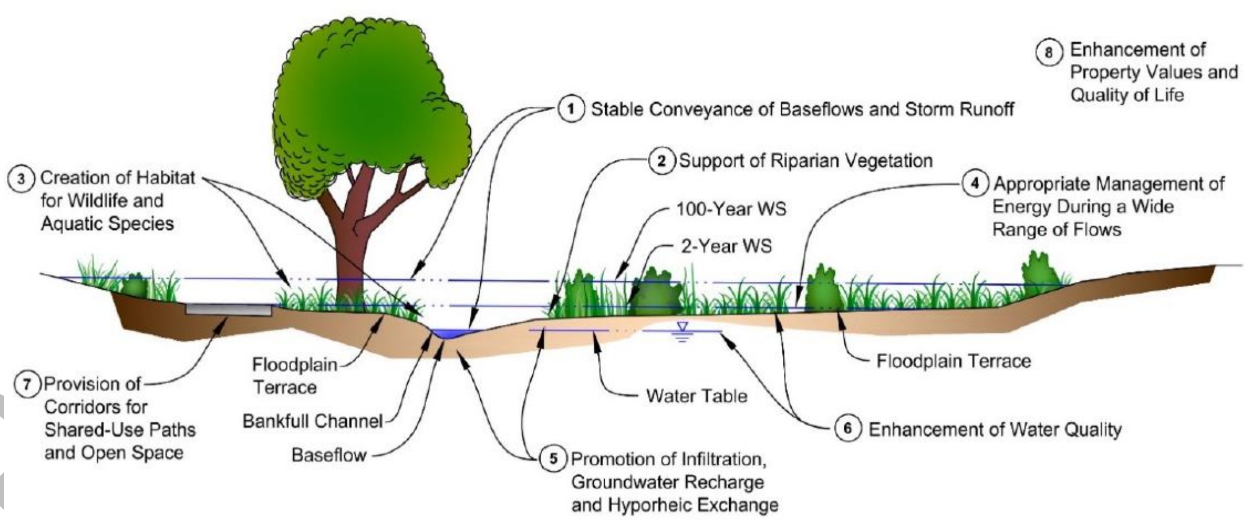
12.0 Introduction

This chapter summarizes the analysis and design methodology for drainageway improvements. Definitions are provided for minor and major drainageways and design considerations for the preservation and stabilization of both drainageway classifications. This chapter contains references to the UDFCD Manual for various design procedures, however where criteria in this chapter conflict with those in the UDFCD Manual, those included in this chapter supercede those in the UDFCD Manual.

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.

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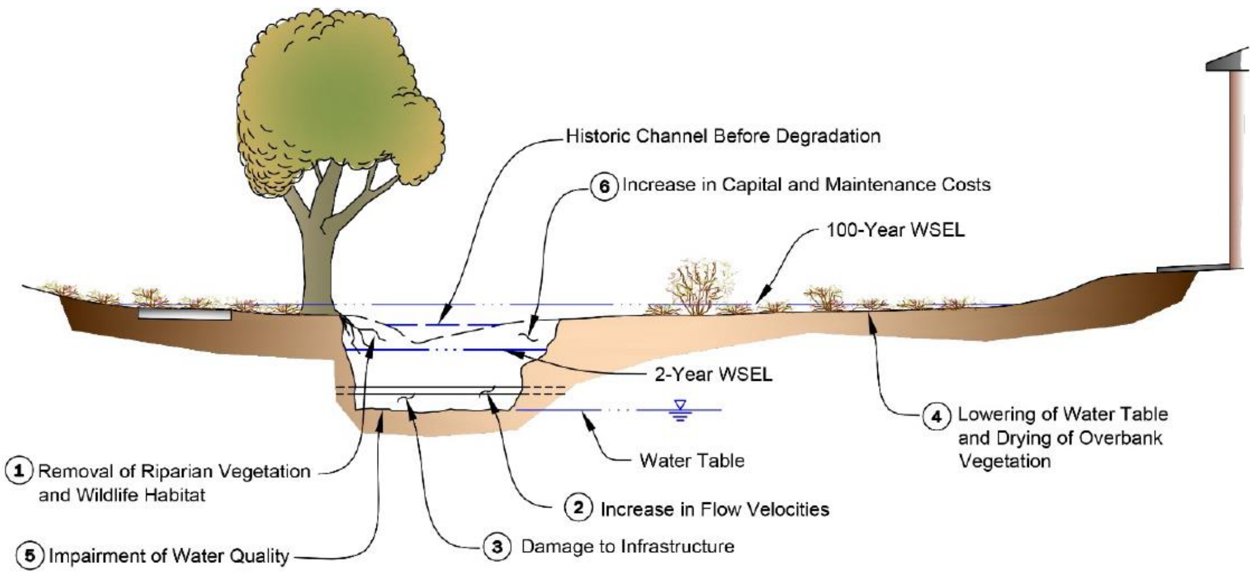
12.0.2 Drainageway Degradation. Urbanization typically increases the frequency, duration, volume, and peak flow of stormwater runoff and efforts to stabilize ground with pavement and landscaping and installing water quality ponds can decrease the supply of watershed sediment as a result. Urban drainageways 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 summarized below and illustrated in Figure 12-2. Additional discussion on these topics is included in the Open Channels Chapter of the UDFCD Manual.

