REVEGETATION

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1.0 INTRODUCTION

This chapter provides information on methods and plant materials needed for revegetation of drainage facilities within the Urban Drainage and Flood Control District (District). Establishment of a robust cover of vegetation is critical to the proper functioning of drainage structures such as grass-lined channels, detention basins, retention ponds, and wetlands. Vegetation serves multiple purposes, including stabilization of structures to prevent excessive erosion and removal of pollutants in stormwater. The semi-arid nature of the climate, prevalence of introduced weeds, and variety of soil types encountered in the District virtually mandate prompt implementation of a revegetation plan to achieve revegetation success.

2.0 SCOPE OF THIS CHAPTER AND RELATION TO OTHER RELEVANT DOCUMENTS

This chapter provides guidelines and recommendations for plant materials and methods for revegetation of components of the drainage system that are to be vegetated. Such components include:

- Natural channels
- Grass-lined channels
- Detention ponds
- Retention ponds
- Constructed wetlands/wetland channels
- Streambank stabilization and grade control structures

This chapter addresses the different revegetation requirements of the various parts of these facilities. For example, the bottom, side slopes and areas immediately adjacent to a facility have different moisture regimes and, therefore, should be planted with different plant species. Different plant forms (e.g., grasses, shrubs, trees) may also be limited to specific areas to enable proper functioning of the facility. For example, planting trees and shrubs along the bottom of a channel can reduce the hydraulic capacity of the channel, increase maintenance requirements, and cause the plugging of downstream bridges and culverts when uprooted by higher flows.

Additional information on revegetation methods in the District can be found in *Guidelines for Development and Maintenance of Natural Vegetation* (Don Godi and Associates 1984) and in *Design Workbook for Establishment of Natural Vegetation* (Don Godi and Associates 1993). Establishment of temporary and permanent vegetation for construction BMPs is addressed in the CONSTRUCTION BMPs chapter in Volume 3 of this *Manual*.

Although the information in this chapter is generally consistent with the information in these other documents, certain areas and topics have been updated (e.g., recommended seed mixes). Refer to the other documents listed for additional information, especially on factors to consider in preparing a revegetation plan.

3.0 GENERAL GUIDELINES FOR REVEGETATION

The guidelines below should be followed when developing a revegetation plan to the extent feasible.

3.1 Plant Materials

- The form(s) of vegetation and species used should be adapted to the soil and moisture conditions and use (e.g., conveyance of flow, side slopes, etc.) of the area.
- Native, perennial species should be used to the extent possible.
- Use of bluegrass and other species requiring irrigation and high maintenance should be avoided except along formal park settings.
- Sod-forming grasses are preferred over bunch grasses.
- Containerized nursery stock should be used for wetlands, trees, and shrubs to the extent feasible.
- Wetland plantings should not include cattails.
- Maintenance requirements should be considered in plant selection (e.g., tall grasses should not be used in urban areas unless regular mowing will occur).
- Live stakes, willow bundles, and cottonwood poles should be obtained from local, on-site sources, whenever possible (see Section 4.7.1).

3.2 Site Preparation

- All areas to be planted should have at least 6 inches of “topsoil” suitable to support plant growth (Don Godi and Associates 1984). Native topsoil should be stripped and saved for this purpose whenever a site is graded.
- The upper 3 inches of the soils in areas to be seeded should not be heavily compacted and should be in a friable condition. An 85% standard proctor density is acceptable.
- When necessary, soil amendments should be added to correct topsoil deficiencies (e.g., soil texture, pH or percent organic matter). (If topsoil and native seed mixes are used, fertilizer is often not needed.)
- Fertilizer should be used if specified by a soil analysis. Slow-release type fertilizers should be used to reduce weed growth and protect water quality. Fertilizer should be worked into soil during seedbed preparation.

3.3 Seeding and Planting

- Seed mixtures should be sown at the proper time of year specified for the mixture.
- Recommended seeding rates specified as “pounds pure live seed per acre” (lbs PLS/acre) should be used.
- Seed should be drill seeded, whenever possible.
- Broadcast seeding or hydro-seeding may be substituted on slopes steeper than 3(H):1(V) or on other areas not practical to drill seed.
- Seeding rates should be doubled for broadcast seeding or increased by 50% if using a Brillion drill or hydro-seeding.
- Broadcast seed should be lightly hand raked into the soil.
- Seed depth should be ⅓ to ½ inch for most mixtures.
- All seeded areas should be mulched, and the mulch should be adequately secured.
- If hydro-seeding is conducted, mulching should be conducted as a separate, second operation.
- All containerized nursery stock should be kept in a live and healthy condition prior to installation.
- Containerized trees and shrubs should be installed according to the planting details provided in Section 4.4.
- Live stakes, poles and willow bundles should be installed when dormant (late winter and early spring) according to the planting details in Section 4.7.
- Beaver protection should be provided for trees and shrubs for species known to be attractive to beavers if beavers are known to be in the area (see Figure RV-6).

3.4 Maintenance

- Sites should be routinely inspected following planting to implement follow-up measures to increase success. Immediate attention to a problem (e.g., weed infestation, failure of seed to germinate) can prevent total failure later.
- Access to and grazing on recently revegetated areas should be limited with temporary fencing and signage while plants are becoming established (normally the first year).
- Weed infestations should be managed using appropriate physical, chemical, or biological methods as soon as possible. (See the other documents referenced for details on weed

management options.)

- Stakes and guy wires for trees should be maintained, and dead or damaged growth should be pruned.
- Beaver protection cages should be used around tree plantings.
- Mulch should be maintained by adding additional mulch and redistributing mulch, as necessary.
- Areas of excessive erosion should be repaired and stabilized.
- Planted trees and shrubs should be watered monthly or as needed from April through September until established.

4.0 PREPARATION OF A PLANTING PLAN

4.1 General

A plan (drawings and specifications) needs to be prepared for revegetation work. The plan should address the following:

- Soil bed preparation
- Species, types, and sizes of materials to be planted
- Planting methods
- Mulching/fertilization
- Planting schedule

Figure RV-1 is a matrix that shows the steps involved in the revegetation process. Additional information on planning and design of a revegetation plan is included in *Design Workbook for Establishment of Natural Vegetation* (Don Godi and Associates 1993). This includes a "design analysis revegetation matrix" and several "checklists." This and other relevant documents should be consulted for details on preparation of a planting plan. In addition, refer to the DESIGN EXAMPLES chapter of this *Manual* for more information on planting plans.

4.2 Soil Amendments

Native topsoil should be stripped and saved for revegetation. If this is not appropriate due to poor soil quality or for some other reason, then subsoil can be made conducive for plant growth through the use of amendments. Since soil pH is typically suitable within the District, amendments are usually needed for increasing organic matter content or providing nutrients in the form of fertilizers. Consideration should be given to importing topsoil, instead of amending poor quality subsoil, as this may be less expensive.

