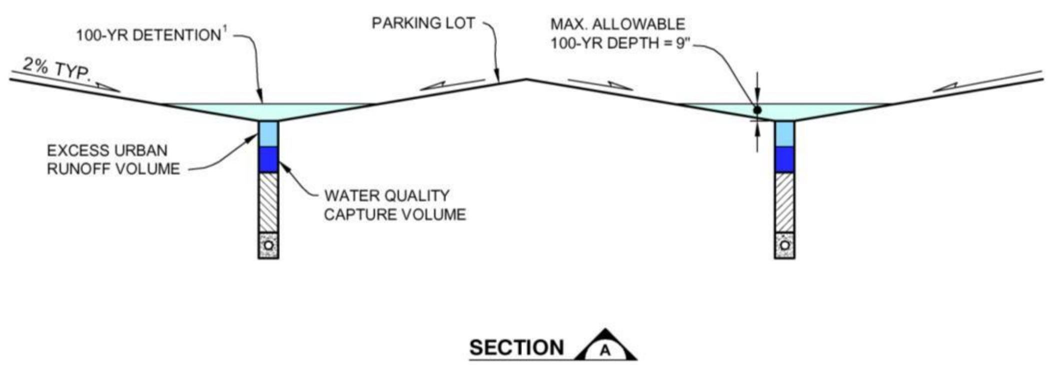


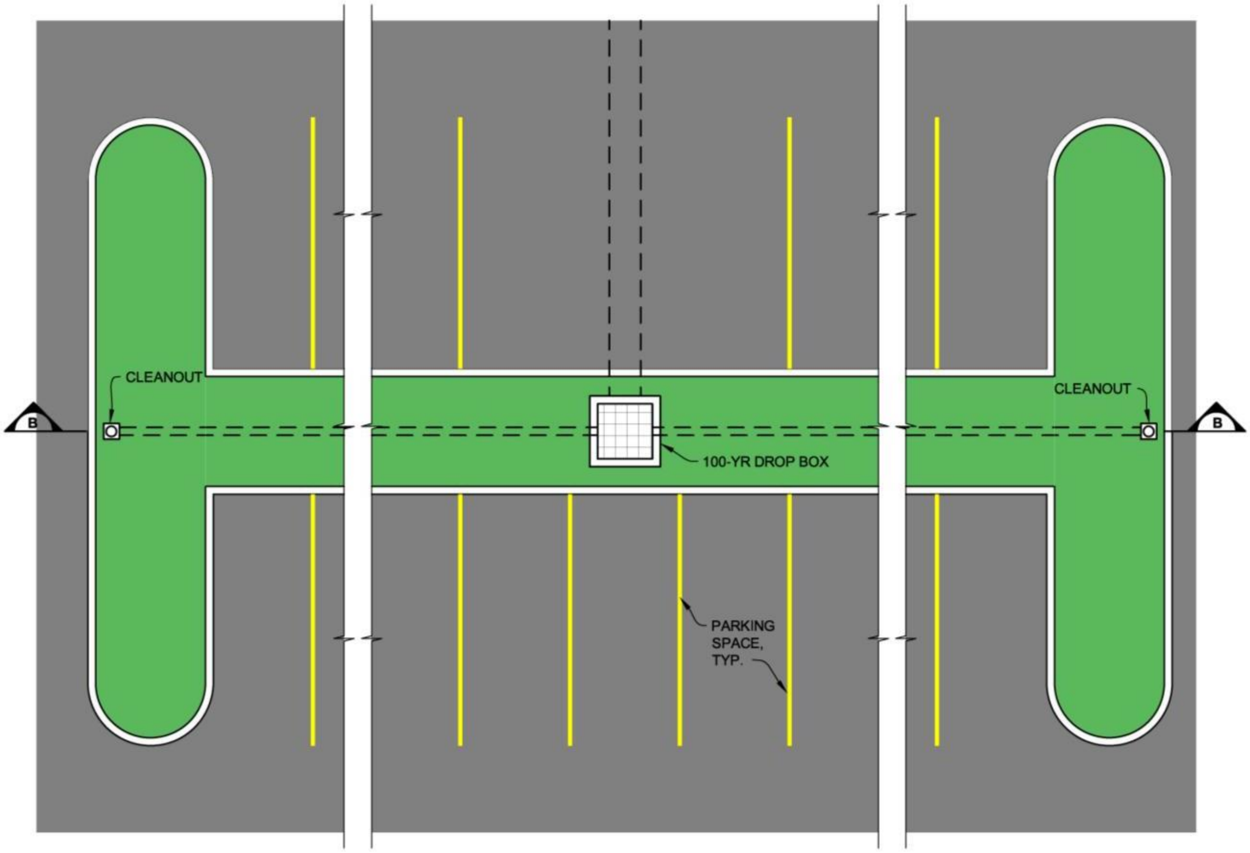
FIGURE 14-12
CONCEPT FOR POROUS LANDSCAPE DETENTION IN PARKING LOT



