4.0 RECOMMENDED IMPROVEMENT PROJECTS

Overview of Project Types

A variety of improvement projects are recommended to address the issues identified as limiting riparian functions in the Red Butte Creek corridor and to improve overall riparian conditions. To be effective, different types of projects must be implemented at different spatial scales. Therefore, the presentation of projects has been organized into four groups based on the appropriate implementation scale.

"General" projects include measures that are appropriate to implement at any scale within the riparian corridor. General projects are effective when implemented at a single point or property within the corridor, and they are also effective when implemented at a broader scale throughout an entire stream reach or the entire riparian corridor.

"Local-scale" projects are relevant to specific individual locations or features such as a particular storm drain, stream-crossing culvert, or in-channel diversion structure. These types of projects are appropriate to implement at a local scale, although upstream and downstream reach and watershed conditions should be considered in the design of local-scale projects.

"Reach-scale" projects are most effective when implemented throughout an entire stream reach or throughout a series of connected stream reaches. Bank-stabilization efforts that affect channel areas within the AHWL, grade-control projects to improve streambed stability, and projects involving pedestrian access are examples of reach-scale projects. The starting and ending locations for reach-scale projects should typically be established "hard" points such as stream crossings where the channel position is fixed.

"Watershed-scale" projects are applicable both within and beyond the riparian corridor, throughout the entire watershed area that drains to Red Butte Creek (Figure 4.1). Watershed-scale efforts attempt to halt or reverse some of the root causes of riparian corridor degradation, such as hydrologic alteration, sediment-supply alteration, and/or water quality pollution.

General Projects

Stream Cleanup

This improvement measure involves organizing a group of people to pick up trash within a specific riparian corridor area. Cleanups on private property should only be held after coordinating with and receiving permission from all landowners within the cleanup area. Planning a cleanup event involves selecting a date and specific location, publicizing the event and recruiting volunteer help, making arrangements for proper disposal and recycling of

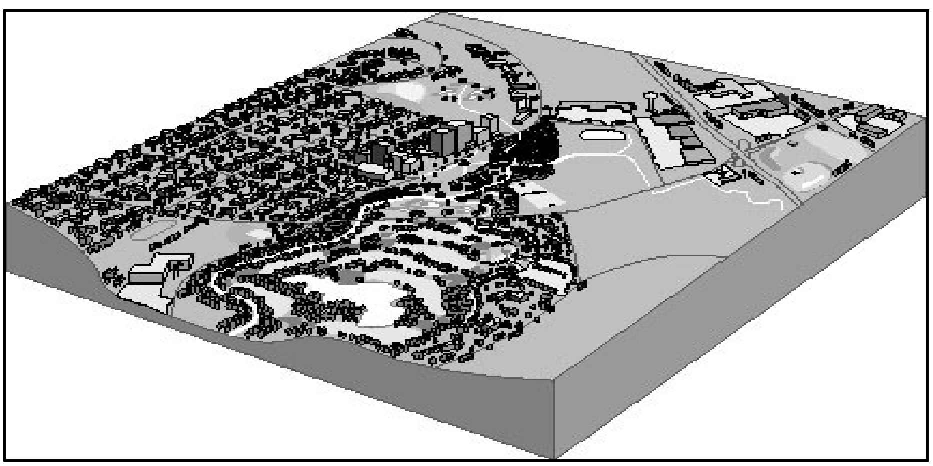


Figure 4.1. Schematic illustration of a contributing watershed area draining to an urban riparian corridor. (Illustration from FISRWG 1998).

Potential partnering organizations for stream-cleanup projects:

- Trout Unlimited
- Natural Resources Conservation Service
- Utah Division of Wildlife Resources
- Utah Federation for Youth
- Girl Scout and Boy Scout Groups
- Utah State University Water Quality Extension
- School Groups or Classrooms
- American Rivers National River Cleanup Program

the collected trash, and obtaining supplies via purchase or donations (trash bags, first aid kits, waders, water/refreshments, etc.). Stream cleanups can be organized by local individual citizens, school groups, local government entities, or other organizations.

A special consideration on Red Butte Creek is that western poison ivy is prevalent in some reaches; cleanup organizers should be sure to educate volunteers to identify and avoid the plant and provide preventative lotions as needed. A County flood-control permit may be required for certain types of cleanup projects. Stream-cleanup projects enhance the aesthetic function of riparian corridors and can also improve water quality by removing potential pollution sources from the riparian corridor.

Mechanized Trash Removal

Many of the litter areas that were noted and mapped during baseline assessment efforts consist of heavy, over-size items that would not be possible to remove by hand during a volunteer cleanup event. Therefore, trash removal in certain locations would require mechanized equipment such as backhoes or all-terrain vehicles. City or County crews would most likely be the most appropriate entities to implement this type of project, as they have the appropriate equipment and trained labor on staff. However, there may also be opportunities to use volunteer labor or equipment by involving local construction or landscaping businesses in the cleanup project.

Planning a mechanized trash cleanup project involves selecting a date and specific location for the project, making arrangements for proper disposal and recycling of the collected trash, constructing temporary equipment access routes if needed, and revegetating access routes once work is complete. As with stream cleanups, mechanized trash removal projects in privately owned areas should only be completed after coordinating with and receiving permission from all relevant landowners. In locations where the trash to be removed includes failed bank revetment or in-channel structures (concrete pieces, etc.), the mechanized cleanup project may need to be implemented in conjunction with a bank or streambed stabilization project to ensure that the removal of the old materials does not initiate any new erosion. Relevant City, County, and/or State permits will be needed if the project would cause significant disturbance or involve the use of heavy equipment in riparian areas. Mechanized trash removal projects enhance the aesthetic function of riparian corridors and can also improve habitat and filtration functions when revegetation is included as a component of the project.

Stream Adoption

The state of Utah has established an “Adopt-a-Waterbody” program through a partnering effort between the Utah Department of Environmental Quality, the Utah Department of Natural Resources, and the Utah Department of Agriculture and Food with support from Utah State University Water Quality Extension (www.adoptawaterbody.utah.gov/). Modeled after the national “Adopt-a-Highway” program, this program provides a way for community volunteer groups or local businesses to make a formal commitment to take care of specific sections or

Internet resources for improvement projects:

Stream cleanup and adoption:

- www.adoptawaterbody.utah.gov/
- www.americanrivers.org/assets/pdfs/national-river-cleanup/nrc-organizer-handbook.pdf

Invasive species control:

- www.recreation.slco.org/planning/natural.html
- www.weeds.slco.org/html/weedInfo/index.html
- extension.usu.edu/weedweb/www.utahweed.org
- www.slch2o.com

Utah State University Extension - firewise plant information:

- www.utahfireinfo.gov/prevention/firewiseplants.pdf

Center for Watershed Protection (low impact development and storm water management):

- www.cwp.org/

areas of a stream, lake, or wetland. Activities could include organizing stream cleanups, monitoring water quality, controlling invasive species, or planting native riparian vegetation. Stream adoption and improvement activities within privately owned land should only take place after coordinating with and receiving permission from all relevant landowners. The Yalecrest Community Council is currently listed as having adopted the section of Red Butte Creek between 900 South and 1500 East.

Removal of Invasive Plant Species

This improvement measure involves controlling and removing invasive plant species and replacing them with native plants. Invasive plant removal projects are important for the enhancement of riparian functions including habitat for wildlife and birds, filtration of sediment and pollutants, and stream stability. Table 4.1 provides a comprehensive list of invasive vegetation species to avoid planting within the Red Butte Creek corridor. In reaches where these species are present, removal of the invasive species and replacement with native plants are recommended.

Techniques for invasive species control and removal include physical, cultural, biological, and chemical measures. Physical controls, also known as mechanical controls, involve pulling or otherwise removing plants or portions of plants. Types of physical controls including hand pulling, disking, or mowing. Cultural controls involve establishing vigorous, desirable plant species that are able to out-compete the invasive weed species. Biological controls involve reducing invasive weed populations through the introduction of insect or pathogen bio-control agents. Chemical controls involve applying herbicides to weed infestations. Because of the sensitive nature of riparian areas, chemical controls should always

Best management practices for herbicide application in streamside areas:

- use herbicides cautiously as one element of an integrated weed control strategy
- spot spray rather than broadcast spray
- avoid spraying during windy conditions
- avoid spraying in the rain or when rain is forecast
- only use chemicals formulated and approved for use near water
- reduce chemical runoff from lawns by leaving a no-mow buffer at the edge of turf areas

Local sources of watershed safe herbicides: [a]

- Steve Regan Company, Salt Lake City, 801-268-4500
- Wilbur Ellis Company, Ogden, 801-399-3775

[a] This list is partial, provided for reference only, and does not constitute an endorsement by Salt Lake City.

Table 4.1. List of weeds and invasive species to avoid planting within the riparian corridor. Where these species are present, they should be controlled using appropriate techniques and replaced with native species.