Peat moss, composted manure, composted organic materials, grass clippings, and plowed-in green crops can be used to increase the organic matter content of a soil. Several of these also provide a source of nutrients. Inorganic and organic fertilizers are commonly used to increase the nutrient content of soils. Deficiencies with trace elements also occur on occasion. Soil samples should be sent to a laboratory for testing (e.g., Colorado State University Soils Test Laboratory), and fertilizer recommendations followed.

Detailed information on the types and amounts of soil amendments and fertilizers needed is beyond the scope of this document and can be found in the documents previously referenced. However, information is provided on the use of humate soil conditioner and biosol fertilizer. Both of these materials are relatively new and show promise as soil conditioners and sources of slow-release fertilizers for revegetation work in the District.

4.2.1 Humate Conditioner

1. Utilize natural humic acid-based concentrated solution or granular material with the following characteristics:
   - Maximum of 10% retained on a #50 mesh screen
   - 4% N, 20% P as P_2O_5, 20% K as K_20
   - 1% Ca, 0.4% Fe, 0.4% S, humic acid 45%
2. Apply granular humate at a rate of 750 pounds/acre in a uniform manner prior to tilling soils for seeding.
3. Apply soluble concentrate at 1.0 pound/acre.
4. Thoroughly mix into soil to increase organic matter and nutrient content.

4.2.2 Biosol

1. Utilize organic fertilizer with the following characteristics:
   - 6% N, 1% P as P_2O_5, 3% K as K_2O
   - 90% fungal biomass
2. Apply at a rate of 1,200 pounds/acre in a uniform manner prior to tilling soils for seeding.
3. Thoroughly mix into soil to increase nutrients.

4.3 Recommended Seed Mixes

Unlined drainage facilities and all areas disturbed during construction should be actively revegetated. Seed mixes should be selected to match the conditions where they will be used. Seed mixes can be developed for the revegetation plan consistent with the guidelines in Section 3.0, or the mixes presented in this section can be used.

Recommended seed mixes for the bottom (wet soils) and side slopes of drainage facilities within the District are included in Tables RV-1 and RV-2. Mixes for different soil conditions in upland areas are provided in Tables RV-3 to RV-6. The seeding rates in these mixes are recommended minimum rates that should be used for drill seeding. These rates should be doubled for broadcast seeding and increased by 50% if a Brillion drill or hydro-seeding is used.

The recommended seed mixes are suitable for the Colorado Front Range for sites from 4,500 to 7,000 feet in elevation and latitude 38° to 42° North. Applications outside these ranges should be made after consultation with a qualified revegetation specialist.

Table RV-1—Recommended Seed Mix for High Water Table Conditions[1]

Common Name (Variety)	Scientific Name	Growth Season	Growth Form	Seeds/Lb	Lbs PLS/Acre
Redtop*	*Agrostis alba*	Warm	Sod	5,000,000	0.1
Switchgrass (Pathfinder)	*Panicum virgatum*	Warm	Sod/bunch	389,000	2.2
Western wheatgrass (Arriba)	*Pascopyrum smithii*	Cool	Sod	110,000	7.9
Inland saltgrass	*Distichlis spicata*	Warm	Sod	520,000	1.0
Wooly sedge	*Carex lanuginose*	Cool	Sod	400,000	0.1
Baltic rush	*Juncus balticus*	Cool	Sod	109,300,000	0.1
Prairie cordgrass	*Spartina pectinata*	Coll	Sod	110,000	1.0
					12.4
Wildflowers					
Nuttall's sunflower	*Helianthus nuttallii*	---	---	250,000	0.10
Wild bergamot	*Monarda fistulosa*	---	---	1,450,000	0.12
Yarrow	*Achillea millefolium*	---	---	2,770,000	0.06
Blue vervain	*Verbena hastata*	---	---		0.12
					0.40

[1] For areas of facilities located near or on the bottom or where wet soil conditions occur. Planting of potted nursery stock wetland plants 2-foot on-center is recommended for sites with wetland hydrology.

* Nonnative.

Table RV-2—Recommended Seed Mix for Transition Areas[1]

Common Name (Variety)	Scientific Name	Growth Season	Growth Form	Seeds/Lb	Lbs PLS/Acre
Sheep fescue (Durar)	*Festuca ovina*	Cool	Bunch	680,000	1.3
Western wheatgrass (Arriba)	*Pascopyrum smithii*	Cool	Sod	110,000	7.9
Alkali sacaton	*Spolobolus airoides*	Warm	Bunch	1,758,000	0.5
Slender wheatgrass	*Elymus trachycaulus*	Cool	Bunch	159,000	5.5
Canadian bluegrass (Ruebens)*[2]	*Poa compressa*	Cool	Sod	2,500,000	0.3
Switch grass (Pathfinder)	*Panicum virgatum*	Warm	Sod/bunch	389,000	1.3
					16.8
Wildflowers					
Blanket flower	*Gaillardia aristata*	---	---	132,000	0.25
Prairie coneflower	*Ratibida columnaris*	---	---	1,230,000	0.20
Purple prairie clover	*Petalostemum purpurea*	---	---	210,000	0.20
Gayfeather	*Liatris punctata*	---	---	138,000	0.06
Flax	*Linum lewisii*	---	---	293,000	0.20
Penstemon	*Penstemon strictus*	---	---	592,000	0.20
Yarrow	*Achillea millefolium*	---	---	2,770,000	0.03
					1.14

[1] For side slopes or between wet and dry areas.

[2] Substitute 1.7 lbs PLS/acre of inland salt grass (*Distichlis spicata*) in salty soils.

* Nonnative.

Table RV-3—Recommended Seed Mix for Alkali Soils

Common Name (Variety)	Scientific Name	Growth Season	Growth Form	Seeds/Lb	Lbs PLS/Acre
Alkali sacaton	*Sporobolus airoides*	Cool	Bunch	1,750,000	0.5
Streambank wheatgrass (Sodar)	*Agropyron riparium*	Cool	Sod	156,000	5.6
Inland salt grass	*Distichlis stricta*	Warm	Sod	520,000	1.7
Western wheatgrass (Arriba)	*Pascopyrum smithii*	Cool	Sod	110,000	7.9
Blue grama (Hachita)	*Chondrosum gracile*	Warm	Sod	825,000	4.0
Buffalograss	*Buchloe dactyloides*	Warm	Sod	56,000	2.0
					21.7
Wildflowers					
Blanket flower	*Gaillardia aristata*	---	---	132,000	0.25
Prairie coneflower	*Ratibida columnaris*	---	---	1,230,000	0.20
Purple prairie clover	*Petalostemum purpurea*	---	---	210,000	0.20
Gayfeather	*Liatris punctata*	---	---	138,000	0.06
Blue Flax	*Linum lewisii*	---	---	293,000	0.20
Rocky Mountain penstemon	*Penstemon strictus*	---	---	592,000	0.20
Yarrow	*Achillea millefolium*	---	---	2,770,000	0.03
					1.14

