

MONITORING, MAINTENANCE, AND ADAPTIVE MANAGEMENT PLANNING AND RESOURCES FOR RIPARIAN RESTORATION PROJECTS

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PURPOSE

The purpose of this resource is to provide general recommendations for monitoring and maintenance of restored conditions in restored riparian areas of Colorado, such that information gathered from monitoring efforts can influence ongoing land management necessary to accomplish project goals. It is important to note that monitoring plans and maintenance strategies must be tailored to the specific site in question. The unique abiotic and biotic conditions of the site, restoration and other management goals, available resources, and other factors will have a large influence on the final monitoring and adaptive management protocols being employed for a given restoration project.

ADAPTIVE MANAGEMENT

Adaptive management is an iterative process, incorporating monitoring results to inform ongoing maintenance and operations of a restoration project. In areas involving numerous land owners and other stakeholders, the development of a final adaptive management plan should involve land owners proactively. The various private land owners, funders, partners, and/or public land owners (stakeholders) will likely have differing objectives, budgets, and philosophies regarding how the natural resources of a site should be managed over time. These objectives and philosophies may not always be in line with the coalition or other organization responsible for managing long-term grant, permitting, and other fiscal/legal project outcomes that are often supported by monitoring data. As such, it is recommended that the entity responsible for meeting funding, regulatory, and other fiscal/legal requirements of a project (lead entity) take the lead role in developing an appropriate monitoring program for a given site.

Understanding the intended post-restoration land-use practices (i.e., recreation, grazing, and conservation) of a site is important for developing an adaptive management plan. Absent a stakeholder-driven process for the development of an adaptive management plan for the site in question, this section outlines some basic guidelines in an effort to assist the lead entity and land owners to develop an adaptive management that is a good fit with their long-term vision, goals, and available resources.

Monitoring and maintenance are interrelated in the adaptive management process. Monitoring provides feedback for land managers, who adapt and alter maintenance practices over time to meet restoration goals. Site maintenance treatments (i.e., weed management, site protection, and ongoing revegetation) help to attain restoration and other management goals in a more comprehensive manner than initial revegetation efforts can. Like initial revegetation results, though, maintenance treatments will also be assessed over the long term via monitoring, the results of which will inform future maintenance efforts via an adaptive management plan.

MONITORING

Overview

Monitoring is the process of measuring or assessing specific physical, chemical, and/or biological parameters of a project (Thayer et al., 2003; NRCS, 2007) over time. Using *subjective* (i.e., qualitative), or *objective* (i.e., quantitative) methods, monitoring can be used to help identify and alleviate potential stressors and inform maintenance activities. Qualitative methods, such as visual monitoring (i.e., repeat photographic points or completion of subjective monitoring forms), can effectively document site changes, and can quickly suggest maintenance activities necessary to correct problems. Quantitative monitoring, conversely, is more data-driven and aims to measure project outcomes through science-based methods aimed at reducing observer bias. Quantitative monitoring results may also be used to guide the criteria and methodology for future restoration projects and maintenance activities of a site, more accurately address permit entity requirements, support requests for contractors to perform on various warranty items (i.e., 50% vegetation cover), and allow for sound long-term tracking of the changes in certain parameters (i.e., changes in plant community structure and composition over time) of a site.

Monitoring can answer important questions for post-restoration management, and provide meaningful direction for adaptation of management plans. Some of these questions, from *Living Streambanks: A Guide to Bioengineering Treatments for Colorado Streams* (Giordanengo et al. 2016) include:

- Were the appropriate treatments design and implemented correctly to achieve restoration goals?
- Were project outcomes achieved according to project goals?
- Are management activities (i.e., boating, camping, hiking, rural/residential landscaping, grazing, other land use) negatively affecting project outcomes?
- Have site conditions changed in a way that requires an adjustment to existing structures, replacement of structures or vegetation, or installation of new treatments?
- Is the vegetation community on the expected trajectory of recovery, or are important design components missing?
- Have invasive or noxious species negatively impacted the site?