COMMON NAME	SCIENTIFIC NAME	UTAH STATE-LISTED NOXIOUS WEED [a]	CITY WATERSHED DIVISION-LISTED WEED	OTHER INVASIVE SPECIES TO AVOID	SPECIES NOTED AS CURRENTLY PRESENT IN THE RED BUTTE CREEK RIPARIAN CORRIDOR
Black henbane	*Hyoscyamus niger*	X	X		
Diffuse knapweed	*Centaurea diffusa*	X	X		
Leafy spurge	*Euphorbia esula*	X	X		
Medusahead	*Taeniatherum caput-medusae*	X	X		
Oxeye daisy	*Chrysanthemum leucanthemum*	X			
Perennial sorghum (Johnson grass)	*Sorghum halepense*	X	X		
Purple loosestrife	*Lythrum salicaria*	X	X		
Spotted knapweed	*Centaurea maculosa*	X	X		
Squarrose knapweed	*Centaurea squarrosa*	X	X		
Yellow starthistle	*Centaurea solstitialis*	X	X		
Yellow toadflax	*Linaria vulgaris*	X	X		
Musk thistle/Nodding plumeless thistle	*Carduus nutans*	X	X		
Bermudagrass	*Cynodon dactylon*	X	X		
Broad-leaved peppergrass	*Lepidium latifolium*	X	X		
Dalmation toadflax	*Linaria dalmatica*	X	X		
Dyer's woad	*Isatis tinctoria*	X	X		
Whitetop (Hoary cress)	*Cardaria spp.*	X	X		X
Poison Hemlock	*Conium maculatum*	X			
Russian knapweed	*Centaurea repens*	X	X		
Squarrose knapweed	*Centaurea virgata*	X	X		
Canada thistle	*Cirsium arvense*	X	X		
Gypsyflower (Houndstongue)	*Cynoglossum officinale*	X	X		X
Saltcedar	*Tamarix ramosissima*	X	X		
Quackgrass	*Elymus repens*	X	X		X
Puncture vine	*Tribulus terrestris*	X	X		
Purple starthistle	*Centaurea calcitrapa*		X		
Myrtle spurge	*Euphorbia myrsinites*		X		
Scotch thistle	*Onopordum acanthium*		X		X
Bull thistle	*Cirsium vulgare*		X		
Common burdock	*Arctium minus*		X		X
Garlic mustard	*Alliaria petiolata*		X		
Camelthorn	*Alhagi pseudalhagi*		X		
Goatsrue	*Galega officinalis*		X		
Russian olive	*Elaeagnus angustifolia*		X		X
Siberian elm	*Ulmus pumila*		X		X
Chinese elm	*Ulmus parvifolia*		X		
Tree of heaven	*Ailanthus altissima*		X		X
Jointed goatgrass	*Aegilops cylindrica*		X		
Field bindweed	*Convolvulus spp.*		X		
English ivy	*Hedera helix*			X	X
Periwinkle spp.	*Vinca minor/major*			X	X
Black locust	*Robinia pseudoacacia*			X	
Rampion bellflower	*Campanula rapunculoides*			X	
Norway maple	*Acer platanoides*			X	
Cheatgrass	*Bromus tectorum*			X	X

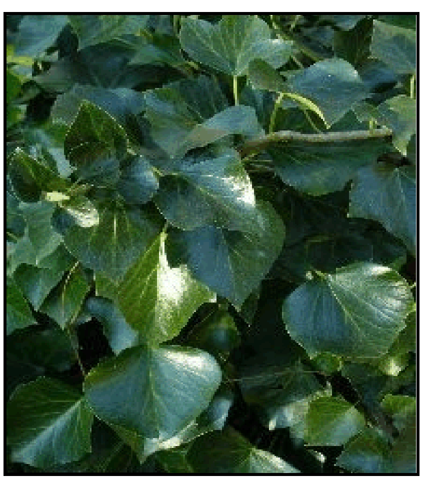
[a] Utah State-listed noxious weeds (http://ag.utah.gov/divisions/plant/noxious/documents/noxUtah.pdf) are subject to regulation by State law under Section 4-17-3, Utah Noxious Weed Act.

be implemented using best management practices (BMPs).

Species-specific control recommendations for many of the species listed in Table 4.1 are described in existing available publications, many of which are available online. Specific control recommendations are included below for several invasive species common to the study area that are not as well documented in available literature. City and County permits may be required for certain types of invasive species removal projects.

English Ivy Control

English ivy is a woody, evergreen climber that has advantageous roots along the stems. The leaves have a dark green, smooth, waxy surface and are found along the length of the stems. This species is a traditional ornamental that establishes a thick mat along the ground and also climbs up adjacent vertical elements, such as trees, fences, and buildings. This species is present as a ground cover within forested riparian areas adjacent to development and has the potential to out-compete native understory, shrub layers, and canopy vegetation components. Because it has a shallow root system and low stem density, English ivy performs poorly in terms of serving the riparian functions of bank stabilization and nutrient filtration.

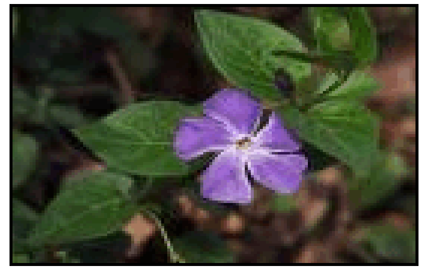


English ivy (*Hedera helix*). From Jeff McMillian, Plants.usda.gov.

Manual control has been sited as one of the best options for effective control of English ivy. Mowing, raking, pulling, and digging accessible plants are viable options. Due to the waxy leaves of English ivy, herbicide treatments have not been very successful. This species is considered tolerant to many herbicides because of the thick, waxy cuticle. If herbicide use is necessary, particular attention should be paid to actively young/growing plants. Make sure that any herbicide used within the riparian corridor is approved for use near water. There are no known biological controls available for this species. Revegetation with native understory plants should always accompany English ivy removal efforts. Revegetation areas should be monitored for successful regrowth of desirable species.

Periwinkle Vine Control

Periwinkle vine (*Vinca major/Vinca minor*) is a perennial, herbaceous species that is low growing and has a trailing or climbing habit. This



Periwinkle vine (*Vinca major/Vinca minor*). From Bermuda-online.org.

Siberian elm (*Ulmus pumila*).

species has been introduced as an ornamental that does well in shaded areas and has naturalized; thus it can be found to dominate areas within urban settings. The foliage is a deep green with a glossy or smooth leaf surface and purple blooms. Because it has a shallow root system and low stem density, periwinkle vine performs poorly in terms of serving the riparian functions of bank stabilization and nutrient filtration.

Periwinkle vine can be removed by digging, raising the runners with a rake, and mowing the plants. All of the plant must be removed. It can also be controlled by cutting the plants in the spring followed by applying a

Local sources of native plants: [a]

- Blue Sky Perennials
801-718-7715
www.blueskyperennials.com
- Cactus and Tropicals
801-485-2542
www.cactusandtropicals.com
- Dryland Horticulture
801-597-6051
DrylandHorticulture@yahoo.com
- Grow Wild LLC
801-467-8660
www.growwild.biz/
- Growing Empire Perennials and Shrubs
801-685-7099
www.growingempire.net
- High Mountain Nursery
435-731-0107
www.highmtnnursery.com
- Millcreek Gardens
801-487-4131
www.millcreekgardens.com
- Sun Mountain Growers
801-941-5535
sunmtngrowers@comcast.net

[a] This list is partial, provided for reference only, and does not constitute an endorsement by Salt Lake City.

glyphosate herbicide to the regrowth. The uptake of applied herbicide may be limited due to the waxy leaves characteristic of periwinkle species. It is recommended that a combination of mechanical and chemical controls be implemented for increased success in control efforts. The herbicide Rodeo® has been approved to use near water. It is suggested that by specifically treating young/new growth, applied herbicide can be more effective. No biological controls have been identified for periwinkle vine. Revegetation with native understory plants should always accompany English ivy removal efforts. Revegetation areas should be monitored for successful regrowth of desirable species.

Siberian Elm Control

Siberian elm (*Ulmus pumila*) is a deciduous tree that has escaped cultivation and become an invasive component within riparian forest ecosystems, around lakes, and other natural areas. This species propagates readily from seeds, establishes in harsh environments, and grows rapidly. It is a brittle tree that often sheds its branches, even during mild winds. This species has been a popular choice as a shade tree.

Girdling the trunks has been cited as a viable option for the control of mature Siberian elm. Girdled trees die over the course of 1–2 years and have been reported not to resprout if the girdling is implemented correctly. This practice should be implemented in late spring to mid summer. When girdling, avoid cutting into the woody part of the tree and only strip a band through the bark. Often, when woody portions of trunks are impacted, resprouting from the roots can occur. Seedlings and small trees can be removed by pulling or using a weed wrench or grubbing hoe.

The use of glyphosate is recommended for use as cut-stem application for large trees and resprouts. Herbicide applications are recommended during fall or winter to prevent spring resprouts. There are no known available biological controls for Siberian elm.

Revegetation with Native Plants

As a general practice, revegetation with native plants is recommended for existing disturbed areas or areas where invasive plants have been removed. Revegetation practices can also be used to re-establish native understory or shrub communities where these vegetative layers are currently lacking. Projects to re-establish healthy, structurally diverse native riparian plant populations can enhance the riparian functions of habitat, nutrient filtration, bank stability, organic matter inputs, shading, and floodplain storage. To be successful, general revegetation efforts should only occur in areas where any underlying causes of disturbance (e.g., streambank erosion or scour, soil compaction from foot traffic) have been addressed. Otherwise, the revegetation efforts should be implemented in conjunction with other types of projects (access control, bank stabilization, etc.), as appropriate.

Steps involved in general revegetation projects include: adding or preparing and loosening topsoil; planting with native vegetation using seed, containerized plants, and/or live plant stakes; and protecting the area with mulch. To maximize wildlife habitat, shading, and filtration, use a mix of understory, shrub, and tree species selected from the recommended riparian corridor planting lists (Tables 4.2, 4.3, 4.4), as appropriate. Bark, straw, or wood fiber mulch is typically adequate to protect relatively gentle slopes of 3:1 or flatter. For slopes between 3:1 to 2:1 in steepness, use the planting techniques described above, but instead of mulch use a biodegradable erosion-control blanket (matting or netting made of jute, wood fiber, straw, or coconut) to protect the revegetated area. Use of additional preparation techniques, such as slope roughening or micro-terracing, can also improve revegetation success on slopes in this steepness range. On slopes steeper than 2:1, revegetation efforts should incorporate biotechnical slope stabilization measures to prevent slope erosion (Figure 4.2).