Table RV-4—Recommended Seed Mix for Loamy Soils

Common Name (Variety)	Scientific Name	Growth Season	Growth Form	Seeds/Lb	Lbs PLS/Acre
Sheep fescue (Durar)	*Festuca ovina*	Cool	Bunch	680,000	0.6
Canby bluegrass	*Poa canbyi*	Cool	Bunch	926,000	0.5
Thickspike wheatgrass (Critana)	*Elymus lanceolatus*	Cool	Sod	154,000	5.7
Western wheatgrass (Arriba)	*Pascopyrum smithii*	Cool	Sod	110,000	7.9
Blue grama (Hahita)	*Chondrosum gracile*	Warm	Sod/bunch	825,000	1.1
Switchgrass (Pathfinder)	*Panicum virgatum*	Warm	Sod/bunch	389,000	1.0
Sideoats grama (Butte)	*Boutelou curtipendula*	Warm	Sod	191,000	2.0
					18.8
Wildflowers					
Blanket flower	*Gaillardia aristata*	---	---	132,000	0.25
Prairie coneflower	*Ratibida columnaris*	---	---	1,230,000	0.20
Purple prairie clover	*Petalostemum purpurea*	---	---	210,000	0.20
Gayfeather	*Liatris punctata*	---	---	138,000	0.06
Flax	*Linum lewisii*	---	---	293,000	0.20
Penstemon	*Penstemon strictus*	---	---	592,000	0.20
Yarrow	*Achillea millefolium*	---	---	2,770,000	0.03
					1.14

Table RV-5—Recommended Seed Mix for Sandy Soils

Common Name (Variety)	Scientific Name	Growth Season	Growth Form	Seeds/Lb	Lbs PLS/Acre
Blue grama (Hachita)	*Chondrosum gracile*	Warm	Sod/bunch	825,000	2.1
Little bluestem (Camper)	*Schizachyrium scoparium*	Warm	Bunch	260,000	3.0
Prairie sandreed	*Calamovilfa longifolia*	Warm	Sod	274,000	3.0
Sand dropseed	*Sporobolus cryptandrus*	Warm	Bunch	5,298,000	0.3
Sideoats grama (Vaughn)	*Bouteloua curtipendula*	Warm	Sod/bunch	191,000	5.6
Western wheatgrass (Arriba)	*Pascopyrum smithii*	Cool	Sod	110,000	8.0
					22.0
Wildflowers					
Blanket flower	*Gaillardia aristata*	---	---	132,000	0.25
Prairie coneflower	*Ratibida columnifera*	---	---	1,230,000	0.20
Purple prairie clover	*Petalostemum purpurea*	---	---	210,000	0.20
Gayfeather	*Liatris punctata*	---	---	138,000	0.06
Flax	*Linum lewisii*	---	---	293,000	0.20
Penstemon	*Penstemon strictus*	---	---	592,000	0.20
Yarrow	*Achillea millefolium*	---	---	2,770,000	0.03
					1.14

Table RV-6—Recommended Seed Mix for Clay Soils

Common Name (Variety)	Scientific Name	Growth Season	Growth Form	Seeds/Lb	Lbs PLS/Acre
Buffalograss	*Buchloe dactyloides*	Warm	Sod	56,000	14.0
Sideoats grama (Vaughn)	*Bouteloua curtipendula*	Warm	Sod	191,000	3.0
Blue grama (Hachita)	*Chondrosum gracile*	Warm	Sod/bunch	825,000	1.1
Western wheatgrass (Arriba)	*Pascopyrum smithii*	Cool	Sod	110,000	7.9
Alkali sacaton	*Sporobolus airoides*	Warm	Bunch	1,758,000	1.0
Inland saltgrass	*Distichlis stricta*	Warm	Sod	520,000	2.0
					29.0
Wildflowers					
Gayfeather	*Liatris punctata*	---	---	138,000	0.1
Purple prairie clover	*Petalostemum purpureum*	---	---	210,000	0.1
Scarlet globemallow	*Sphaeralcea coccinea*	---	---	500,000	0.1
Rocky Mountain beeplant	*Cleome serrulata*	---	---	65,900	0.1
					0.4

The seed mixes in Tables RV-1 through RV-6t06 also include recommended wildflowers that can be included in a mix when wildflowers are desired. The wildflower seeds can be sown at the same time or after the grass seed mix. Table RV-7 includes a general wildflower seed mix that can be used in sunny locations. This mix stresses more drought tolerant, native perennials, and can be sown at the same time as a grass seed mix, or after. The mix in Table RV-7 is recommended instead of the species shown in Tables RV-1 through RV-6, when more wildflowers are desired.

Table RV-7—Wildflower Mix (to be seeded with grass seed mix)[1]

Common Name (Variety)	Scientific Name	Flower Color	Seeds/Lb	Lbs PLS/Acre
Scarlet globemallow	*Sphaeralcea coccinea*	Red/orange	500,000	0.6
Blue flax	*Linum lewisii*	Blue	293,000	0.6
Purple prairie clover	*Petalostemum purpureum*	Red-purple	210,000	0.7
White prairie clover	*Petalostemum candidum*	White	354,000	0.6
California poppy	*Eschscholtzia californica*	Orange	293,000	0.3
Blanket flower	*Gaillardia aristata*	Yellow/red	132,000	1.0
Prairie aster	*Aster tanacetifolius*	Violet	496,000	0.3
Blackeyed Susan	*Rudbeckia hirta*	Yellow	1,710,000	0.3
Purple coneflower	*Echinacea purpurea*	Purple	117,000	0.9
Yarrow	*Achillea millefolium*	White	2,770,000	0.1
Gayfeather	*Liatris punctata*	Rose/purple	138,000	0.6
Total				6.0

[1] This is a general mix for the District that stresses native perennials that do well in a range of soil types in sunny locations.

4.4 Trees, Shrubs and Wetland Plantings

Trees and shrubs add diversity to a planting plan and value for wildlife and birds. Trees and shrubs that impede flow and reduce the capacity of the structure should not be planted in the bottom of a drainage channel. It is recommended that containerized stock of the species listed in Table RV-8 be planted, as shown on Figures RV-2 and RV-3. Alternatively, cottonwood pole plantings and coyote (or sandbar) willow cuttings may be used to establish cottonwood trees and willows especially in soils with a shallow groundwater table.

The species of trees and shrubs to be planted should be chosen carefully to meet specific site conditions. For example, a shrub species that requires moderate to high soil moisture (e.g., sandbar willow) should not be planted on a dry hillside or upper streambank unless there is evidence of a high groundwater table or another continuous water source.