1. Removal of riparian vegetation.
2. Increase in flow velocities.
3. Damage to infrastructure.
4. Lowering of water table and drying out of overbank vegetation.
5. Impairment of water quality.
6. Increase in capital and maintenance costs.

FIGURE 12-2
IMPACTS OF STREAM DEGREDATION



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

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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 all streams or conveyance channels draining watershed areas equal to or 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, SEMSWA 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.

12.0.6 Governing Criteria. All open channel design criteria shall be in accordance with the Open Channels Chapter of the UDFCD Manual unless as modified herein. Major drainageways shall be designed as Naturalized Channels, as discussed in the Open Channels Chapter of the UDFCD Manual. Minor drainageways shall either be Naturalized Channels or Grass-lined Swales. The use of riprap-lined or concrete-lined channels is may be considered under special circumstances and may require a variance.

12.1 Drainageway Preservation and Stabilization

12.1.1 Preservation of Naturalized Channels. Natural channels and floodplains shall be preserved. SEMSWA will require that all major drainageways (upstream watershed area equal to or greater than 130 acres) be preserved. In addition, consideration shall be given to minor drainageways which may be considered to have a high resource value[1]. Site planning documents shall accurately identify all existing drainageways, floodplains, and other site features that should be protected and preserved where feasible and practicable. Areas shown to be protected will be subject to the review and acceptance of SEMSWA.

[1] High resource value may include, but is not limited to: infiltration capacity, habitat and aesthetics.

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

- Upstream watershed area equal to or greater than 130-acres.
- Presence of riparian vegetation such as cottonwood or willow trees, shrub willows, and wetland or transitional grasses.
- Presence of baseflows.
- Presence of protected habitat for threatened and endangered or other protected species.
- Presence of jurisdictional wetlands.
- 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 site 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. SEMSWA will require the stabilization of drainageways as a condition of development approval. 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 according to methods provided in the Open Channels Chapter of the UDFCD Manual.

SEMSWA requires that channel stabilization measures shall be implemented on all drainageways that are either contained within the development, or are adjacent to the property. The need for additional measures downstream of the site shall be determined based on discussions with SEMSWA during site planning.

All development projects, including those which do not contain or are not adjacent to a drainageway may be required to provide or participate in channel stabilization improvements (per approved master plan recommendations) to address water quality concerns within the drainageway which are created by the impact of all development within the watershed.

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12.1.3 Design Considerations. The Planning Chapter of the UDFCD 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. UDFCD Outfall Systems Planning and Major Drainageway Planning Studies, commonly referred to as master plans, have been developed for many of the watersheds. These studies typically provide recommended design guidance for major drainageways. It is recognized that many of the master plans were completed several years ago and may not have been updated to reflect current approaches and design details, technology, and philosophies regarding channel stabilization improvements. 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 and the UDFCD Manual.

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 bankfull conditions.

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 engineer shall be responsible for providing the appropriate analysis to determine the design flow rate. The final design flow rate shall be approved by SEMSWA and UDFCD.

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. The following are some of the permitting requirements, however, the Project Engineer is responsible for contacting the appropriate agencies to determine all of the permitting requirements for a specific project.