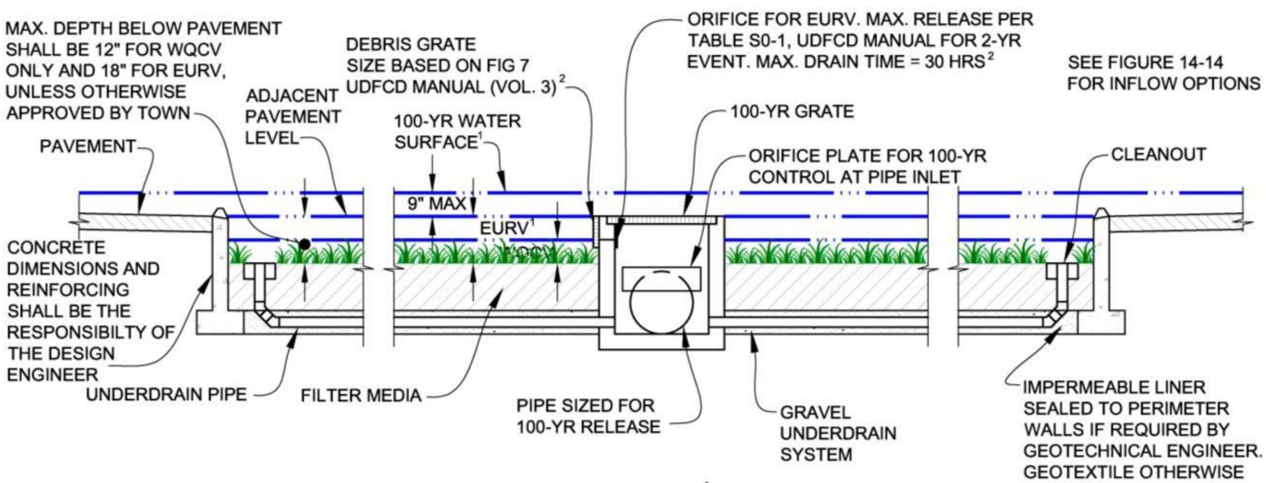


[1]OPTIONAL - MAY BE PROVIDED AT DOWNSTREAM FACILITY

FIGURE 14-13
CONCEPT FOR POROUS LANDSCAPE DETENTION IN PARKING LOT
(DETAILED VIEW)