Table RV-8—Recommended Shrubs and Trees[1]

Common Name	Scientific Name	Height (ft)	Sun/Shade	Planting Zone	Notes
Shrubs					
Saskatoon serviceberry	*Amelanchier alnifolia*	3 – 15	Sun	Upland	Good for wildlife
Lead plant	*Amorpha fruticosa*	3 – 8	Sun	Upland	Drought tolerant
Rubber rabbitbrush	*Chrysothamnus nauseosus*	2 – 3	Sun	Upland	Drought tolerant
Wild plum	*Prunus Americana*	5 – 20	Sun/shade	Transition	Forms thickets
Chokecherrry	*Prunus virginiana*	5 – 20	Sun/shade	Transition	Forms thickets
Smooth sumac	*Rhus glabra*	4 – 7	Sun/shade	Upland	Good for wildlife
Oakbrush sumac	*Rhus trilobata*	2 – 6	Sun/shade	Upland	Drought tolerant
Wax currant	*Ribes cereum*	3 – 5	Sun/shade	Transition	Good for wildlife
Redosier dogwood	*Cornus stolonifera*	3 – 9	Shade	Wetland	Drought tolerant
Sandbar willow	*Salix exigua*	6 – 10	Sun	Transition or wetland	Requires more water
Snowberry	*Symphoricarpos oreophilus*	2 – 5	Sun/shade	Transition	Prefers moist area
Spanish bayonet	*Yucca glauca*	1 – 2	Sun	Upland	Drought tolerant
Woods rose	*Rosa woodsii*	2 – 3	Sun	Upland	Establishes quickly
Silver buffaloberry	*Shepherdia argentea*	6 – 13	Sun	Upland	Drought tolerant
Trees					
Narrow leaf cottonwood	*Populus angustifolia*	10 – 30	Sun	Transition or wetland	Requires more water
Plains cottonwood	*Populus deltoides*	50	Sun	Transition	Requires more water
Rocky Mountain juniper	*Juniperus scopulorum*	5 – 15	Sun	Upland	Drought tolerant
Colorado blue spruce	*Picea pungens*	60 – 100	Sun	Transition	Requires more water
Ponderosa pine	*Pinus ponderosa*	75 – 100	Sun	Upland	Drought tolerant
Peach leaf willow	*Salix amygdaloides*	15 – 30	Sun	Wetland	Requires more water

[1] Trees and shrubs should not be planted in the bottoms of drainage channels or where they could impede flow and decrease channel capacity. It is recommended that containerized stock (e.g., 2-gallon, 5-gallon) be used for trees and shrubs.

Wetland vegetation should be established in constructed wetlands, wetland bottom channels and, at times, along the shoreline of retention ponds. Such vegetation serves multiple functions, including assistance with pollutant removal, shoreline stabilization, aesthetics, and wildlife and bird habitat. Wetland plants should be planted in “zones” based on water depth. A common problem with establishing

wetlands within the District is invasion by cattails. Actively planting a constructed wetland and keeping open areas with a water depth greater than 2 feet will discourage cattail invasion. Recommended plants for wetlands are shown in Table RV-9 by water depth. It is recommended that containerized stock be used for wetland plantings. Additional information on design of constructed wetlands and retention ponds can be found in Volume 3 of this *Manual*.

Table RV-9—Recommended Plants for Constructed Wetlands and Retention Pond Shelf[1]

Depth of Water (ft)	Common Name	Scientific Name	Notes
0 - 1.5	Soft stem bulrush Hard stem bulrush Arrowhead Alkali bulrush Smart weed	*Scirpus validus* *Scirpus acutus* *Sagittaria latifolia* *Scirpus maritimus* *Polygonum persicaria*	• Planted plants should extend above water • Plants will invade deeper water with time
0.25 - 0.5	Three-square Spike rush	*Scirpus americanus* *Eleocharis palustris*	• Planted plants should extend above water
0 - 0.25	Rice cut grass Nebraska sedge Soft rush Baltic rush Torrey's rush Foxtail barley	*Leersia oryzoides* *Carex nebrascensis* *Juncus effuses* *Juncus balticus* *Juncus torreyi* *Hordeum jubatum*	• Species will adjust to moisture conditions with time
Height above water 0 – 1 0 – 3	 Milkweed Switchgrass Prairie cordgrass Beebalm	 *Asclepias incarnata* *Panicum virgatum* *Spartina pectinata* *Monarda fistulosa*	 • Best to plant near water where soil is wet • Colorful wildflower

[1] It is recommended that containerized stock be used for wetland plantings. It is not recommended that cattails be planted since they will invade naturally.

4.5 Mulching

All planted areas should be mulched preferably immediately following planting, but in no case later than 14 days from planting. Mulch conserves water and reduces erosion. The most common type of mulch used is hay or grass that is crimped into the soil to hold it. However, crimping may not be practical on slopes steeper than 3:1.

The following guidelines should be followed with mulching:

- Only weed-free and seed-free straw mulch should be used (grass hay often contains weedy exotic species). Mulch should be applied at 2 tons/acre and adequately secured by crimping,

tackifier, netting, or blankets.

- Crimping is appropriate on slopes of 3:1 or flatter and must be done so as to tuck mulch fibers into the soil 3 to 4 inches deep.
- Tackifier or netting and blankets anchored with staples should be used on slopes steeper than 3:1.
- Hydraulic mulching may also be used on steep slopes or where access is limited. Wood cellulose fibers mixed with water at 2,000 to 2,500 pounds/acre and organic tackifier at 100 pounds per acre should be applied with a hydraulic mulcher.
- Wood chip mulch should be applied to planted trees and shrubs, as shown in Figures RV-2 and RV-3.

Additional details on mulching can be found in Volume 3 of this *Manual*.

4.6 Bioengineering

Willow bundles, live stakes, and cottonwood poles are plant materials that can be used to revegetate drainage facilities. Willow bundles can be placed to provide bank protection along lower slopes of channels. Live stakes and poles can be planted near the toe of a slope where there is a source of high groundwater. They are especially applicable for vegetating large riprap and boulders filled with soil. Information is provided below on methods for collecting and planting willow bundles, live stakes and cottonwood poles. In addition, see Section 4.5, Bioengineered Channels, in the MAJOR DRAINAGE chapter of this *Manual* for additional information and figures.

4.7 Collection of Live Stakes, Willow Cuttings, and Poles

Live stakes, willow cuttings, and poles are straight branches or saplings that have been cut and pruned from dormant living plant material (plants that have lost their leaves).

Single live stakes: The live branches which shall be trimmed and cut to length for this installation shall be a minimum of 2½ feet long and a minimum of ½ inch in diameter for bare ground installation, and a minimum of 3½ feet long for riprap joint planting. These units shall be free from all side branches. The terminal bud must remain undamaged. The "root" end of each cutting shall be cut at a 45-degree angle. This serves as an indicator of which end of the stake to tamp into the ground or riprap and also facilitates the tamping process.