The nature, frequency, and intensity of monitoring will vary depending on the questions being answered by the monitoring program, available resources (i.e., volunteers, staff, equipment, finances), and the nature of the elements (i.e., vegetation cover) being monitored. With an assumption that monitoring resources are limited, yet in an effort to ensure reliable data

gathering, we have drafted a monitoring strategy and resources to support the lead entity and land owners to carry out monitoring activities.

Monitoring Goals

An essential first step to monitoring is the development of specific restoration goals for the site, against which monitoring results can be measured. The following goals are provided as a recommendation. These goals should be verified by the lead entity, and additional goals may be required by various permit agencies such as the US Army Corps of Engineers, US Fish and Wildlife Service (i.e., management for T&E species), and others.

Revegetation Goals (example):

Goal 1: Enhance the biological and structural diversity to meet the Potential Natural Community elements and Potential Structural Diversity outlined in **Table 1** and **Table 2**.

Goal 2: Bank, overbank, and transition zone vegetation cover in excess of 70% absolute cover of all strata (herbaceous, shrubs, trees, and vines), with at least 50% relative cover of woody plants, especially willows and cottonwoods. Upland zone vegetation cover in excess of 40% cover in all strata (herbaceous, shrubs, trees, and vines).

Goal 3: Maintain weed cover to less than 15% (absolute cover) of total ground cover, and less than 30% of relative vegetation cover. No list A (i.e., control required by Colorado Department of Agriculture) species present.

Given these goals, specific elements to measure over time include:

- Vegetation cover, woody species density, and vegetation structure in (at a minimum) bank and overbank zones. As time permits, vegetation cover and woody plant density and structure should be measured in all restored habitats;
- Weed densities and distribution;
- Aquatic species diversity and abundance;
- Bank erosion rates;
- Channel and floodplain geomorphic changes;
- Condition of constructed features (i.e., cross vanes, bioengineering structures, bridges, cut-off structures, protective fencing, etc.);

Zone	Primary Canopy Types*	Structural diversity
toe	<ul style="list-style-type: none"> • Early-seral herbaceous dicots and monocots 	Low (ground cover only)
bank	<ul style="list-style-type: none"> • Herbaceous dicots and monocots • Early-seral shrubs and trees • Mid-seral shrubs and trees 	Medium (ground cover + single woody canopy)
overbank	<ul style="list-style-type: none"> • Mid- to Late-seral Herbaceous dicots and monocots • Early-seral shrubs and trees • Mid-seral shrubs and trees • Few late-seral trees 	High (ground cover + 2-3 woody canopies)
gallery forest/transition	<ul style="list-style-type: none"> • Mid- to late-seral herbaceous dicots and monocots • Few early-seral shrubs and trees • Mid-seral shrubs and trees • Late-seral shrubs and trees 	Very High (ground cover + 3-4 woody canopies)
upland	<ul style="list-style-type: none"> • Mid- to late-seral herbaceous dicots and monocots • Mid- to late-seral shrubs and trees 	Medium (ground cover + 1-2 woody canopies)

* For list of dominant species refer to Potential Natural Community table.

** Native species only listed

Table 1. Potential Structural Diversity of Apple Valley (example).

Types of Monitoring

Monitoring, by definition, should be conducted over time, and should utilize consistent approaches in order to accurately compare data over the length of the monitoring effort. Lewis et al. (2009) recommend four fundamental monitoring types to answer principle questions:

- *Pre-project assessment* (i.e., documentation of the current site conditions and how they inform project selection and design).
 - What are the existing site conditions and the reasons for project implementation? This is similar to baseline monitoring, though does not attempt to document pre-disturbance conditions.
- *Implementation monitoring* is done to establish the accuracy of construction.
 - Was the project installed according to design specifications, permits and landowner agreements?
- *Effectiveness monitoring* is used to assess post-project site conditions and to document changes resulting from the implemented project.

- Did attributes and components at the project site change in magnitude expected over the appropriate time frame? This is accomplished through comparison with pre-project and post construction conditions.
- *Validation monitoring* is used to determine the cause and effect relationship between the project and biotic or physical response.
 - Did fish, wildlife, or water quality respond to the changes in physical and biological attributes or components brought about by the project?