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

2. USACE 404 Wetlands Permit. Construction along existing drainageways may require a Section 404 permit from the US Army Corps of Engineers (USACE). The USACE should always be contacted early in the design

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process to determine if the activities will require a 404 permit. Figure MD-4 of the UDFCD 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.

4. Grading, Erosion and Sediment Control (GESC) Permit. A GESC permit is required for construction activities located outside in unincorporated areas of Arapahoe County.

5. Stormwater Management Plan (SWMP) Permit. A SWMP permit is required for construction activities located within incorporated areas of Arapahoe County.

6. Stormwater Public Improvement (SPIP) Permit. A SPIP is required for stormwater-related construction activities within the City of Centennial.

12.2 Design Criteria for Major Drainageways

12.2.1 Natural Channel Approach. Major drainageway design shall abide by the following seven design elements. Refer to the Open Channels Chapter of the UDFCD Manual and Figure 12-3 for additional details on these elements.

1. Apply fluvial geomorphology principles to manage sediment balance.
2. Establish effective cross-sectional shape.
3. Maintain natural planform geometry.
4. Develop grade control strategy to manage longitudinal slope.
5. Address bank stability.
6. Enhance streambank and floodplain vegetation.
7. Evaluate stream hydraulics over a range of flows.

FIGURE 12-3
DESIGN ELEMENTS ASSOCIATED WITH MAJOR DRAINAGEWAYS

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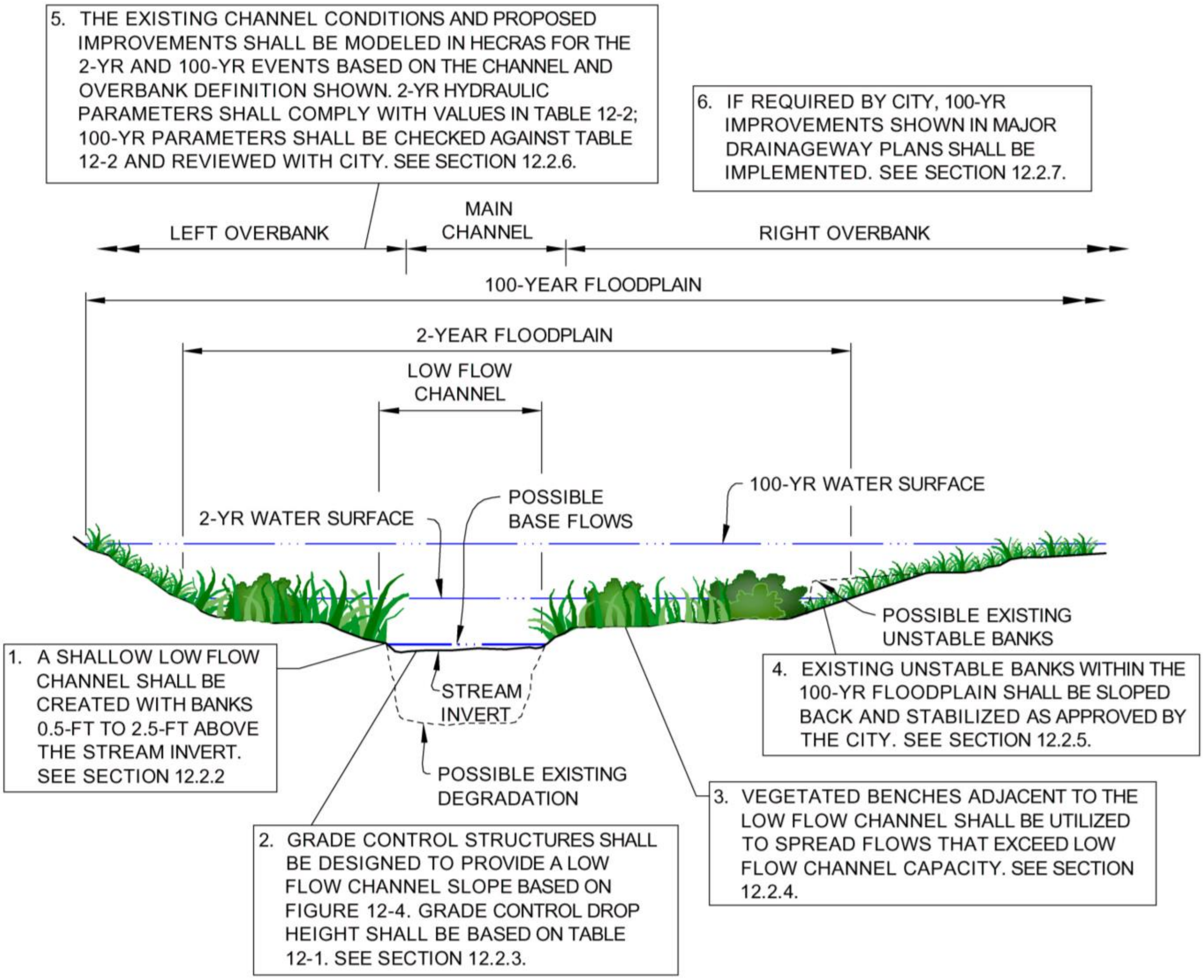