Willow bundling: The live branches, which shall be trimmed and cut to length for this installation, shall be a minimum of 4 feet long and a minimum of ⅜ inch in diameter. These units shall be free from all side branches. The "root" end of each cutting shall be cut at a 45-degree angle. This serves as an indicator of

which end of the stake to insert into the ground or riprap.

Cottonwood poling: The live saplings or straight branches, which shall be trimmed and cut to length for this installation, shall be a minimum of 10 feet long and a minimum of 1 inch in diameter. These units shall be free from all side branches. The "root" end of each pole shall be cut at a 45-degree angle. This serves as an indicator of which end of the pole to insert into the ground or riprap.

4.7.1 Harvest Procedure

1. Timing of harvest and Installation: All live willow staking, bundling, and poling shall be performed between February 1 and April 1, prior to leafing out.

2. Source and species of live cut materials: Live cuttings shall be taken from approved, existing, natural, native-growing sites. All cuttings shall be taken from a dormant plant. Willow species shall be *Salix exigua* (Sandbar willow) or approved equivalent. Cottonwood species shall be *Populus deltoides* (Plains cottonwood) or equivalent. Willow cuttings shall be at least ¼ inch in diameter, and cottonwood poles no less than ¾ inch in diameter.

3. Cutting: The use of weed whips with metal blades, loppers, brush cutters, and pruners is recommended, provided that they are used in such a manner that they leave clean cuts. The use of chain saws is not recommended. Live plant materials shall be cut and handled with care to avoid bark stripping and trunk wood splitting. Cuts shall be made 8 to 10 inches from the ground when cutting from the approved sites. Cuts shall be made flat or at a blunt angle.

   All cuttings should be placed in water deep enough to cover at least the lower 6 inches of the cutting immediately after harvest.

4. Harvesting site: No more than 30% of available branches should be harvested at a site. The harvesting site must be left clean and tidy. Excess woody debris should be removed from the site and disposed of properly, or could be cut up into 16-inch lengths and evenly distributed around the site.

5. Binding and storage: Live branch cuttings shall be bound together securely with twine at the collection site, in groups, for easy handling and for protection during transport. Live branch cuttings shall be grouped in such a manner that they stay together when handled. Outside storage locations shall be continually shaded and protected from the wind. Cuttings shall be held in moist soils or kept in water until ready for planting. Cuttings shall be protected from freezing and drying at all times.

6. Transportation: During transportation, the live cuttings shall be placed on the transport vehicles in an orderly fashion to prevent damage and to facilitate handling. The live cuttings shall be kept wet and covered with a tarp or burlap material during transportation.

7. Arrival time: All cuttings shall arrive on the job site within 8 hours of cutting. Upon arrival at the installation site, cuttings shall be inspected for acceptability. Cuttings not installed on the day of arrival at the job site shall be stored and protected (kept in water and in cold storage) until installation. All cuttings shall be installed within 24 hours of harvesting.

8. Inspection and approval: Upon arrival at the construction site, live branch cuttings shall be

inspected for acceptability. Live cuttings shall be collected from sources that shall be approved prior to the commencement of cutting operations.

4.7.2 Installation

Single live stakes: Live stakes shall be planted in three rows starting 0.5 feet above the ordinary high water line, at 1 foot spacing. Stakes shall be installed in a 2-feet by 2-feet grid pattern. Live stakes shall be tamped directly into the soil or between rock riprap and shall protrude 4 to 8 inches from the soil surface. Live stakes shall be installed at least 12 inches into the soil and at least 6 inches into saturated soil. In no case will the live stakes protrude more than 8 inches above the soil surface. In the case of joint planting in riprap, the protruding measurement shall be taken from the soil level between the rocks and not from the top of rock. Only dead blow hammers or rubber mallets shall be used to tamp the live stakes into the soil. Care shall be taken to prevent splitting the stakes due to impact from the hammers. Sledgehammers shall not be used to tamp the live stakes into the soil. In cases where the soil is too hard to tamp the live stake in directly, a metal rod of ½- to ¾-inch-diameter may be driven in first to prepare a pilot hole. Backfill around the installed live stake with the original soil to eliminate air voids, then tamp the ground lightly around the stake with a hammer to hold it securely in place. A slight "saucer" shall be formed around each cutting to capture and hold precipitation. This saucer should be filled with water after planting. After the stakes are fully tamped into the soil, the top 1 to 2 inches of each live stake shall be pruned to a clean, non-damaged cut. Figure RV-4 shows a typical installation of live willow staking.

Willow bundling: Bundles shall consist of five to seven cuttings bound together into a 2- to 3-inch-diameter. Bundles shall be planted in rows starting 0.5 feet above the ordinary high water line at 4-foot spacing. Bundles shall be inserted directly into the soil or between rock riprap and shall protrude 4 to 8 inches from the soil surface. Bundles shall be installed at least 12 inches into the soil and reach at least 6 inches into saturated soil. In no case should the cuttings protrude more than 8 inches above the soil surface. In the case of joint planting in riprap, the protruding measurement shall be taken from the soil level between the rocks and not from the top of rock. If tamping is necessary, care shall be taken to prevent splitting the cuttings. Backfill around the installed bundle with the original soil to eliminate air voids, then tamp the ground lightly around the bundle with a hammer to hold it securely in place. A slight saucer shall be formed around each bundle to capture and hold precipitation. This saucer should be filled with water after planting. After the bundles are fully inserted into the soil, the top 1 to 2 inches of each cutting shall be pruned if necessary to a clean, non-damaged cut. Figure RV-5 shows a typical installation of willow bundling.

Cottonwood poling: All branches must be trimmed from the pole except those at the tip. Prepare the pilot hole by using an auger, stinger, or probe to bore to a minimum depth of 5 feet or as needed to penetrate groundwater. Poles should pass through 18 inches of aerated soil before penetrating the water table.

The pilot hole shall be of sufficient diameter to facilitate easy insertion of a cottonwood pole. Backfill around the installed pole with loose sand to eliminate air voids, then tamp the ground lightly around the pole with a hammer to hold it securely in place. A slight saucer shall be formed around each pole to capture and hold precipitation. This saucer should be filled with water after planting. Cottonwood poles should be protected against beaver damage by the installation of a 30-inch-diameter beaver protection sleeve made from an 8½-foot length of 48-inch-wide 2-inch by 2-inch welded wire fabric fastened with wire or hogring fasteners. Figure RV-6 shows a typical installation of cottonwood poles.