Pre-project monitoring at Apple Valley has already begun, though current baseline efforts were rapid and intended to influence design rather than to serve as a formal baseline against which detailed evaluation monitoring activities could be measured. Implementation monitoring (i.e., quantifying the location and type of restoration work actually completed, as compared to the intended design) should be conducted throughout the construction phase. Effectiveness and validation monitoring will occur upon completion of the project and will continue for several years. Both qualitative and quantitative methods will be employed to ensure management objectives are being met. If it is determined that objectives are not being met, management will adapt in order to ensure the desired results.

Given budgetary constraints, even the most basic monitoring methods can inform adaptive management decisions important to the long-term maintenance of a project. However, as the results of qualitative monitoring can vary significantly from one observer to another, every effort should be made to integrate at least categorical observations (i.e., high, moderate, low, none; or scoring 0-5 for various element conditions). An important key, regardless of the complexity or cost of the monitoring method(s) used, is to employ repeatable/consistent methods over time. As personal and management circumstances change over time, data will be collected and managed in a way that can be easily understood and interpreted by a variety of future land managers and practitioners.

Toe Zone	Grasses/Grass-like		Forbs		Shrubs/Vines		Trees	
	Common Name	Scientific Name	Common Name	Scientific Name	Common Name	Scientific Name	Common Name	Scientific Name
	Baltic rush	<i>Juncus balticus</i> var. <i>montanus</i>	American speedwell	<i>Veronica americana</i>	coyote willow	<i>Salix exigua</i> spp. <i>interior</i>		
	cattail	<i>Typha latifolia</i>	cursed buttercup	<i>Ranunculus sceleratus</i> var. <i>sceleratus</i>				
	Dudley's rush	<i>Juncus dudleyi</i>	field horsetail	<i>Equisetum arvense</i>				
	rushes	<i>Juncus</i> sp.	fringed willowherb	<i>Epilobium ciliatum</i>				
	sedges	<i>Carex</i> sp.	maretail	<i>Conyza canadensis</i>				
	softstem bullrush	<i>Shoenoplectes tabernaemontani</i>	showy milkweed	<i>Asclepias speciosa</i>				
	spikerushes	<i>Eleocharis</i> spp.	smooth horsetail	<i>Equisetum laevigatum</i>				
	toad rush	<i>Juncus bufonis</i>	water speedwell	<i>Veronica catenata</i>				
	witchgrass	<i>Panicum capillare</i>	watercress	<i>Nasturium officinalis</i>				
	wooly sedge	<i>Carex pellita</i>	yellow-cress	<i>Rorippa</i> sp.				

Bank Zone	Grasses/Grass-like		Forbs		Shrubs/Vines		Trees	
	Common Name	Scientific Name	Common Name	Scientific Name	Common Name	Scientific Name	Common Name	Scientific Name
	alkalai sakaton	<i>Sporobolus airoides</i>	Canada goldenrod	<i>Solidago canadensis</i>	Bebb's willow	<i>Salix bebbiana</i>	peachleaf willow	<i>Salix amygdaloides</i>
	American mannagrass	<i>Glyceria grandis</i>	field horsetail	<i>Equisetum arvense</i>	coyote willow	<i>Salix exigua</i> spp. <i>interior</i>		
	beaked sedge	<i>Carex utriculata</i>	giant goldenrod	<i>Solidago gigantea</i>	redosier dogwood	<i>Cornus sericea</i>		
	bluejoint reedgrass	<i>Calamagrostis canadensis</i>	goldenbanner	<i>Thermopsis divaricarpa</i>	river birch	<i>Betula occidentalis</i>		
	fowl bluegrass	<i>Poa palustris</i>	Nuttall's sunflower	<i>Helianthus nuttallii</i>	shining willow	<i>Salix lucida</i>		
	inland saltgrass	<i>Distichlis spicata</i>	purple meadow-rue	<i>Thalictrum dasycarpum</i>	thinleaf alder	<i>Alnus incana</i> ssp. <i>tenuifolia</i>		
	Nebraska sedge	<i>Carex nebrascensis</i>	showy milkweed	<i>Asclepias speciosa</i>	Wood's rose	<i>Rosa woodsii</i>		
	prairie cordgrass	<i>Spartina pectinata</i>	smooth horsetail	<i>Equisetum laevigatum</i>	poison ivy	<i>Toxicodendron rydbergii</i>		
	sedges	<i>Carex</i> sp.	starry false solomon seal	<i>Maianthemum stellatum</i>				
	Spikerushes	<i>Eleocharis</i> sp.	stinging nettle	<i>Urtica dioica</i> spp. <i>gracilis</i>				
	switchgrass	<i>Panicum virgatum</i>	swamp verbena	<i>Verbena hastata</i>				
	wooly sedge	<i>Carex pellita</i>	wild mint	<i>Mentha arvensis</i>				