Containerized plants susceptible to herbivory by deer or other wildlife should be protected using wire mesh or other methods. Fall (September 15–December 1) is the recommended time period for revegetation efforts using seed and containerized plants; projects completed during the spring are often successful as well. Late winter/early spring is the recommended time period for conducting projects using live plant stakes, which should be harvested while dormant and planted prior to the growing season.

Biotechnical Slope Stabilization

This improvement measure involves combining revegetation with more traditional, "hard"

Table 4.2. Recommended native canopy (tree) species for planting efforts within the riparian corridor.

COMMON NAME	SCIENTIFIC NAME	PREFERRED LIGHT CONDITIONS			PREFERRED MOISTURE CONDITIONS			SPECIES SUITABLE FOR PLANTING AS A LIVE CUTTING
		Sun	Shade	Part Sun/ Shade	Relatively Dry Upper-Slope Areas	Seasonally Moist Areas	Spring or Seep Area	
Bigtooth maple	*Acer grandidentatum*	X				X		
Chokecherry	*Prunus virginiana*	X			X	X		
Douglas fir	*Pseudotsuga menziessi*	X			X			
Gray alder	*Alnus incana*	X				X		
Narrowleaf cottonwood	*Populus angustifolia*	X				X		X
Netleaf hackberry	*Celtis laevigata*	X				X		
Peachleaf willow	*Salix amygdaloides*	X				X	X	X
Twoneedle pine	*Pinus edulis*	X			X			
Utah juniper	*Juniperus osteosperma*	X			X	X		
Water birch	*Betula occidentalis*			X		X		

Table 4.3. Recommended native shrub species for planting efforts within the riparian corridor.

COMMON NAME	SCIENTIFIC NAME	PREFERRED LIGHT CONDITIONS			PREFERRED MOISTURE CONDITIONS			SPECIES SUITABLE FOR PLANTING AS A LIVE CUTTING OR STAKE
		Sun	Shade	Part Sun/ Shade	Relatively Dry Upper-Slope Areas	Seasonally Moist Areas	Spring or Seep Area	
Alderleaf mountain mahogany	*Cercocarpus montanus*	X			X			
Antelope bitterbrush	*Purshia tridentata*	X			X			
Big sagebrush	*Artemisia tridentata*	X			X	X		
Creeping barberry	*Mahonia repens*			X	X	X		
Golden currant	*Ribes aureum*			X	X	X		
Mallow ninebark	*Physocarpus malvaceus*			X	X	X		X
Mountain snowberry	*Symphoricarpos oreophilus*			X	X	X		
Narrowleaf willow	*Salix exigua*			X		X	X	X
Oregon boxleaf	*Paxistima myrsinites*		X			X		
Redosier dogwood	*Cornus sericea*			X		X	X	X
Skunkbush sumac	*Rhus trilobata*			X		X		
Snowbrush ceanothus	*Ceanothus velutinus*	X				X		
Twinberry honeysuckle	*Lonicera involucrata*		X			X		X
Utah mountain-lilac	*Ceanothus martinii*	X				X		
Utah serviceberry	*Amalanchier utahensis*	X			X	X		
Western snowberry	*Symphoricarpos occidentalis*		X			X		
Whitestem gooseberry	*Ribes inerme*	X				X		
Woods' rose	*Rosa woodsii*			X	X	X		X
Yellow willow	*Salix lutea*			X		X	X	X
Yellow rabbitbrush	*Chrysothamnus viscidiflorus*	X			X			

Table 4.4. Recommended native understory (ground cover) species for planting efforts within the riparian corridor.

COMMON NAME	SCIENTIFIC NAME	PREFERRED LIGHT CONDITIONS			PREFERRED MOISTURE CONDITIONS		
		Sun	Shade	Part Sun/ Shade	Relatively Dry Upper-Slope Areas	Seasonally Moist Areas	Spring or Seep Area
Arctic rush	*Juncus arcticus*						X
Arrowleaf balsamroot	*Balsamorhiza sagittata*	X			X		
Aspen fleabane	*Erigeron speciosus*	X			X		
Blue wildrye	*Elymus glaucus*			X		X	
Butterfly weed	*Asclepias tuberosa*			X	X		
Desert needlegrass	*Achnatherum speciosum*	X				X	
Feathery false lily of the valley	*Maianthemum racemosum*		X			X	
Fendler's meadow-rue	*Thalictrum fendleri*					X	
Firecracker penstemon	*Penstemon eatonii*	X			X	X	
Hairy false goldenaster	*Heterotheca villosa*	X				X	
Indian ricegrass	*Achnatherum hymenoides*	X				X	
Indianhemp	*Apocynum cannabinum*			X		X	
Littleseed ricegrass	*Poptatherum micranthum*	X				X	
Longleaf phlox	*Phlox longifolia*			X	X		
Mountain phlox	*Phlox austomontana*	X			X		
Muttongrass	*Poa fendleriana*			X	X		
Prairie flax	*Linum lewisii*	X				X	
Purple threeawn	*Aristida purpurea*	X				X	
Rocky Mountain penstemon	*Penstemon strictus*	X			X	X	
Showy lupine	*Lupinus polyphyllus*	X			X	X	
Slender cinquefoil	*Potentilla gracilis*	X			X		
Starry false lily of the valley	*Maianthemum stellatum*		X			X	
Sticky purple geranium	*Geranium viscosissimum*			X		X	
Torrey's rush	*Juncus torreyi*						X
Towering Jacob's ladder	*Polemonium foliosissimum*			X		X	
Wasatch beardtongue	*Penstemon cyananthus*	X			X	X	
Western sweetroot	*Osmorhiza occidentalis*			X		X	
Western columbine	*Aconitum columbianum*						X
Western white clematis	*Clematis ligusticifolia*			X		X	
White sagebrush	*Artemisia ludoviciana*	X			X		
Wild bergamot	*Monarda fistulosa*			X		X	

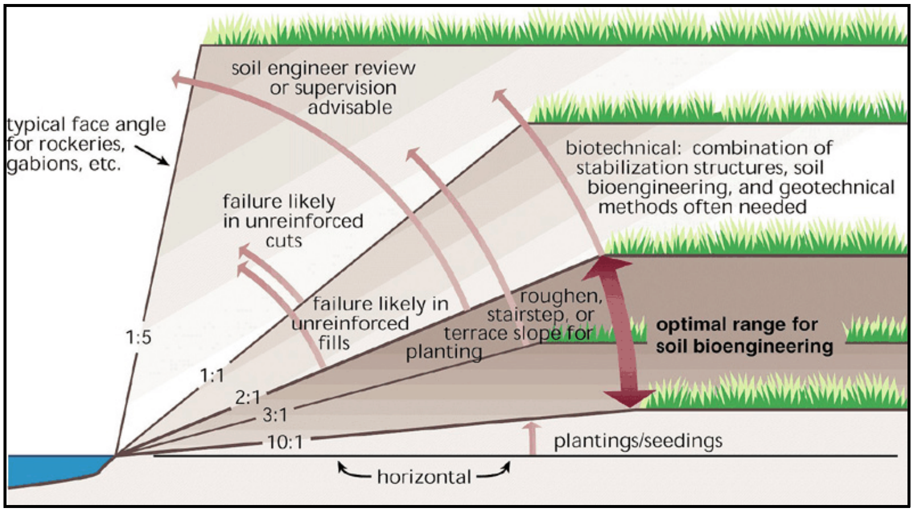


Figure 4.2. Importance of slope steepness in selecting appropriate revegetation and stabilization measures. (Illustration from FISRWG 1998).

Native seed sources: [a]

- Ames Utah Native Seed, Eureka
  435-433-6924
  xeriseeds@yahoo.com
- Granite Seed Co., Lehi
  801-768-4422
  www.graniteseed.com
- Maughan Seed Co., Manti
  801-835-0401

Other Planting Resources:

- Utah Native Plant Society
  www.unps.org
- Intermountain Native Plant Growers Association
  www.utahschoice.org
- Tree Utah
  www.treeutah.org

[a] This list is partial, provided for reference only, and does not constitute an endorsement by Salt Lake City.

geotechnical slope-stabilization techniques. Biotechnical slope-stabilization methods incorporate structural elements that make it possible to achieve stability on steep slopes where plants alone would not provide adequate strength. Because they incorporate vegetation, these techniques enhance the riparian functions of habitat, filtration, aesthetics, organic matter inputs, shading, and floodplain storage as well as bank stability. Stabilization methods that lack vegetation (e.g., concrete walls, rip-rap) are not recommended for the study area because they decrease the ability of the corridor to serve these riparian functions. In general, the use of concrete and other impervious treatments should be avoided because of widespread erosion problems observed at soil-concrete interfaces during RCS field assessments. Concrete structures are also generally less aesthetically pleasing than vegetative techniques and are prone to being defaced with graffiti.