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These seven steps are discussed in the following sections and comprise the recommended design approach for preserving, restoring, or constructing natural, healthy drainageways. Designers shall address these seven elements and submit their proposed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

12.2.2 Apply Fluvial Geomorphology Principles to Manage Sediment Balance. This first step is intended for the designer to understand the existing and potential future conditions of aggradation and degradation along the open channel, such that the open channel can be designed to properly manage the sediment balance. This may involve tasks such as desktop and field studies to estimate long-term aggradation/degradation and predicting future changes to the watershed that could affect the sediment balance. Results of these tasks will inform the designer on general restoration approaches that might be applicable (e.g. equilibrium or threshold) and the channel's equilibrium slope. Refer to the

Open Channels Chapter of the UDFCD Manual for additional information on this step.

12.2.3 Establish Effective Cross-Sectional Shape. An effective cross-sectional shape has a properly sized bankfull channel, maintains connection with a functional floodplain, addresses incised channels and has floodplain terraces that spread out flood flows to reduce the depths and velocities of those flows. Refer to the Open Channels Chapter in the UDFCD Manual for additional information on these functions and design criteria to follow.

12.2.4 Maintain Natural Planform Geometry. Naturalized open channels should be designed to mimic the planforms of natural channels, including, but not limited to, bankfull channels that meander, exhibit sinuosity, and generally have varying widths and shapes of both channels and terraces. Refer to the Open Channels Chapter in the UDFCD Manual for additional information on these functions and design criteria to follow.

12.2.5 Develop Grade Control Strategy to Manage Longitudinal Slope. The longitudinal slope of a naturalized open channel is critical to managing the sediment balance (e.g. preventing long-term aggradation/degradation) and assuring a long-term, sustainable open channel. In many urbanized settings, grade control structures will be required to establish a longitudinal slope that achieves those objectives. Three primary factors must be considered when determining the placement of grade control structures; 1) equilibrium slope, 2) cross-sectional capacity and 3) drop structure height. 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	5.0

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 SEMSWA, grade control structures shall be laid out assuming the baseflow channel slope shown in Figure 12-4.