Overbank Zone	Grasses/Grass-like		Forbs		Shrubs/Vines		Trees	
	Common Name	Scientific Name	Common Name	Scientific Name	Common Name	Scientific Name	Common Name	Scientific Name
	alkalai sakaton	<i>Sporobolus airoides</i>	American vetch	<i>Vicia americana</i> spp. <i>americana</i>	beaked hazelnut	<i>Corylus cornuta</i>	boxelder	<i>Acer negundo</i> spp. <i>interius</i>
	big bluestem	<i>Andropogon gerardii</i>	cutleaf coneflower	<i>Rudbeckia laciniata</i> var. <i>ampla</i>	Bebb's willow	<i>Salix bebbiana</i>	Douglas-fir	<i>Pseudotsuga menziesii</i>
	bluejoint reedgrass	<i>Calamagrostis canadensis</i>	field horsetail	<i>Equisetum arvense</i>	chokecherry	<i>Prunus virginiana</i> spp. <i>melanocarpa</i>	lancheaf cottonwood	<i>Populus ex. Acuminata</i>
	Canada wildrye	<i>Elymus canadensis</i>	giant goldenrod	<i>Solidago gigantea</i>	coyote willow	<i>Salix exigua</i> spp. <i>interior</i>	narrowleaf cottonwood	<i>Populus angustifolia</i>
	fowl bluegrass	<i>Poa palustris</i>	goldenbanner	<i>Thermopsis divaricarpa</i>	false indago	<i>Amorpha fruticosa</i>	peachleaf willow	<i>Salix amygdaloides</i>
	fowl bluegrass	<i>Poa palustris</i>	northern bedstraw	<i>Galium boreale</i>	golden currant	<i>Ribes aureum</i>	plains cottonwood	<i>Populus deltoides</i>
	fringed brome	<i>Bromus ciliatus</i>	Nuttall's sunflower	<i>Helianthus nuttallii</i>	mountain willow	<i>Salix monticola</i>		
	green needlegrass	<i>Nasella viridula</i>	purple meadow-rue	<i>Thalictrum dasycarpum</i>	redosier dogwood	<i>Cornus sericea</i>		
	inland saltgrass	<i>Distichlis spicata</i>	selfheal	<i>prunella vulgaris</i>	river hawthorn	<i>Crataegus erythropoda</i>		
	marsh muhly	<i>Muhlenbergia racemosa</i>	stinging nettle	<i>Urtica dioica</i> spp. <i>gracilis</i>	Rocky Mountain maple	<i>Acer glabrum</i>		
	Nebraska sedge	<i>Carex nebrascensis</i>	swamp verbena	<i>Verbena hastata</i>	shining willow	<i>Salix lucida</i>		
	prairie cordgrass	<i>Spartina pectinata</i>	wild licorice	<i>Glycyrrhiza lepidota</i>	strapleaf willow	<i>Salix ligulifolia</i>		
	switchgrass	<i>Panicum virgatum</i>			western snowberry	<i>Symphoricarpos occidentalis</i>		
	Western wheatgrass	<i>Pascopyrum smithii</i>			western white clematis	<i>Clematis ligusticifolia</i>		
	yellow indiagrass	<i>Sorghastrum nutans</i>			Wood's rose	<i>Rosa woodsii</i>		