PLAN

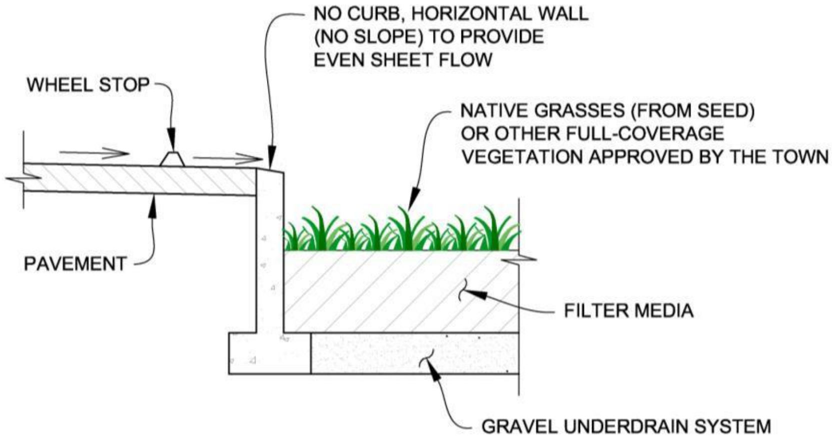


SECTION B

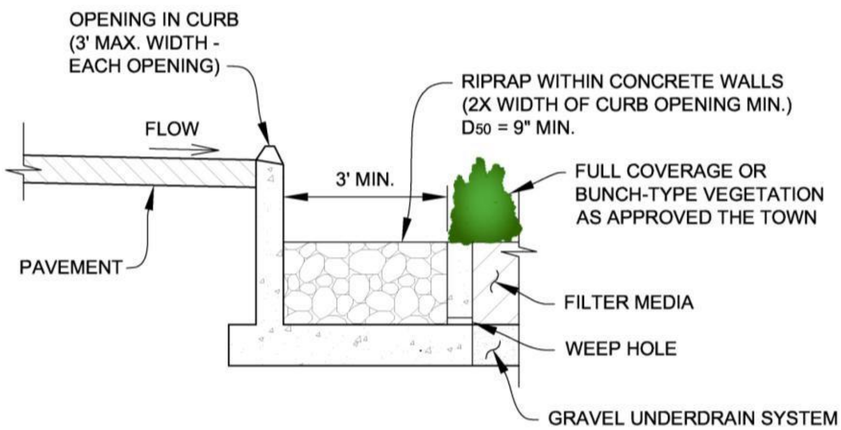
[1]OPTIONAL - MAY BE PROVIDED AT DOWNSTREAM FACILITY

[2]IF APPROVED BY THE TOWN ORIFICE MAY BE ELIMINATED AND EURV MAY BE DRAINED THROUGH FILTER MEDIA AND UNDERDRAIN

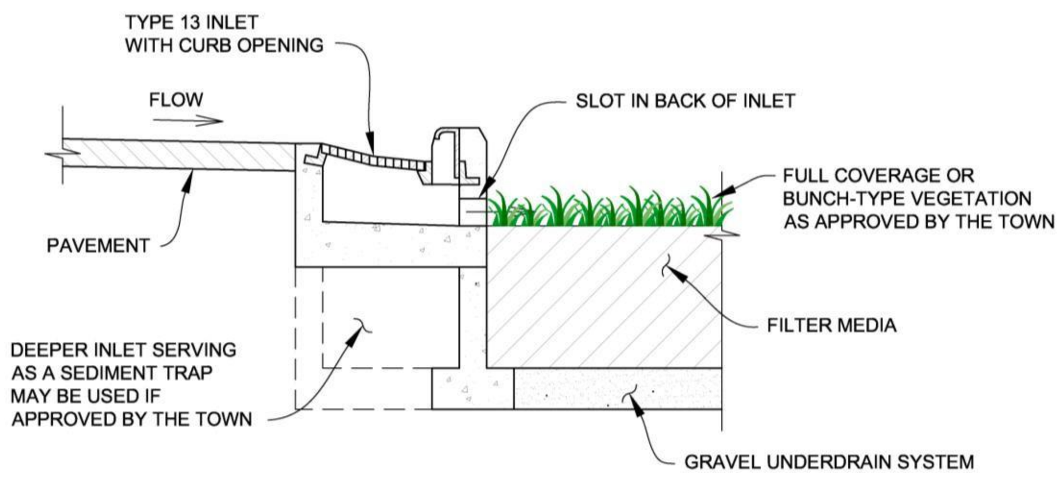
FIGURE 14-14
CONCEPTS FOR INFLOWS TO POROUS LANDSCAPE DETENTION IN PARKING LOT



OPTION 1. SHEET FLOW (IF APPROVED BY THE TOWN)



OPTION 2. CURB OPENING



OPTION 3. INLET

FIGURE 14-15
CONCEPT FOR POROUS LANDSCAPE DETENTION IN LANDSCAPE AREA
(IF APPROVED BY TOWN)