FIGURE 12-4
BASE FLOW CHANNEL SLOPE CRITERIA

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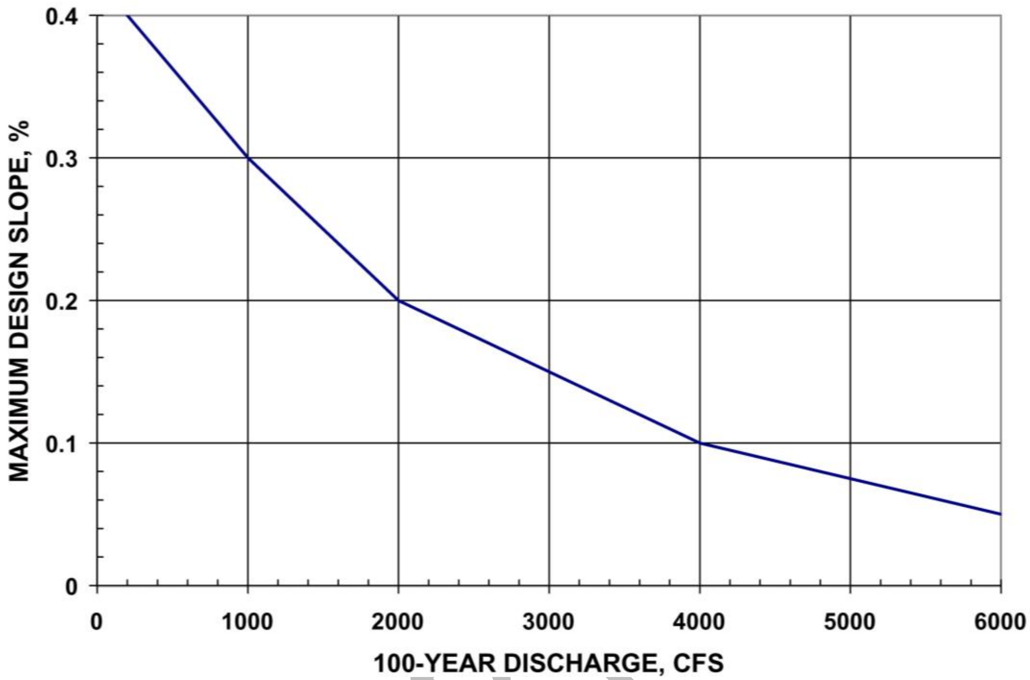

Refer to the Open Channels Chapter in the UDFCD Manual for additional information on these factors and design criteria to follow.

12.2.6 Address Bank Stability. Steep, unstable channel banks and outer channel banks on bends should be sloped back and stabilized using vegetation, bioengineering techniques or structural measures such as rip rap and boulders. Vegetation and bioengineering are preferred over structural measures. Specific design requirements include:

1. <u>Sloping Back Banks</u>. 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 SEMSWA and need to be blanketed in accordance with SEMSWA's Grading, Erosion, and Sediment Control (GESC) 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 SEMSWA (normally up to the 2-year elevation).
2. <u>Riprap Bank Protection.</u> Riprap bank protection is widely used 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 SEMSWA approval, part way up the bank to an approved elevation. Riprap bank protection shall be designed in accordance with the Open Channel Section of the UDFCD Manual. All riprap bank protection shall consist of

soil riprap that is buried with 6-inches of topsoil and revegetated or void-filled riprap.

Refer to the Open Channels Chapter in the UDFCD Manual for additional information on these practices and example applications.

12.2.7 **Enhance Streambank and Floodplain Vegetation.** It is important to preserve and establish healthy vegetation along the stream banks and floodplain to reduce erosion and slow down flows. Refer to the Open Channels Chapter and Revegetation Chapter of the UDFCD Manual for additional information and design criteria for these practices.

12.2.8 **Evaluate Stream Hydraulics over a Range of Flows.** The design of natural open channels requires hydraulic modeling to assess flow depth, velocity, Froude number, shear stress and other important parameters, and should be performed for a range of flows from bankfull to at least the 100-year return flow. Refer to the Open Channels Chapter of the UDFCD Manual for additional guidance on modeling stream hydraulics, including recommended maximum values for the parameters listed above as well as recommended modeling scenarios and results summaries.

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 SEMSWA 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	Upland Grass Vegetation	Wetland Grass (Dense Sod Forming Type)	Wetland Shrubs Trees (dense stand)
Maximum 2-year Velocity (ft/s)	3.5 ft/s (2.5 ft/s)	4.5 ft/s (3.0 ft/s)	5.5 ft/s (3.0 ft/s)
Maximum 100-year Velocity	6 ft/s (4.5 ft/s)	7 ft/s (5 ft/s)	8 ft/s (5 ft/s)
Froude No., 2-Year	0.6 (0.5)	0.6 (0.5)	0.6 (0.5)

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Froude No., 100-Year	0.8 (0.5)	0.8 (0.5)	0.8 (0.5)
Maximum Tractive Force, 100-year	0.60 lb/sf	0.6 lb/sf	1.00 lb/sf

Values are shown for erosion-resistant soils (values in parentheses apply to erosive soils).

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 2-ft 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 1 ft. of freeboard is acceptable. 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 SEMSWA. The previous five design elements associated with major drainageway stabilization are mandatory; undertaking further major drainageway plan

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improvements will be required by SEMSWA on a case-by-case basis. Section 3.4.4 provides additional guidance.