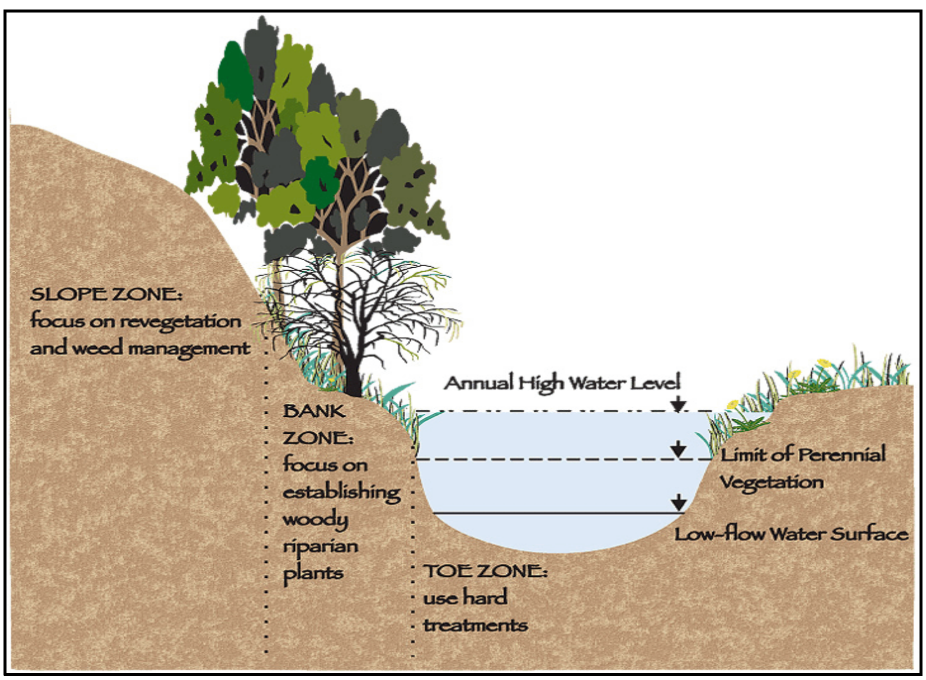


Figure 4.3. Schematic illustration of toe, bank, and upper slope zones and recommended treatment approaches.

Biotechnical slope stabilization is recommended as a general type of project when implemented in areas above the AHWL where any underlying causes of disturbance have been addressed. Appropriate areas for general application of biotechnical measures include the slope zone and upper portion of the bank zone as identified in Figure 4.3 . If stability problems at a specific location are associated with stream erosion or undercutting of the bank toe, biotechnical slope-stabilization projects should be implemented at the reach scale and should incorporate toe protection and grade control, as appropriate. Relevant State, County, and City permits are required for most biotechnical slope-stabilization projects occurring within the riparian corridor.

Specific types of biotechnical slope-stabilization techniques recommended for use within the Red Butte Creek riparian corridor include:

- vegetated soil lifts
- vegetated rock revetment using live stakes, pole plantings, and/or brush layering
- vegetated modular block retaining walls
- vegetated crib retaining walls
- vegetated gabion basket retaining walls

Figure 4.4. Photographs of revegetation and biotechnical slope-stabilization techniques. (Top left: erosion-control blanket and live stakes [image from FISRWG 1998]. Top right: live pole plantings [image from FISRWG 1998]. Bottom left: containerized cottonwood (*Populus* sp.) planting protected from herbivory with wire mesh cage. Middle right: installation of live plant posts to create vegetated rock revetment [image from NRCS 2007]. Bottom right: vegetated soil lifts with live plant stakes and rock toe protection.)

Photographs illustrating some of these techniques are provided in Figure 4.4, and selected detail drawings are provided in Appendix B, drawings 1–5. This list is not intended to be exhaustive. Biotechnical planting techniques are adaptable and can readily be combined in creative ways to meet site-specific needs. Other techniques such as willow bundles, brush mattresses, live fascines, vegetated rock walls, and coir fiber rolls are also recommended for use within the study area. Comprehensive discussion of individual techniques is beyond the scope of this document, but more detailed information is readily available in existing publications such as those listed to the right.

Local-Scale Projects

Storm Drain Outlet Protection

The use of vegetated rock is recommended as outlet protection for new storm drain outfalls installed within the riparian corridor and as a retrofit measure to correct erosion problems at existing outfalls. A vegetated, rock-lined swale should be installed to convey runoff from the protected outlet to Red Butte Creek. Use of these techniques avoids the erosion and scour problems commonly associated with concrete outlet protection structures and provides enhancement of the riparian functions of wildlife habitat, streambank stability, and filtration of pollutants, sediment, and nutrients.

Photographs illustrating these techniques are provided in Figure 4.5, and detail drawings are provided in Appendix B, drawings 6 and 7. Installation of storm drain outlet-protection measures requires relevant State, County, and City permits. In some locations where existing drain outfall systems appear to be inadequate for runoff volume, outlet protection measures should be accompanied by measures to improve storm water management (e.g., installation of retention basins, flow spreaders, French drains, or additional drain pipes).

Stream Crossings and Culvert Replacement

This recommended improvement measure involves installing bridges and open-bottom box culverts where roads and trails cross Red Butte Creek. The bridge and box culvert structures should have relatively wide spans equal to or greater than the wetted width of the stream channel during high-flow conditions. The use of these wide-span crossing structures with natural-substrate bottoms allows for continued transport of sediment and debris, and eliminates the deposition and scour problems associated with flow constriction at narrow-diameter culvert crossings. Hence new crossings should be designed as bridges or open-bottom box culverts and existing culvert crossings replaced with these wider-span structures, as feasible. Implementation of this measure will improve the riparian functions of stream stability, connectivity for fish and wildlife, aesthetics, and floodplain storage, and will reduce the maintenance needed to prevent culverts from clogging.

Publications that provide detailed descriptions of slope stabilization and stream repair techniques (complete references are provided in the References section of this document):

- CFWP. 2004. Urban subwatershed restoration manual 4: urban stream repair practices. Available at: www.cwp.org/Store/usrm.htm#4/.
- Gray and Sotir. 1996. Biotechnical and soil bioengineering slope stabilization: a practical guide for erosion control.
- FISRWG 1998. Stream corridor restoration: principles, processes, and practices. Available at: www.nrcs.usda.gov/technical/stream_restoration/.
- NRCS. 2007. National engineering handbook part 654: stream restoration design. Available at: policy.nrcs.usda.gov/viewerFS.aspx?hid=21433.
- NCHRP. 2005. NCHRP report 544: environmentally sensitive channel- and bank-protection measures.

Photographs of these techniques are provided in Figure 4.5. Stream-crossing projects will typically require site-specific professional engineering design as well as relevant State, County, and City permits.

Figure 4.5. **Photographs of outlet protection and stream crossing techniques. (Top left: rock outlet protection. Top right: stream crossing using a bridge made from a recycled railroad flatcar. Middle left: vegetated rock-lined swale immediately following construction. Middle right: stream crossing using an open-bottom box culvert. Bottom left: vegetated rock-lined swale in second growing season. Bottom right: tailwater pool at culvert outlet.)**

Culvert Outlet Protection

Where replacement of existing stream-crossing culvert pipes is not feasible in the near future, outlet protection improvements (FHWA 2006) are recommended as a short-term measure until funding becomes available for replacement. Installation of a rock-lined tailwater pool, in combination with vegetated rock bank protection and/or rock step-pool features, is recommended for protection of existing culvert outlets. The use of these techniques will improve the riparian functions of stream stability and aesthetics. However, these efforts will not improve riparian connectivity and will not resolve problems with sedimentation or deposition at culvert inlets.

The purpose of these recommended outlet protection measures is to reduce culvert outlet velocities, dissipate energy, create a stable streambed elevation that will not be susceptible to scour, and create stable streambanks adjacent to the culvert outlet. Culverts with especially high outlet velocities may require the installation of a series of step-pool features below the initial rock-lined tailwater pool to ensure a stable transition to the natural channel and to limit the likelihood of bed and bank scour. Detail drawings are provided in Appendix B, drawings 8–10. As with culvert replacement, culvert outlet-protection projects require site-specific professional engineering design as well as relevant State, County, and City permits.

Stream Daylighting

Where feasible, daylighting selected portions of Red Butte Creek that are currently piped is recommended as a riparian corridor improvement measure. Returning piped stream sections to the landscape as natural channel features is potentially one of the most valuable types of improvement projects. Daylighting projects can improve habitat connectivity, aesthetics, filtration, floodplain storage, recreational opportunities, and overall habitat quality and area. Because these projects convert straight, narrow pipes to more sinuous, wider open-air channels, downstream erosive velocities are also reduced, leading to additional stability benefits. Stream daylighting projects involve the use of heavy equipment and require site-specific professional design as well as relevant State, County, and City permits.

No-trespassing Signage

During RCS subcommittee meetings and public workshops, stakeholders emphasized concerns regarding trespassing onto private property from publicly owned portions of the riparian corridor. To address this issue, the creation of standardized no-trespassing signs is recommended. The signs could either be installed at public-private land interfaces throughout the corridor, or they could be made available to property owners by request.

Figure 4.6. Photographs of grade-control, bank-stabilization, and access-control techniques. (Top left: construction of a vortex rock weir. Top right: A-jacks toe protection [image from Schueler and Brown 2004]. Bottom left: downstream view of two vortex rock weir structures. Bottom right: steps that provide stabilized stream access.)

Reach-Scale Projects

Grade Control

Comprehensive installation of grade-control structures is recommended for stream reaches where streambed lowering was observed to be a problem. By stabilizing the streambed profile, grade-control projects can reduce bank erosion problems associated with undermining of the bank toe. In addition to improving bank stability, grade-control projects can also enhance aquatic habitat by creating pool features. Because grade-control structures influence channel shape and flow hydraulics, they have the potential to destabilize upstream and downstream areas if they are not implemented correctly and comprehensively. Therefore, it is important to install grade-control devices as a series throughout an entire stream reach.

The use of vortex rock weirs is recommended as the primary grade-control technique for the Red Butte Creek riparian corridor. These structures use two offset layers of immobile boulders arranged in a "V" shape to create a stable hard point in the streambed profile that will resist future scour. Photographs of vortex rock weirs are provided in Figure 4.6, and a detail drawing is provided in Appendix B, drawing 11.