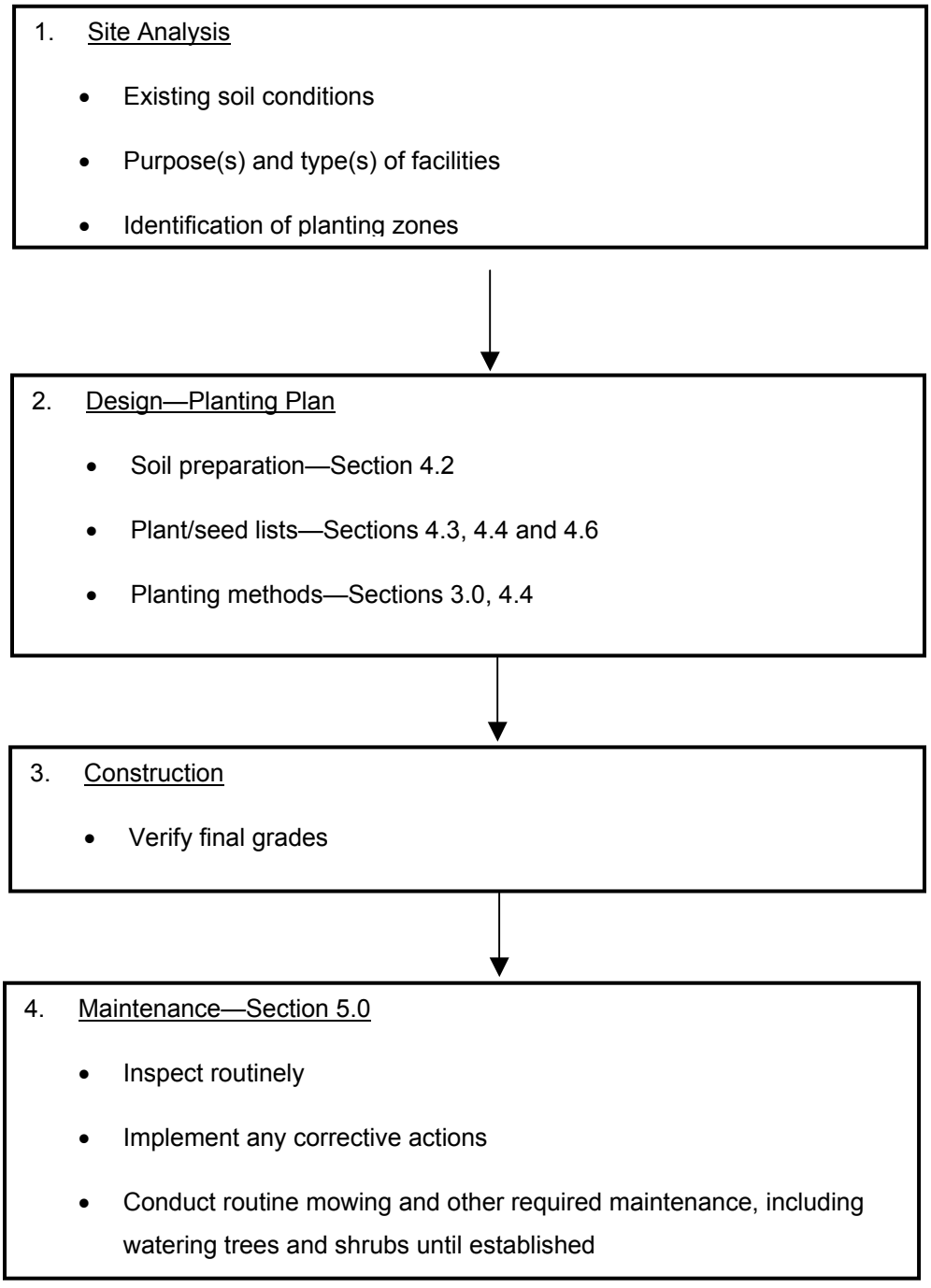
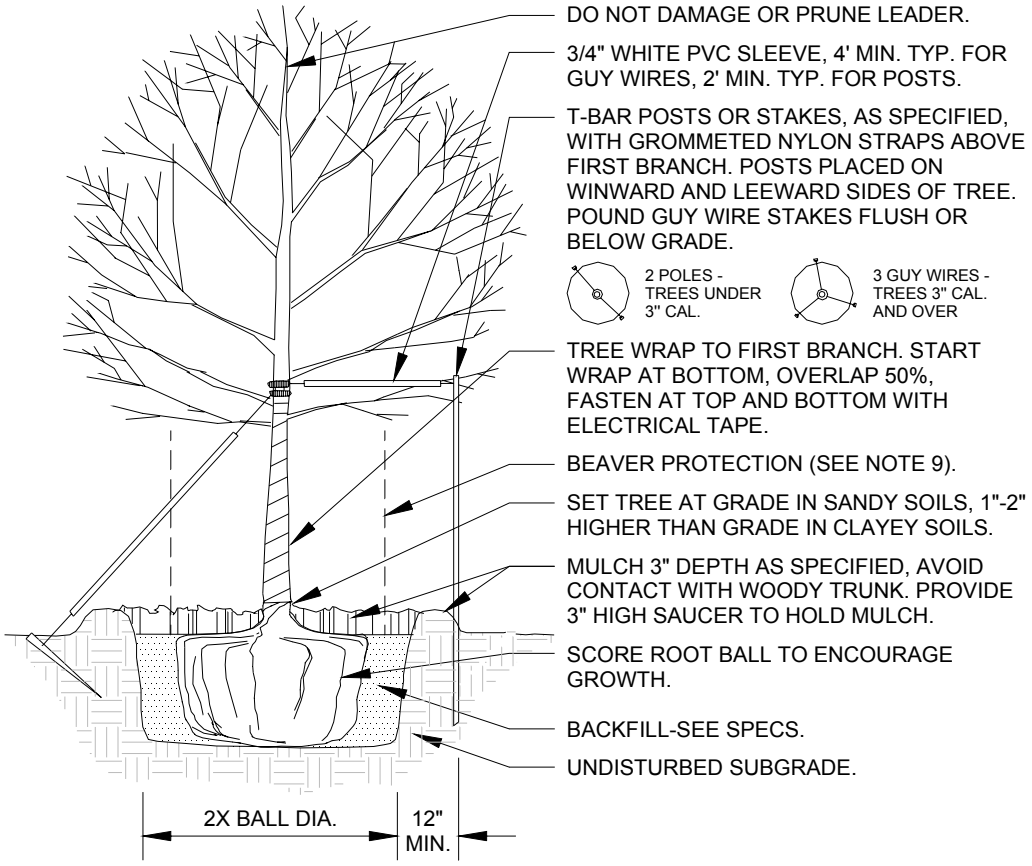