12.3 Design Criteria for Minor Drainageways

12.3.1 Natural Channels. The natural channel criteria identified for major drainageways also apply to minor drainageways.

12.3.2 Grass-Lined Channels. Grass-lined channels are another alternative for minor drainageways within private developments, 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. Design criteria for grass-lined channels (i.e. swales) are provided in the Open Channels Chapter of the UDFCD Manual.

Design criteria for grass-lined channels (i.e. swales) are provided in the Open Channels Chapter of the UDFCD Manual. Preliminary design guidance for grass-lined channels from Table MD-2 in the Major Drainage chapter of Volume 1 of the UDFCD Manual is reproduced below for reference:

TABLE 12.3
HYDRAULIC DESIGN CRITERIA FOR GRASS-LINED CHANNELS

Design Item	Major Drainage Section (UDFCD 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.

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12.3.5 Riprap-Lined and Concrete-Lined Channels. The use of riprap-lined or concrete-lined channels is generally not allowed in by SEMSWA.

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 Major Drainageway Drop Structures. Drop structures on major drainageways extend across the entire waterway and must be designed to convey the 100-year flood. Drop structures shall be limited in height to 5 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. Heights in excess of 5 feet may be considered on a case-by-case basis for conditions which warrant a larger drop, however, they must be approved by SEMSWA as a variance, upon review of a detailed analysis that justifies the requirements of a larger drop structure. Drop structures in excess of 10 feet will not be permitted. Acceptable drop structure types include the following:

- Grouted Stepped Boulder (GSB) drop structures
- Sculpted Concrete (SC) drop structures
- Vertical drop structures

Refer to the Hydraulic Structures Chapter of the UDFCD Manual for design criteria and guidance on these type of structures.

SEMSWA shall have final approval on the type of drop structure that is allowed.

12.4.2 Minor Drainageway Drop Structures. Minor drainageway drop structures (i.e. low-flow drop structures) generally will only extend across the low-flow (bankful) channel and are applicable where tributary areas are less than or equal to 130 acres. In addition to the drop structure types mentioned above, less expensive and complex structures such as sheet piles and concrete check structures may be used. The minimum crest depth for low flow drops structures is 1.5-feet. Refer to the Hydraulic Structures Chapter of the UDFCD Manual for additional design criteria and guidance on these type of structures.

SEMSWA shall have final approval on the type of drop structure that is allowed.

12.5 Easements, Maintenance, and Ownership

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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 SEMSWA for inspection and maintenance purposes, and shall be shown on all plans associated with a development or capital improvement project. Drainage easements shall be kept clear of impediments to the flow. Easements must also be provided to allow access to channels for maintenance from the right-of-way. Easement templates are available for download on the SEMSWA website. http://www.semswa.org/manuals-templates.aspx

12.5.2 Drainageway Ownership - Residential. To ensure that drainageways and the associated conveyances are adequately preserved and properly maintained, all major drainageways and minor drainageways within residential areas that convey flows from other properties should be placed on tracts of land owned by a common entity (i.e., Park or Metro district, Homeowner's Association, County, City, SEMSWA, other regional agencies, etc.). Easements are allowed for drainage swales between individual lots, provided they accept a limited amount of drainage, from no more than two adjacent lots.

12.5.3 Drainageway Ownership – Business/Commercial. Within business and commercial land uses, all major drainageways and those minor drainageways which convey flows from other properties, must be placed within drainage easements or within separate tracts with a drainage easement.