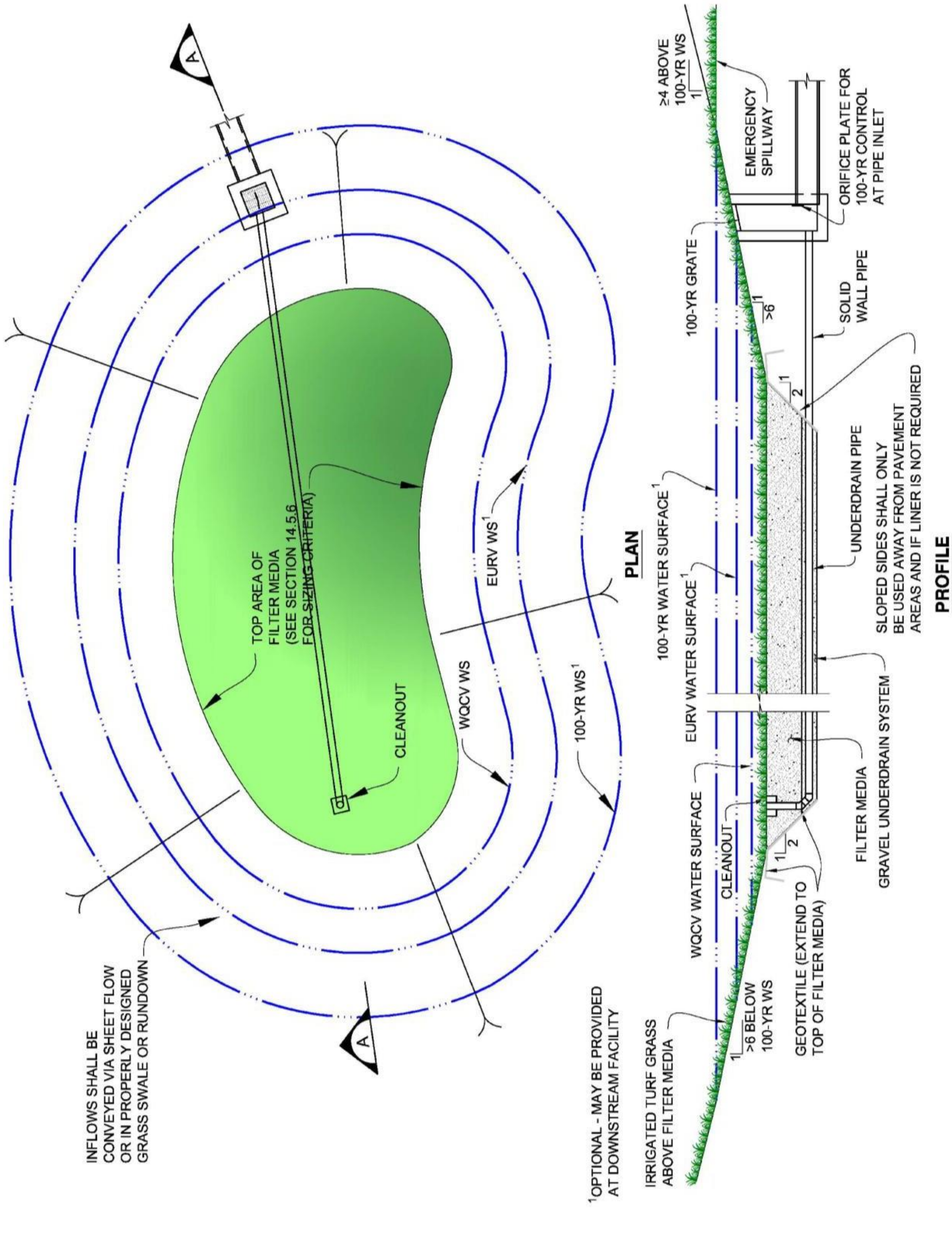
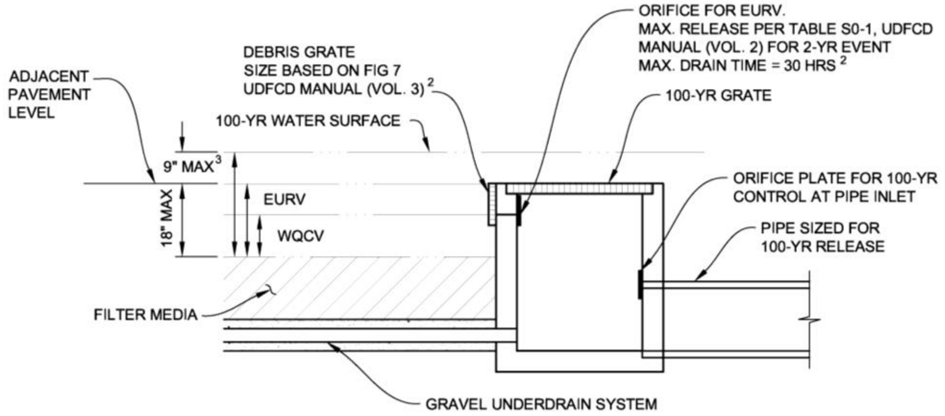