Because the horizontal spacing between the upper layer of rocks is fairly wide, sediment being transported downstream is able to pass through the weir without becoming trapped. Vortex rock weirs are also relatively low-profile structures that do not alter flow hydraulics to the same extent as other types of grade structures that function more like small dams. Because large-size boulder materials are required, installation of vortex rock weirs will generally involve the use of heavy equipment. In stream reaches where heavy equipment access is not possible, other grade-control techniques, such as rock riffles, may need to be used. Rock-riffle installation involves the engineered placement of cobble-sized rock into a channel-spanning "ramp" feature to increase streambed resistance to scour. Additional details regarding this technique can be found in Technical Supplement 14G of NRCS (2007). Vortex rock weirs are recommended instead of rock riffles wherever possible because they have greater anticipated longevity and overall effectiveness.

Grade-control projects require site-specific professional design to determine required rock sizes, structure spacing, and weir dimensions. Relevant State, County, and City permits are needed for grade-control projects. Such projects also require that precautions, such as flow diversion or temporary dewatering, be taken to limit disturbance during construction and reduce potential impacts to water quality and fish.

Bank Stabilization

In reaches where excessive bank erosion poses a risk to adjacent infrastructure, comprehensive bank stabilization is recommended as a reach-scale improvement project. Reach-scale bank stabilization efforts involve the installation of treatment measures within the AHWL and affect the bank and toe zones (Figure 4.3). These types of efforts affect the shape and flow hydraulics of the active stream channel and have the potential to destabilize upstream and downstream areas if not implemented correctly and comprehensively. Therefore, to maximize long-term effectiveness and minimize future maintenance costs, bank-stabilization projects should be implemented at the reach scale.

As a general principle, bank treatments that protrude into the active channel or floodplain should be avoided whenever possible. To improve bank stability, channel width should be maintained or expanded wherever possible to allow flood flows to spread out, reduce downstream velocities, and dissipate erosive energy. In situations where infrastructure constraints on a given

Material suppliers for improvement projects: [a]

- www.contech-cpi.com (bridge, drainage, stabilization, storm water)
- www.thebmpstore.com (erosion control, inlet protection, slope stabilization)
- www.maccaferri-northamerica.com (erosion control, retaining walls, bioengineering)
- www.rolanka.com (erosion control, sediment control, soil bioengineering)
- www.geovireo.com (erosion control, sediment control, soil bioengineering)
- www.horizononline.com (erosion control and landscaping)
- www.herculesmfg.com (modular retaining walls)
- www.skipgibbs.com (recycled railroad car bridges)
- www.americanexcelsior.com (erosion control solutions)

[a] This list is partial, provided for reference only, and does not constitute an endorsement by Salt Lake City.

streambank require that treatment measures protrude beyond the existing bank location, concurrent measures should be taken to re-establish accessible floodplain area on the opposite bank to maintain flood conveyance capacity and avoid increasing downstream flow velocities.

Bank stabilization projects require site-specific professional design to determine scour depth, required rock sizes, structure spacing, and dimensions. Relevant State, County, and City permits are needed for bank-stabilization projects. These projects also require that precautions, such as flow diversion or temporary dewatering, be taken to limit disturbance during construction and reduce potential impacts to water quality and fish. Some specific bank-stabilization techniques are discussed below (detail drawings are provided in Appendix B, drawings 12–14).

Toe Protection

Because of the erosive flow velocities associated with the urbanized condition of the Red Butte Creek corridor, bank-stabilization projects should incorporate the use of hard treatments within the toe zone (Figure 4.3) where the resistive strength of vegetation alone is typically not adequate. Above the toe zone, the treatment emphasis should focus on the establishment of vegetation using the revegetation and biotechnical stabilization techniques described above in the General Projects section.

Toe protection using large, immobile rock installed to the maximum depth of scour is recommended for areas where heavy equipment access is possible (see toe protection component of drawings 1–4 in Appendix B). In areas where access is more limited, the use of A-jacks® toe protection is recommended as an alternative to large rock. A-jacks® are concrete, three-dimensional, cross-shaped devices that can be assembled onsite to create a stable "cage" to hold cobble-sized rock that would otherwise be mobile (see Figure 4.6 and Appendix B, drawing 12). As with rock toe protection, A-jacks® toe protection should be trenched in below the channel bed to the depth of maximum scour. Toe protection can be combined with any of the biotechnical slope stabilization techniques described previously to design a reach-appropriate comprehensive bank stabilization project.

Redirective Techniques

Redirective techniques involve installing measures to redirect flow away from an eroding bank, typically at the outside of a bend. Because of the risk that the redirected flows could cause erosion on the opposite bank or adjacent channel areas, these techniques should always be designed by qualified professionals and special caution must be used to ensure that all susceptible bank areas are adequately protected. Specific types of redirective techniques include wing deflectors, log or rock vanes, root wads, and spur dikes (Schueler and Brown 2004, McCullah and Gray 2005, NRCS 2007). Rock vanes with J-hooks are a recommended technique for appropriate locations in the Red Butte Creek corridor (Appendix B, drawing 14). The specific recommended design involves keying-in the hook structure to the bank opposite the vane structure to reduce the risk of erosion.

Access Control and Trail Stabilization

Implementation of measures to control foot traffic and stabilize access trails is recommended in stream reaches that receive heavy recreational use. Such measures can reduce soil compaction, enhance vegetation quality, and improve stream stability. Access needs should be assessed and planned at the reach scale so that control measures do not simply shift erosion and soil compaction problems elsewhere. Specific recommended measures include the installation of split rail fencing to focus and direct foot traffic and installation of pervious steps to provide stream access (Figure 4.6 and Appendix B, drawing 15).

Watershed-Scale Projects

Manage and Reduce Impervious Surfaces

This improvement measure involves taking steps to limit the adverse hydrologic effects of increased impervious-surface associated with new construction. Retrofit measures could also be implemented to reduce existing impervious surface acreage and increase stormwater infiltration. The use of low-impact development techniques and long-term storm water BMPs should be encouraged within the study area. Managing and reducing impervious surfaces would help return the creek's hydrology to a more natural pattern. This in turn would reduce erosive storm-flow velocities, improve water quality and channel stability, and increase summertime base flows.

Specific techniques could include runoff disconnection and infiltration practices, green roofs, installation of bio-swales instead of curb and gutter/raised median systems, and use of alternative paving techniques. An in-depth discussion of specific techniques is beyond the scope of this document, but detailed information is readily available in existing publications (Schueler and Brown 2004, SLCO 2009) and at web sites identified in the sidebars in this document section. Coordination with the existing Stormwater Coalition group, a City-County partnership, is also recommended.

Within the Red Butte Creek watershed, future development activities are most likely to affect the areas managed by the University of Utah and VA Medical Center. Meetings should be held regularly with these entities to ensure good communication regarding planned construction projects and ways to reduce the hydrologic impacts of new construction.

Explore Instream Flow Opportunities

This recommended improvement measure involves exploring opportunities to secure and manage water rights for instream flows. As discussed previously, maintenance of summertime base flows is a high-priority issue for stream-side residents. Meetings should be held with the Utah Division of Water Rights (DWRT) to clarify which types of

Internet resources for storm water management:

- www.cwp.org
- www.epa.gov/owow/nps/lid/
- www.stormwatercoalition.org
- www.seattle.gov/UTIL/About_SPU/Drainage_&_Sewer_System/NaturalDrainage_Systems/Natural Drainage_Overview/index.asp

organizations are eligible to lease water rights for instream flows under recently passed legislation.

In addition to exploring possibilities associated with water rights, measures to increase infiltration and groundwater recharge within the watershed should also be explored. Increased instream flows would enhance riparian corridor aesthetics, water quality, and aquatic habitat conditions.

Increase Public Awareness

Improving conditions within the Red Butte Creek riparian corridor will be a long-term effort that will require continued awareness, interest, and support from stakeholders and the community at-large. To achieve this type of support, public awareness of the Red Butte Creek riparian corridor and its ecological functions will need to increase. Therefore, a public awareness campaign should be implemented. Elements of this campaign could include installation of signs identifying neighborhoods and parks as being within the Red Butte Creek watershed. Signs saying "crossing Red Butte Creek" could also be installed where roads and trails cross the stream.

Currently, the creek is rarely identified on existing maps or signs, and most City residents are not well informed of its location. Many opportunities to increase awareness through signs and interpretive displays exist in locations such as the University of Utah, VA Medical Center, Sunnyside Park, Miller Park, and Bonneville Glen. The interpretive signs currently located within the Red Butte Garden portion of the creek could be used as a model for displays in other stream reaches. Other public awareness efforts could include sponsoring stream cleanups, storm drain stenciling projects, weed pulls, field trips, and educational workshops. Such efforts could be coordinated with existing outreach campaigns such as Salt Lake City's "Water Week" event and the annual Salt Lake Countywide Watershed Symposium.

Permitting Requirements

Depending on the nature of a specific improvement project, permits may be required prior to initiating work in or near the stream channel. Information on the jurisdictions and the requirements of relevant permitting authorities is provided below. Permit requirements are summarized by project type in Table 4.5. Where jurisdictions overlap, separate permits from all relevant agencies are required.

State Stream Alteration

The State of Utah's DWRT administers a stream alteration program through the office of the State Engineer. Under Section 73-3-29 of the Utah Code, authorization is required prior to initiating alterations to the bed or banks of a natural stream channel. The intent of the program is to limit adverse impacts to the natural stream environment and associated natural resources. State jurisdiction generally includes those areas within a distance of two times the bankfull width of the channel, up to a maximum of 30 feet beyond bankfull on either side of the channel. In most cases for streams within the City, the bankfull channel width is roughly equivalent to the AHWL channel width used to establish setback distances under the City's RCO ordinance. Therefore, State stream alteration jurisdiction typically includes the channel itself, RCO Area A, and up to a 5-foot extent of RCO Area B (Figure 1.3). If a project will impact jurisdictional wetlands, a Federal permit from the U.S. Army Corps of Engineers (ACOE) may be required under Section 404 of the Clean Water Act in addition to the State Stream Alteration permit. Where this is the case, the DWRT would typically forward an application to the ACOE and the two agencies would issue separate permits.