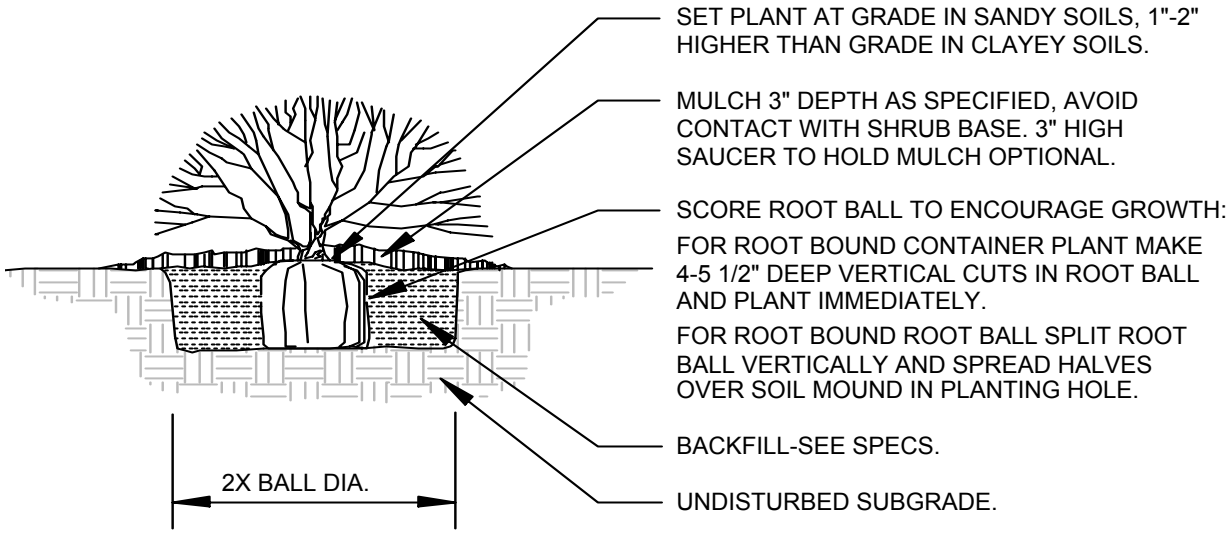
Figure RV-1—Revegetation Process Chart



NOTES:

1. SEE SPECS FOR ADDITIONAL PLANTING REQUIREMENTS.
2. KEEP PLANTS MOIST AND SHADED UNTIL PLANTED. PRUNE ALL DAMAGED AND DEAD BRANCHES AND WEAK OR NARROW CROTCHES. DO NOT REMOVE LOWER LIMBS AND SPROUTS FOR AT LEAST TWO GROWING SEASONS.
3. PLUMB AND ORIENT PLANTS FOR BEST APPEARANCE.
4. REMOVE ALL TWINE AND WIRE FROM ROOT BALL AND FOLD BURLAP BACK 2/3. REMOVE ALL RESTRAINING MATERIAL AFTER TREE IS SET IN PLANTING HOLE.
5. ROOT BALL SHALL REST ON FIRM, UNDISTURBED SOIL. IN SANDY SOIL PLANTING HOLE SHALL BE NO DEEPER THAN ROOT BALL. IN CLAYEY SOIL PLANTING HOLE SHALL BE 1"-2" SHALLOWER THAN ROOTBALL.
6. SCARIFY VERTICAL SLOPES INSIDE HOLE WITH SPADE.
7. ON SLOPES GREATER THAN 5:1 SET ROOT BALL 2" ABOVE LINE OF SLOPE AT GRADE. PROVIDE SAUCER RIM ON DOWNHILL SIDE OF ROOT BALL, 2:1 MAX. SLOPE, COVER EXPOSED ROOT BALL MIN. 6".
8. WATER ALL PLANTS WELL AT PLANTING.
9. PROVIDE A BARRIER PROTECTION SLEEVE (SEE FIGURE RV-6) WHENEVER BEAVER ARE SUSPECTED TO LIVE OR ARE EXPECTED TO MOVE INTO THE PROJECT AREA LATER.

Figure RV-2—Tree Planting Details



NOTES:

1. SEE SPECS FOR ADDITIONAL PLANTING REQUIREMENTS.
2. KEEP PLANTS MOIST AND SHADED UNTIL PLANTED. PRUNE ALL DAMAGED AND DEAD WOOD.
3. PLUMB AND ORIENT PLANTS FOR BEST APPEARANCE.
4. REMOVE ALL TWINE FROM ROOT BALL AND FOLD BURLAP BACK 2/3. REMOVE PLASTIC BURLAP, CONTAINERS AND WIRE BASKETS ENTIRELY.
5. ROOT BALL SHALL REST ON FIRM, UNDISTURBED SOIL. IN SANDY SOIL PLANTING HOLE SHALL BE NO DEEPER THAN ROOT BALL. IN CLAYEY SOIL PLANTING HOLE SHALL BE 1"-2" SHALLOWER THAN ROOTBALL.
6. SCARIFY VERTICAL SLOPES INSIDE HOLE WITH SPADE.
7. ON SLOPES GREATER THAN 5:1 SET ROOT BALL EVEN WITH LINE OF SLOPE AT GRADE. PROVIDE SAUCER RIM ON DOWNHILL SIDE OF ROOT BALL, 2:1 MAX. SLOPE, COVER EXPOSED ROOT BALL MIN. 6".
8. WATER ALL PLANTS WELL AT PLANTING.

Figure RV-3—Shrub Planting Details

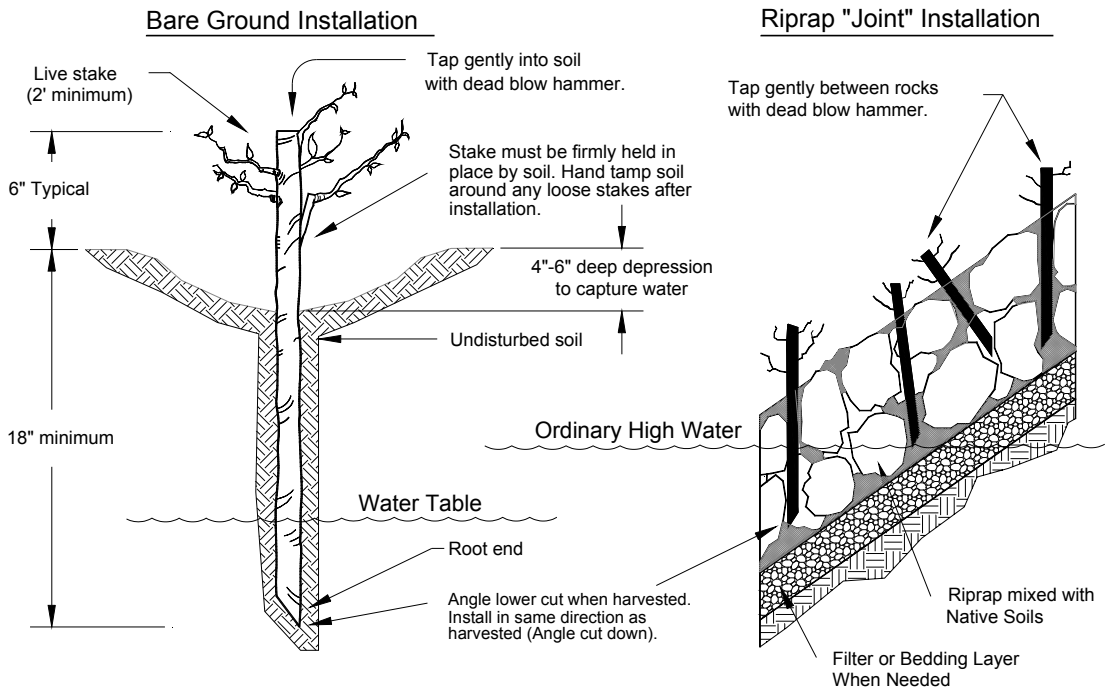


Figure RV-4—Single Willow Stake Detail for Use in Granular Soils With Available Groundwater