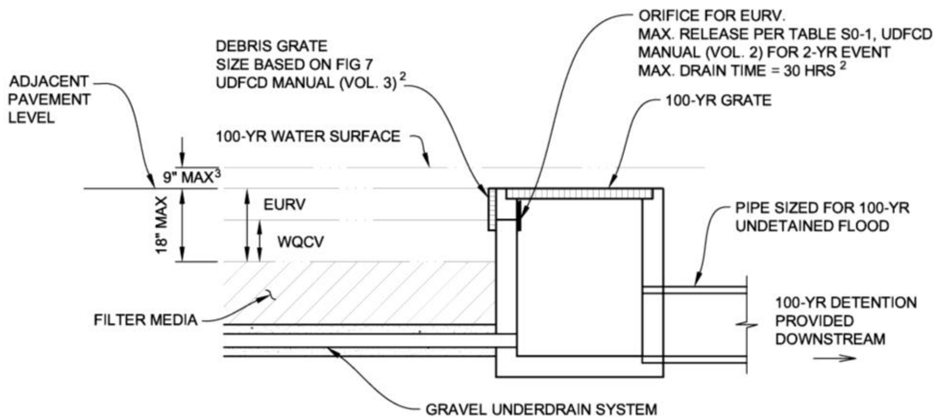