County Flood Control

The County's Public Works Department, Engineering and Flood Control Division administers a flood-control permit program under Title 17 of the County code. The focus of the County program is to ensure that activities do not increase

Table 4.5. Summary of permit requirements for recommended types of improvement projects.

	IMPROVEMENT PROJECT	PERMITS REQUIRED [a]				
		State Stream Alteration	County Flood Control	City Riparian Protection - Developed Lots		
				Area A (25 feet) [b]	Area B (50 feet)	Area C (100 feet)
GENERAL PROJECTS	Stream Cleanup (manual)	N	M	N	N	N
	Mechanized Trash Removal	Y1	Y2	Y	Y	Y
	Removal of Invasive Plants	N	Y2	M1	M1	M1
	Revegetation (seed or plantings, no grading)	N	N	N	N	N
	Biotechnical Slope Stabilization	Y1	Y2	Y	Y3	N
	Slope flattening or terracing	Y1	Y2	Y	Y3	N
	Vegetated soil lifts	Y1	Y2	Y	Y3	N
	Vegetated rock revetment	Y1	Y2	Y	Y3	N
	Vegetated modular block retaining wall	Y1	Y2	Y	Y3	N
	Vegetated crib retaining wall	Y1	Y2	Y	Y3	N
	Vegetated gabion basket retaining wall	Y1	Y2	Y	Y3	N
LOCAL PROJECTS	Storm Drain Outlet Protection	Y1	Y2	Y	Y	Y
	Outlet protection using vegetated rock	Y1	Y2	Y	Y	Y
	Vegetated rock-lined swale	Y1	Y2	Y	Y	Y
	Stream Crossings and Culvert Replacement	Y	Y	Y	Y	Y
	Full-span bridge	Y	Y	Y	Y	Y
	Open-bottom box culvert	Y	Y	Y	Y	Y
	Culvert Outlet Protection	Y	Y	Y	Y	Y
	Rock-lined tailwater pool	Y	Y	Y	Y	Y
	Rock step pool	Y	Y	Y	Y	Y
	Stream Daylighting	Y	Y	Y	Y	Y
REACH-SCALE PROJECTS	Grade Control	Y	Y	Y	Y	Y
	Vortex rock weirs	Y	Y	Y	Y	Y
	Constructed rock riffles	Y	Y	Y	Y	Y
	Bank Stabilization	Y	Y	Y	Y	Y
	Toe protection	Y	Y	Y	Y	Y
	Redirective techniques	Y	Y	Y	Y	Y
	Floodplain re-establishment	Y	Y	Y	Y	Y
	Access Control and Trail Stabilization	N	Y2	N	N	N
	Split rail fence	N	Y2	N	N	N
	Access steps	N	Y2	Y	N	N

[a] N = not required, M = may be required, Y = required, Y1 = required if work occurs within two times the bankfull width of the channel, Y2 = required if work occurs within 20 feet of accessible top of channel bank, Y3 = required if work involves heavy equipment, M1 = removal of live, invasive trees greater than 2 inches caliper requires (1) approval by the Salt Lake City Department of Public Utilities and (2) replacement with approved tree species.
[b] On undeveloped land Area A extends to 100 feet.

Internet resources for more detailed permitting information:

- State Stream Alteration: www.waterrights.utah.gov/strmalt/default.asp
- County Flood Control: www.pweng.slco.org/flood/html/permits/permits.html
- City Riparian Protection: www.slcgov.com/Utilities/Stream Study Website/ud_rcs_Ordinance.htm

Common items required in a permit application submittal:

- project location and responsible party information
- narrative project description
- site plan
- design drawings (cross section, plan, profile views)
- hydrologic and hydraulic calculations
- soils and slope steepness data
- channel size and slope data
- scour and rock sizing calculations
- information on proposed BMPs to protect water quality

flooding risk or restrict the County's access to channels for flood-control purposes. The creeks within the City are considered county-wide flood-control facilities and are subject to the County requirements under Title 17. Jurisdiction includes those areas within a distance of 20 feet of the top of the accessible channel bank. The accessible channel bank is defined as the point beyond which slopes become too steep for access by vehicles or equipment. Where a stream channel is bordered by relatively flat surfaces, the accessible channel bank location may be similar to the AHWL, but where the channel is entrenched between steep slopes County jurisdiction may extend well beyond RCO Area A and into Areas B and/or C. Because of this variability, the extent of County jurisdiction should be determined on a site-specific basis.

City Riparian Protection

Salt Lake City's RCO ordinance (Ordinance 62) establishes restrictions and provisions for activities occurring within setback areas extending 25 feet (Area A), 50 feet (Area B), and 100 feet (Area C) from the AHWL (Figure 1.3) of above-ground streams. The intent of the RCO ordinance is to protect and preserve the City's streambed corridors and associated natural resources. The City requires that a Riparian Protection Permit (RPP) be obtained for certain activities occurring within the relevant setback area. The RPP program is administered through the Department of Public Utilities.

Relative Costs of Improvement Projects

Estimated unit cost information for different types of improvement projects is summarized in Table 4.6. These costs are approximate and were obtained from various sources including price estimates from manufacturers, reference documents (Schueler and Brown 2004, SLCO 2009), previous improvement projects designed by BIO-WEST, Utah Department of Transportation bid summaries from 2008 and 2009 (UDOT 2008 and 2009), and DPU engineering staff.

Total costs for implementation of specific projects will be variable depending on project scale and the specific treatment practices involved. Many projects will include a combination of techniques based on the needs of a given site or reach. The unit costs listed in Table 4.6 can be used as a basis from which to develop more complete cost estimates for specific efforts as funding sources, lead entities, and detailed work scopes are defined. It is important to bear in mind that many projects will also involve costs associated with preconstruction planning tasks such as detailed topographic surveys, permits, applications,

Table 4.6. Approximate unit cost information for improvement projects.

	TYPE OF PROJECT	UNIT	UNIT COST [a]	SOURCE OF COST INFORMATION
GENERAL PROJECTS	Removal/control of invasive plants	acre	$600–900	BIO-WEST (2009)
	Revegetation using custom seed mix	acre	$2,000–4,000	BIO-WEST (2009)
	Erosion control blanket	square yard	$2–5	UDOT 2008 and 2009
	Revegetation - live plant stakes	per stake	$2–5	supplier estimate, BIO-WEST (2009)
	Revegetation - 1-gallon containerized plants	per plant	$9–17	UDOT 2009, BIO-WEST (2009)
	Revegetation - 5-gallon containerized plants	per plant	$15–80	UDOT 2009, BIO-WEST (2009)
	Revegetation - 2-inch caliper trees	per plant	$175–325	UDOT 2009, BIO-WEST (2009)
	Slope flattening or terracing	square yard	$3–10	UDOT 2008 and 2009 [b]
	Vegetated soil lifts	linear foot	$30–60	DPU (2009)
	Vegetated rock revetment	linear foot	$50–80	DPU (2009)
	Vegetated modular block retaining wall	linear foot	$120–160	supplier estimate, DPU (2009)
	Vegetated crib retaining wall	linear foot	$250–300	Schueler and Brown 2004
	Vegetated gabion basket retaining wall	linear foot	$70–110	DPU (2009)
LOCAL PROJECTS	Outlet protection using vegetated rock	square yard	$70–120	DPU (2009)
	Vegetated rock-lined swale	linear foot	$60–85	DPU (2009)
	Railroad flatcar bridge (89 feet long x 8.5 feet wide)	each	$50,000–90,000	supplier estimate, BIO-WEST (2009)
	Pre-fabricated truss pedestrian bridge (30 feet long x 6 feet wide)	each	$30,000–100,000	supplier estimate, BIO-WEST (2009)
	Open-bottom box culvert (10–12 feet wide x 4–6 feet high)	linear foot	$2,500–6,500	DPU (2009)
	Rock-lined tailwater pool	cubic yard	$70–120	DPU (2009)
	Rock step pool	each	$2,000–6,000	Schueler and Brown 2004
	Stream daylighting	linear foot	$100–300	Schueler and Brown 2004
REACH PROJECTS	Vortex rock weirs	each	$1200–2100	Schueler and Brown 2004
	Constructed rock riffles	cubic yard	$70–110	DPU (2009)
	A-jacks toe protection	linear foot	$65–85	Schueler and Brown 2004
	Rock toe protection	cubic yard	$70–110	DPU (2009)
	Rock vanes with J-hooks	cubic yard	$150–250	SLCO 2009
	Floodplain re-establishment	cubic yard	$5–20	UDOT 2008 and 2009 [c]
	Split rail fence (minimum 1,500 feet, 10 feet on center)	linear foot	$8–15	supplier estimate, BIO-WEST (2009)
	Access steps	linear foot	$25–75	BIO-WEST (2009)

[a] Unit costs will typically be on the low end of the indicated range for large-scale projects that involve large quantities and on the high end of the range for small-scale projects.
[b] Cost reported for clearing/grubbing and landscape grading.
[c] Cost reported for excavation.

and site-specific design. In addition, most projects will also require expenditures for postconstruction maintenance and monitoring.