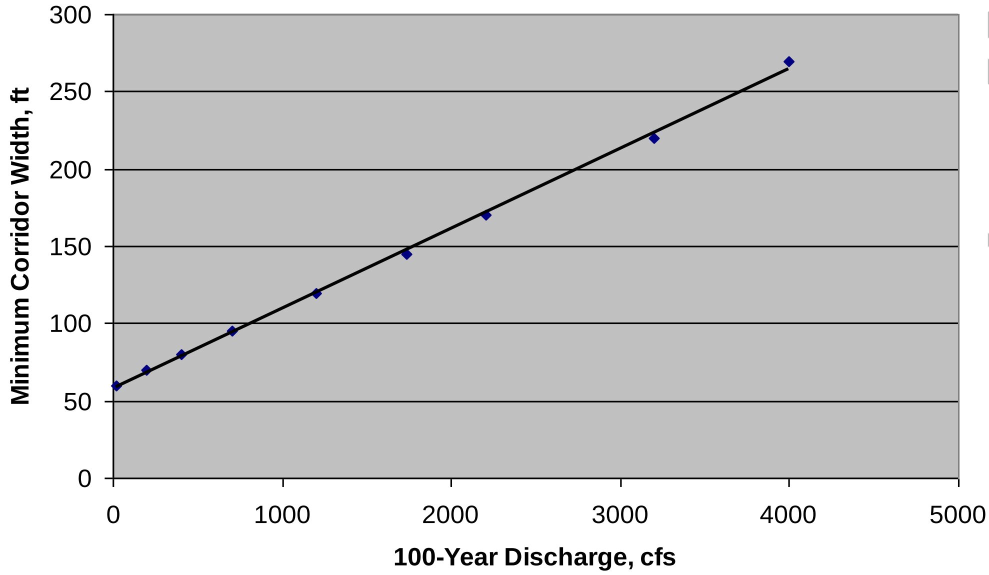
12.5.4 Easements for Natural Drainageways. Required easement widths for natural drainageways need to provide for conveyance of the 100-year flow and the required freeboard, including access for maintenance. Any banks allowed to remain in place at a slope steeper than 4 to 1 shall have the easement line set back from the top of 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. As a guideline, Figure 12-3 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 channels. Proposed easement widths less than indicated in Figure 12-3 will be subject to the approval of SEMSWA.

$$\text{Minimum easement width (ft)} = 0.06 * Q_{100} + 60,$$

Where Q_{100} = 100-year discharge in cfs.

FIGURE 12-5
MINIMUM EASEMENT WIDTH FOR NATURAL DRAINAGEWAYS



12.5.5 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 assure 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 which 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 UDFCD 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 10 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.

Major and minor drainageways shall have continuous maintenance access along the entire length of the drainageway. 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

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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.

12.5.6 Maintenance Responsibility. Maintenance responsibility lies with the owner of the land, except as modified by specific agreement(s). Maintenance responsibility shall be delineated on the Final Plat and 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.

12.5.7 Major Drainageways and UDFCD Maintenance Eligibility. Major drainageways within the UDFCD boundary shall be designed and constructed in accordance with UDFCD maintenance eligibility requirements. The design and construction shall be reviewed and approved by the UDFCD prior to SEMSWA construction approval. Appropriate drainage easements and access improvements shall be provided to ensure that adequate access is provided to the channel and related structures. When the channel design and construction are accepted by the UDFCD, it will be eligible for maintenance assistance. When channel improvements are eligible for UDFCD maintenance assistance it does not relieve the property owner, or other designee from the responsibility of providing the necessary maintenance. Refer to UDFCD for the most recent Maintenance Eligibility Program (MEP) requirements.

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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	0.025	0.030	0.033
pools	0.030	0.035	0.040
b. Same as above, but more stones and weeds	0.033	0.040	0.045
c. Clean, winding, some pools and shoals	0.035	0.045	0.050
d. Same as above, but some weeds and stones	0.040	0.048	0.055
e. Same as above, lower stages, more			
ineffective slopes and sections	0.045	0.050	0.060
f. Same as c, but more stones	0.050	0.070	0.080
g. Sluggish reaches, weedy, deep pools	0.075	0.100	0.150
h. Very weedy reaches, deep pools, or			
floodways with heavy stand of timber and			
underbrush	see		
2. Mountain Streams, no vegetation in channel, banks	Jarrett's		
usually steep, trees and brush along banks	equation*		
submerged at high stages			
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		Flow Depth
1. Bermuda grass, buffalo grass, Kentucky bluegrass	Depth =		> 3.0 ft
a. Mowed to 2 inches	0.1-1.5 ft		0.030
b. Length = 4 to 6 inches	0.035		0.030
2. Good Stand, any grass	0.040		
a. Length = 12 inches			0.035
b. Length = 24 inches	0.070		0.035
3. Fair Stand, any grass	0.100		
a. Length = 12 inches			0.035
b. Length = 24 inches	0.060		0.035
	0.070		

*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.)*

PRELIMINARY DRAFT