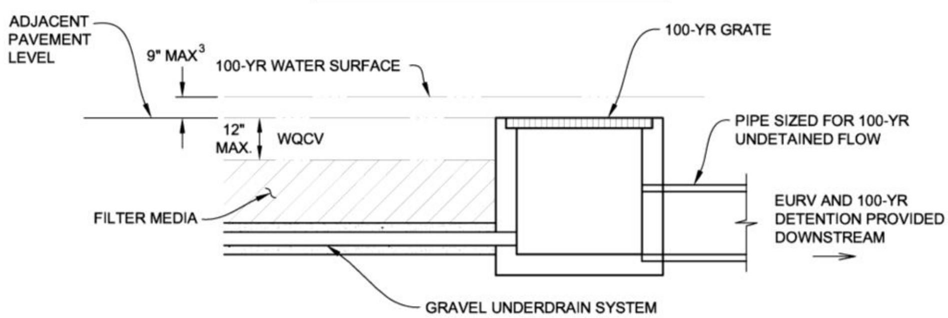
FIGURE 14-16
CONCEPTS FOR POROUS LANDSCAPE DETENTION OUTLET STRUCTURES[1]



OUTLET STRUCTURE WHERE WQCV, EURV, AND 100-YEAR DETENTION ARE COMBINED IN A SINGLE FACILITY



OUTLET STRUCTURE WHERE WQCV AND EURV ARE COMBINED; 100-YEAR DETENTION IS PROVIDED DOWNSTREAM

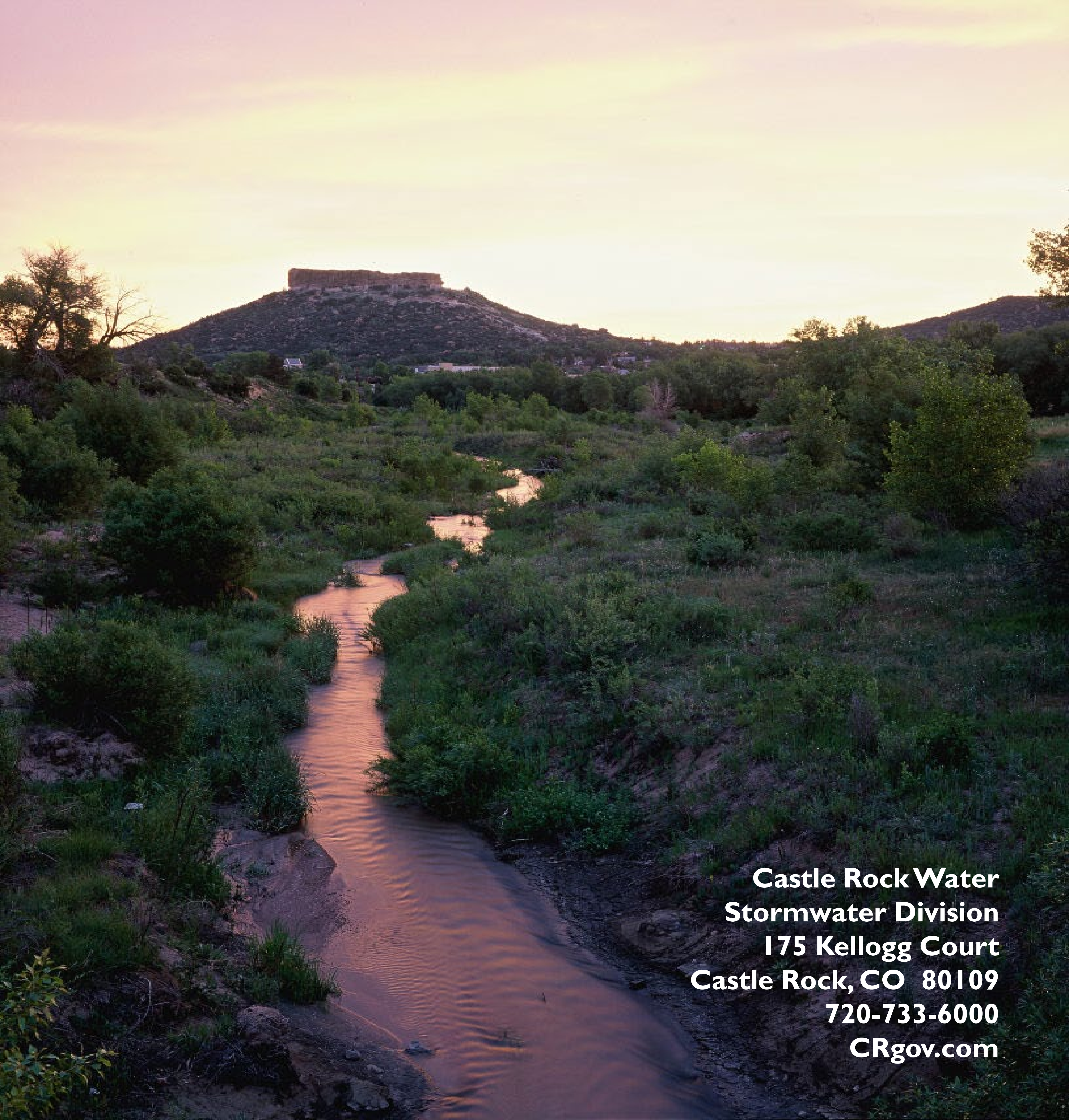


OUTLET STRUCTURE WHERE WQCV STANDS ALONE; EURV AND 100-YEAR DETENTION ARE PROVIDED DOWNSTREAM

[1] OUTLET STRUCTURE SHOWN MAY ALSO BE USED FOR SAND FILTER BASIN

[2] IF APPROVED BY THE TOWN, ORIFICE MAY BE ELIMINATED AND EURV MAY BE DRAINED THROUGH FILTER MEDIA AND UNDERDRAIN

[3] MAXIMUM 100-YR DEPTH = 9" IN PAVEMENT AREAS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