Although it is not possible to quantitatively distinguish total costs for the different improvement techniques in a general sense, relative costs can be evaluated qualitatively (Table 4.7). At one end of the spectrum, costs for stream-cleanup and -adoption efforts, which are typically done by volunteers with donated supplies, will be very low. Public awareness, invasive plant removal, revegetation, and mechanized trash-removal efforts can also often incorporate the use of volunteer labor and donations. These types of efforts will typically fall in the low-to-moderate range in terms of relative cost depending on the scale and complexity of the specific effort. Projects involving access control, trail stabilization, and storm drain outlet protection will typically fall in the moderate range. These techniques require preconstruction planning and site-specific design but materials costs will typically be in the moderate range.

Costs for relatively small-scale biotechnical slope-stabilization efforts that are implemented only in areas above the AHWL will also typically be in the moderate range. Biotechnical stabilization projects that involve work within the AHWL will also require toe protection, and possibly grade control, as well as more involved permitting and design work: These will be high-cost efforts. For the same reasons, comprehensive bank-stabilization, grade-control, culvert outlet-protection, and stream-daylighting projects will generally be high in cost. Costs to replace culvert crossings with bridges or box culverts will generally be high to very high, depending on the size of the culvert to be replaced, the size of the specific road or trail crossing, and traffic volume of the affected road or trail.

Different types of improvement practices also vary in terms of the range of potential riparian function benefits they provide (Table 4.7). For example, efforts to increase public awareness and encourage stream adoption will help generate long-term support, commitment, and interest in the Red Butte Creek riparian corridor. This support and commitment, in turn, have the potential to lead to implementation of a variety of improvement measures that could potentially benefit all the identified riparian functions. Other types of projects target a more specific subset of riparian functions. The information provided in Table 4.7 can be used to help guide decisions about the types of projects to pursue based on stakeholders' priorities for different sites and stream reaches within the study area.

Maintenance and Monitoring Considerations

Costs associated with long-term maintenance and monitoring are important to consider when planning, designing, and implementing riparian corridor improvement projects. Maintenance and monitoring considerations for different types of projects are summarized in Table 4.8.

For many of the recommended improvement measures, maintenance costs can be reduced by up-front investments to ensure that projects are initially designed well, implemented at the appropriate scale, and installed correctly. As discussed, many observed problems within the riparian corridor are associated with stabilization efforts that were installed without proper attention to toe protection, grade control, reach-scale hydraulics, natural channel dimension, or bed scour. Lack of attention to these items often results in projects that fail after only a few years—or, worse, projects that cause new stability problems in other nearby channel locations.

For some types of projects such as invasive plant control, access control, or stream-cleanup projects, long-term monitoring and maintenance requirements are inherently relatively high. Because litter, foot/dog traffic,

Table 4.7 Summary of relative project costs and potential riparian function benefits.

IMPROVEMENT PROJECT	APPROXIMATE RELATIVE COST	POTENTIAL RIPARIAN FUNCTION BENEFITS									
		Habitat	Shading and Water - Temperature Control	Aesthetics	Recreation	Floodplain Storage	Connectivity	Organic Matter Inputs	Filtration of Sediments and Pollutants	Streambank Stability	Stormwater Conveyance
Stream Cleanup (manual)	very low	x		x							
Mechanized Trash Removal	low to moderate	x		x					x	x	
Stream Adoption	low	x	x	x	x	x	x	x	x	x	x
Removal of Invasive Plants	low to moderate	x							x	x	
Revegetation with Native Plants	low to moderate	x	x	x		x		x	x	x	
Biotechnical Slope Stabilization	moderate to high	x	x	x		x		x	x	x	
Storm Drain Outlet Protection	moderate	x		x					x	x	x
Culvert Replacement with Bridge or Open-Bottom Box Culvert	high to very high	x		x		x	x			x	x
Culvert Outlet Protection	high			x						x	
Stream Daylighting	high	x		x	x	x	x	x	x		
Grade Control	high	x	x	x		x		x	x	x	
Comprehensive Bank Stabilization	high	x	x	x		x		x	x	x	
Access Control and Trail Stabilization	moderate	x		x	x				x	x	
Manage & Reduce Impervious Surfaces	variable	x		x		x			x	x	x
Explore Instream Flow Opportunities	variable	x		x			x				
Increase Public Awareness	low to moderate	x	x	x	x	x	x	x	x	x	x

Table 4.8. Summary of maintenance and monitoring considerations for various improvement projects.

IMPROVEMENT PROJECT	MONITORING MEASURES	MAINTENANCE MEASURES	NOTES
Stream Cleanup (manual)	Report any observed illegal dumping to authorities	Hold a cleanup event once a year	Areas that receive heavy use may require more frequent cleanups
Mechanized Trash Removal	Inspect once a year; note/photograph/report locations of any new over-sized items; report dumping to authorities	Schedule removals as needed based on monitoring observations	Monitoring could be completed in conjunction with annual stream cleanup event
Removal/ Control of Invasive Plants	Inspect treated areas for control effectiveness 1 month after each treatment; monitor/map invasive plants once every 3 years in conjunction with general riparian vegetation monitoring	Three treatments during year 1; one to three treatments per year during years 2–5; one treatment every 2 years during years 6 and beyond	Invasive plant control cost is approximately $250/acre/treatment
Revegetation with Native Plants	Inspect revegetated areas monthly during first 6 months; inspect twice per growing season during years 2 and 3	If needed, irrigate during initial establishment period; after first growing season replace any dead plants and spot-apply new seed as needed	Based on typical plant mortatily rates, budget for replacement of 25% of initial plantings
Biotechnical Slope Stabilization	Monitor during construction to ensure correct installation; inspect during and after first high flow period following installation; monitor revegetation success; inspect project after major floods	If needed (following first high flow period), make adjustments/repairs to any "hard" elements (rock etc.) to ensure project is performing as intended; replace dead or dying vegetation as needed	Long-term maintenance typically minimal once vegetation becomes well established [a]
Storm Drain Outlet Protection	Monitor during construction to ensure correct installation; inspect during/after first major storm event following installation; monitor revegetation success	If needed (following post-storm inspection), adjust/repair rock to ensure structure is performing as intended; replace dead or dying vegetation/reseed as needed	Long-term maintenance typically minimal once vegetation becomes well established; may need maintenance when storm drain pipe reaches end of life span and is replaced
Culvert Replacement with Bridge or Open-Bottom Box Culvert	Monitor during construction to ensure correct installation; inspect during/after first high flow period following installation; throughout life of structure inspect periodically and after major floods for channel stability and for signs of structural degradation	Repair channel stabilization treatments in vicinity of structure as needed/relevant; replace the bridge or box culvert at the end of its life span (estimated at approximately 35–65 years)	Because they are more efficient at passing debris and sediment, these wide-span crossing structures should require significantly less maintenance during high flow periods than existing smaller-diameter culvert pipes
Culvert Outlet Protection	Monitor during construction to ensure correct installation; inspect during/after first high flow period following installation; monitor revegetation; inspect outlet and inlet for stability after major floods	If needed (following first high flow), adjust/repair rock to ensure structure is performing as intended; replace dead or dying vegetation/ re-seed as needed; culvert inlet will still require ongoing maintenance to remove debris etc.	Outlet protection may need maintenance/ replacement when culvert pipe reaches end of life span and is replaced
Grade Control	Monitor during construction to ensure correct installation; inspect during and after first high flow period following installation; inspect after major floods	If needed (following first high flow period), adjust/repair to ensure structure is performing as intended	No special long-term maintenance typically required [a]
Comprehensive Bank Stabilization	Monitor during construction to ensure correct installation; inspect during and after first high flow period following installation; monitor revegetation success; inspect project after major floods	If needed (following first high flow period), make adjustments/repairs to any "hard" elements (rock etc.) to ensure project is performing as intended; replace dead or dying vegetation as needed	Long-term maintenance typically minimal once vegetation becomes well established [a]
Access Control Fencing	Monitor monthly for damage/vandalism during first year following installation; inspect twice a year during following years	Repair as needed based on monitoring observations; add deterrents such as brush barriers, signs, etc. as needed in chronic problem areas	Budget additional $1/linear foot/year for expected repair costs; more in highest-use areas

[a] Major floods on the order of 100-year recurrence interval events may result in channel changes that may require maintenance or re-installation of stabilization measures.

and invasive plant problems are chronic/ongoing by nature, they cannot be fixed through a one-time investment alone. Stream reaches affected by these issues require vigilance and regular maintenance; without follow-up, any benefits from a one-time effort will likely be short-lived despite high initial investment. Invasive plant control projects, in particular, should not be implemented unless plans are in place to insure that funding and labor will be available for needed long-term maintenance.

Grant Resources for Funding Improvement Projects

Implementing the recommended riparian corridor improvement projects will require significant financial investment. A variety of resources for financial assistance via grants and loans are available from Federal, State, and private sources. Information on specific relevant funding programs is summarized in Table 4.9.

Table 4.9. Information on funding programs to support riparian corridor improvement projects.

PROGRAM NAME	AWARDING ENTITY	DESCRIPTION	AVAILABILITY	DEADLINE	AWARD AMOUNT	CFDA [a] NUMBER	CONTACT INFORMATION, WEBSITE, AND NOTES
Five Star Restoration Grant	EPA [b]	grants for collaborative community-based riparian, coastal, or wetland restoration projects	partnership of government, nonprofit, academic, private, and community interests	mid February	$5,000–$20,000	66.462	www.epa.gov/wetlands/restore/5star/ *Emphasis on collaborative efforts with educational, training, and scientific merit.*
State Revolving Fund/American Recovery and Reinvestment Act	Utah DWQ [c]	Federal stimulus funds to address demonstrated water quality needs	open	June 1	$4 million total available	N/A	Shelly Andrews, Leah Ann Lamb, or Ed Macauley: 801-538-6146 www.waterquality.utah.gov/stimulus/ *Project must address demonstrated water quality need in nonpoint source pollution, water or energy efficiency, or green infrastructure/environmental innovation.*
Financial Assistance Program	Utah DWQ [c]	grants and 0% and low-interest loans for projects to address water quality needs, provide environmental education, and improve water resources	open	none	$20 million total available	N/A	801-538-6146 www.waterquality.utah.gov/FinAst/NPSFinAid.htm *Eligible projects include runoff reduction, water-resource conservation, groundwater quality, water quality, nonpoint source pollution prevention, and environmental education.*

Table 4.9. Information on funding programs to support riparian corridor improvement projects (cont.).