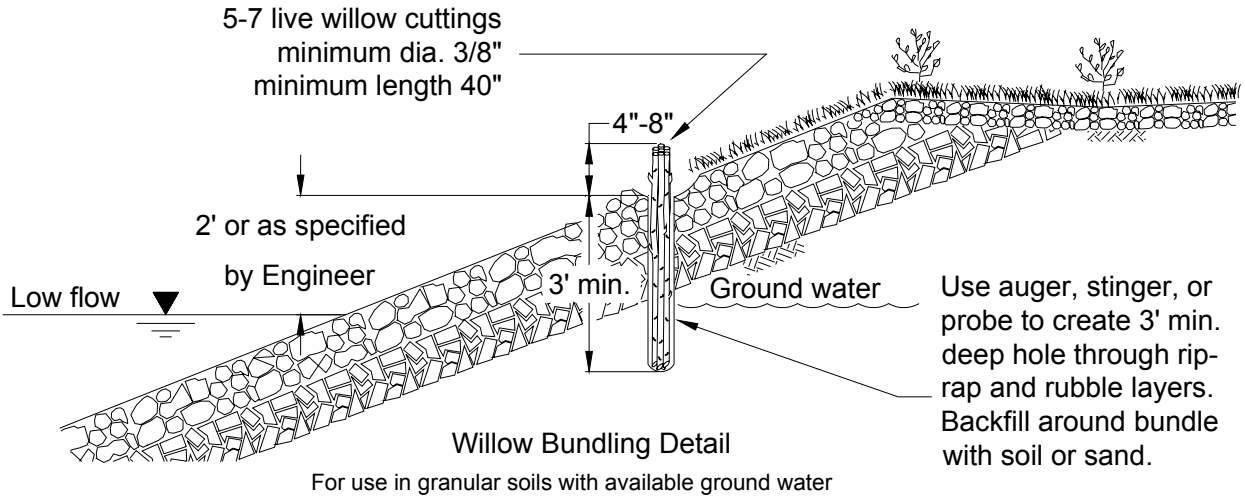
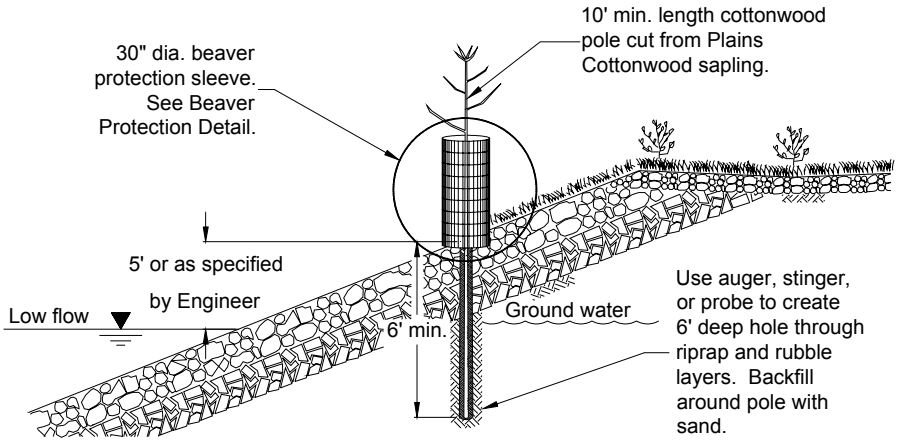
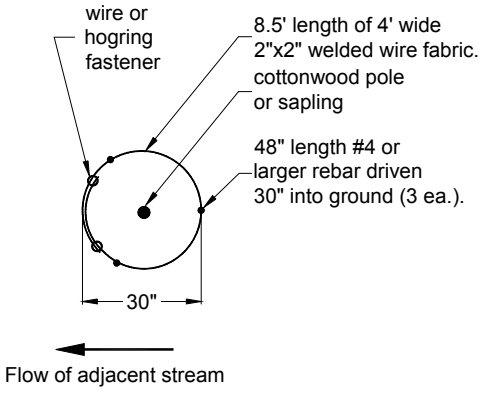


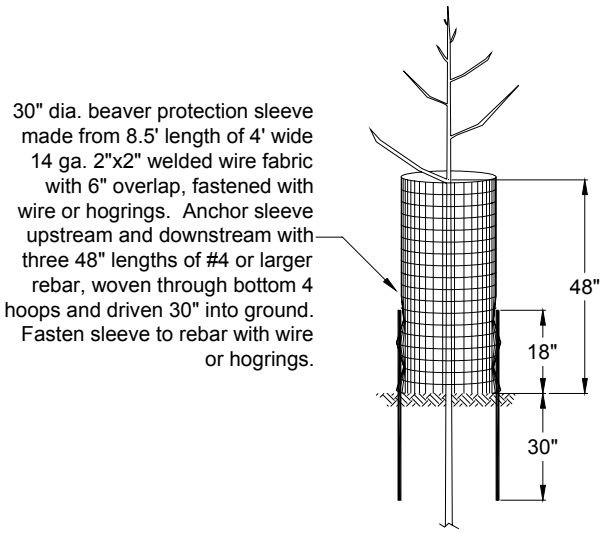
Figure RV-5—Willow Bundling Detail



Cottonwood Poling Detail

For use in granular soils with available ground water





Beaver Protection Detail

Figure RV-6—Cottonwood Poling Details

5.0 POST-CONSTRUCTION MONITORING

Monitoring is necessary to check the status of revegetation work and to implement any follow-up measures needed, such as mowing, weed control, watering, overseeding, etc. This is especially important for establishing native species since it may take several years for vegetation to become adequately established. Sites should be observed several times during their first two growing seasons and at least once a year thereafter. The guidelines in Section 3.4 should be followed.

6.0 REFERENCES

Don Godi and Associates. 1984. *Guidelines for Development and Maintenance of Natural Vegetation*. Denver, CO: Urban Drainage and Flood Control District.

———. 1993. *Design Workbook for Establishment of Natural Vegetation*. Denver, CO: Urban Drainage and Flood Control District.