PROGRAM NAME	AWARDING ENTITY	DESCRIPTION	AVAILABILITY	DEADLINE	AWARD AMOUNT	CFDA [a] NUMBER	CONTACT INFORMATION, WEBSITE, AND NOTES
Project Assistance Program	Utah DWQ [c]	collaboration and funding for water quality improvement projects through grants and low-interest loans	community	none	variable	N/A	801-538-6146 www.waterquality.utah.gov/FinAst/Comgd1.htm *Project must result in a water quality benefit. Stream bank restoration projects are eligible.*
ACORN Foundation Grant	ACORN Foundation	grants for community-based projects to preserve and restore habitats, advocate for environmental justice, or prevent/remedy pollution	nonprofit grassroots organizations working in low-to-moderate-income communities	January 15, June 15	\$5,000–\$10,000	N/A	510-834-2995 grantsadmin@commoncounsel.org www.commoncounsel.org/Acorn%20Foundation *Letters of inquiry are accepted but full applications are by invitation only. Projects require a strong community focus, especially low-to-moderate income and leadership development.*
Blue Water Community Action Grant	Royal Bank of Canada	grants for nonprofit grassroots initiatives (including municipalities) for watershed protection and drinking water access	nonprofit 501c(3) organizations	March 6 (rolling)	\$1,000–\$5,000	N/A	www.rbc.com/donations/blue-water.html *Project must be involved in watershed protection or drinking water access. Online applications are available.*
Riverway Enhancement Grant	Utah DPR [d]	grants for the enhancement of river and stream corridors, including recreation and flood control	cities, counties, and special-service districts	May 1 (annually)	\$50,000–\$100,000 (50% matching)	N/A	Lyle Bennett: 801-538-7354 www.governor.state.ut.us/rplr/rdcc/2001webfolders/dnr/riverway-enhanc.pdf *While use of assistance may only include river and stream corridors prone to flooding, it may include a variety of outdoor recreation development.*
Nonpoint Source Implementation (Clear Water Act Section 319) Grant	Utah DWQ [c]	funding to address nonpoint source pollution	state and tribal agencies and municipalities	variable	variable (typical range \$30,000–\$50,000)	66.460	Michael Reichert: 801-538-6954 www.epa.gov/owow/funding.html
Watershed Protection and Flood Prevention/Small Watershed Protection Program	NRCS [e]	technical and financial assistance to help communities protect, improve, and develop land and water resources in watersheds	any entity with state authority to carry out, maintain, and operate proposed improvement, including nonprofit groups	none	\$650,000 average total amount available per state	10.904	Norm Evenstad: 801-524-4550 www.ut.nrcs.usda.gov/programs/pl566.html *Eligible projects include flood prevention, public recreation, groundwater recharge, and watershed protection.*
Plant Materials for Conservation	NRCS [e]	provision of (1) plant materials for use in restoration and (2) breeder stock and seed for use by commercial growers	cooperating state and Federal agencies and commercial growers	none	plant materials	10.905	NRCS [e] office: 801-524-4550 *Emphasis on field-testing and plant-material technology*

Table 4.9. Information on funding programs to support riparian corridor improvement projects (cont.).

PROGRAM NAME	AWARDING ENTITY	DESCRIPTION	AVAILABILITY	DEADLINE	AWARD AMOUNT	CFDA [a] NUMBER	CONTACT INFORMATION, WEBSITE, AND NOTES
Watershed Surveys and Planning	NRCS [e]	technical and advisory assistance for watershed planning	open (includes nonprofit organizations, private entities may not be eligible)	none	technical and advisory assistance	10.906	NRCS [e] State Conservationist Sylvia Gillen: 801-524-4551 sylvia.gillen@ut.usda.gov www.ut.nrcs.usda.gov
Wildlife Habitat Incentive Program	NRCS [e]	assistance for protection, restoration, development, or enhancement of habitat for wildlife, threatened and endangered species, and fisheries, as well as other types of wildlife	landowners meeting highly erodible land/wetland conservation and adjusted gross income requirements	none	5–10 year cost share (NRCS [e] 75%)	10.914	www.ut.nrcs.usda.gov Tooele Service Center: 435-882-2276 *Apply at a local USDA [f] service center or location found at www.sc.egov.usda.gov. (Form NRCS-CPA-1200). Applicant must remain in control of land for duration of assistance contract.*
Fish, Wildlife, and Plant Conservation Management	BLM [g]	grants for fish, wildlife, and plant conservation on BLM [g] lands and other public or private lands	open	1 fiscal year prior to need	$1,000–$100,000 (average award less than $10,000)	15.231	801-539-4001 www.blm.gov/ut/st/en.html *Cost match increases likelihood of an award.*
Wildlife Restoration	FWS [h]	Federal aid for a broad range of activities to restore, conserve, manage, or enhance wild bird and mammal populations and support public use of these resources	state agencies with lead fish and wildlife management responsibilities	none (30-day processing)	$2,750,000 average award	15.611	wsfrprograms.fws.gov/subpages/toolkitfiles/toolkit.pdf *Funds dispensed only to state wildlife agencies; requires legislation prohibiting use of hunting fees for nonhunting agency purposes.*
North American Wetlands Conservation Fund	FWS [h]	funding for acquisition and management, enhancement, and restoration of wetlands	public or private organizations with wetland conservation projects in Canada, the United States of America, and Mexico	March and July	up to $75,000 (small); $75,000–$1 million (standard) (requires 1:1 non Federal match)	15.623	www.fws.gov/birdhabitat/Grants/NAWCA
Wildlife Conservation and Restoration	FWS [h]	aid to states for efforts to benefit wildlife and habitat	state agencies with lead fish and wildlife management responsibilities	none	$904,000 average award	15.625	wsfrprograms.fws.gov/subpages/toolkitfiles/toolkit.pdf *Includes projects to benefit species that are not hunted or fished.*
Partners for Fish and Wildlife	FWS [h]	assistance for restoration and improvement of habitat	private landowners, local government entities, and nongovernmental organizations	none	$200–$25,000 (average $5,400); seeks 50% cost share	15.631	www.fws.gov/partners *Project must be located on private land, including lands held by individuals, local governments, nongovernmental organizations, and tribes.*
Challenge Cost Share	FWS [h]	grants for projects that encourage partnerships with non-FWS [h] groups for conservation, protection, and enhancement of fish, wildlife, and plants	open	variable by region	$300–$25,000 (average $7,800); requires 50% non Federal match	15.642	801-975-3330 *Submit proposals to a cooperating service office.*

Table 4.9. Information on funding programs to support riparian corridor improvement projects (cont.).

PROGRAM NAME	AWARDING ENTITY	DESCRIPTION	AVAILABILITY	DEADLINE	AWARD AMOUNT	CFDA [a] NUMBER	CONTACT INFORMATION, WEBSITE, AND NOTES
National Wetland Program Development Grant	EPA [b]	grants to help build programs to protect, manage, and restore wetlands	nongovernmental organizations, interstate agencies, and intertribal consortia	contact for information	$25,000–$225,000 per fiscal year	66.462	www.epa.gov/owow/wetlands/initiative/#financial *Priority areas are monitoring/assessment, improving wetland mitigation effectiveness, and refining protection of vulnerable wetlands and aquatic resources.*
Water Quality Cooperative Agreement	EPA [b]	grants for innovative efforts related to prevention, reduction, and elimination of water pollution	open (may exclude businesses, but open to individuals)	proposal requests	$15,000–$270,000	66.463	requests for proposals: https://www.grants.gov *Funding priorities include storm water control for targeted watersheds and urban wet weather watershed protection.*
Targeted Watershed Grant	EPA [b]	grants to support innovative community-based watershed approaches aimed at reducing water pollution	excludes for-profit enterprises, Federal agencies, and lobbying groups	variable (contact EPA [b])	$100,000–$1,000,000; requires 25% non Federal match	66.439	Eric Steinhaus: 303-312-6837 steinhaus.eric@epa.gov www.epa.gov/twg *Emphasis on monitoring, outreach/education, and demonstration of tangible environmental improvement.*
Patagonia Environmental Grant	Patagonia	grants to support action-oriented efforts to address root causes of environmental problems and protect local habitat	nonprofit 501c(3) organizations	contact for information	$3,000–$8,000 (typical)	N/A	www.patagonia.com/web/us/patagonia.go?slc=en_US&sct=US&assetid=2942 *Contact local retail store. Emphasis on measurable goals and objectives.*
Community Forestry Partnership Grant	Utah FFSL [i]	funding to support urban and community forestry projects	open	September 14, 2009	$1,000–$5,000; requires 1:1 match	N/A	Meredith Perkins: 801-538-5505 www.ffsl.utah.gov/grants/grants.php#urbangrants *Cities must achieve Tree City USA status to be eligible.*

[a] Catalog of Federal Domestic Assistance.
[b] U.S. Environmental Protection Agency.
[c] Division of Water Quality.
[d] Division of Parks and Recreation.
[e] Natural Resources Conservation Service.
[f] U.S. Department of Agriculture.
[g] U.S. Bureau of Land Management.
[h] U.S. Fish and Wildlife Service.
[i] Division of Forestry, Fire, and State Lands.