Gallery Forest/ Transition Zone	Grasses/Grass-like		Forbs		Shrubs/Vines		Trees	
	Common Name	Scientific Name	Common Name	Scientific Name	Common Name	Scientific Name	Common Name	Scientific Name
	blue grama	<i>Bouteloua gracilis</i>	American vetch	<i>Vicia americana</i> spp. <i>americana</i>	American plum	<i>Prunus americana</i>	boxelder	<i>Acer negundo</i> spp. <i>interius</i>
	green needlegrass	<i>Nasella viridula</i>	black-eyed susan	<i>Rudbeckia hirta</i>	chokecherry	<i>Prunus virginiana</i> spp. <i>melanocarpa</i>	Douglas-fir	<i>Pseudotsuga menziesii</i>
	mountain muhly	<i>Muhlenbergia montana</i>	bluebells	<i>Mertensia lanceolata</i>	creeping barberry	<i>Mahonia repens</i>	lancheaf cottonwood	<i>Populus ex. Acuminata</i>
	muttongrass	<i>Poa fendleriana</i>	goldenbanner	<i>Thermopsis divaricarpa</i>	delicious raspberry	<i>Rubus deliciosus</i>	plains cottonwood	<i>Populus deltoides</i>
	parry's oatgrass	<i>Danthonia parryii</i>	milkvetch	<i>Astragalus</i> spp.	golden currant	<i>Ribes aureum</i>	ponderosa pine	<i>Pinus ponderosa</i>
	sideoats grama	<i>Bouteloua curtipendula</i>	northern bedstraw	<i>Galium boreale</i>	grayleaf red raspberry	<i>Rubus idaeus</i> subsp. <i>Strigosus</i>	Rocky Mountain Juniper	<i>Juniperus scopulorum</i>
	sleepygrass	<i>Achnatherum robustum</i>	prairie coneflower	<i>Ratibida columnifera</i>	three-leaf sumac	<i>Rhus trilobata</i>		
	slender wheatgrass	<i>Elymus trachycaulis</i>	smooth aster	<i>Symphyotrichum laevigata</i>	western snowberry	<i>Symphoricarpos occidentalis</i>		
	switchgrass	<i>Panicum virgatum</i>	western yarrow	<i>Achillea millefolium</i> var. <i>occidentalis</i>	rubber rabbitbrush	<i>Ericameria nauseosus</i>		
	thickspike wheatgrass	<i>Elymus lanceolatus</i>						
	Western wheatgrass	<i>Pascopyrum smithii</i>						

Table 2. Dominant and sub-dominant native species by riparian zone (example from Apple Valley)

Because of the complex nature of a river corridor's physical and biological elements, no single monitoring method will answer every question. As such, a combination of monitoring methods will be required to properly assess whether management objectives are being met at Apple Valley. In *Living Streambanks: A Guide to Bioengineering Treatments for Colorado Streams*, Giordanengo et al. (2016) summarized a few common monitoring methods and procedures that may be utilized to monitor stream and floodplain restoration projects:

- Cross-section and latitudinal transects to measure geomorphic changes over time (Hardy, Panjan, & Mathias, 2005);
- Line-intercept procedure (Herrick, Van Zee, Haustad, Burkett, & Whitford, 2005) to measure plant community composition, especially herbaceous vegetation. This method is highly accurate and repeatable over time;
- Daubenmire Method (Daubenmire, 1959);
- Kick net procedure for aquatic invertebrate communities. Because aquatic invertebrate communities are a cost-effective and powerful way to track project effectiveness over time, a single aquatic invertebrate sample should be collected at each site pre- and post-construction. Standard metrics (i.e., EPA) should be used to characterize the aquatic community pre- and post-construction;
- Electrofishing to quantify age class distribution and population density; and
- Bank Erosion Hazard Index (Rosgen, 2001), by itself or coupled with the Near Bank Shear Index (Bank Assessment for Non-point source Consequences of Sediment, BANCS).

Depending on the resources available, and the yet-to-be-adopted monitoring program, some or all of the above monitoring methods may be conducted, and additional monitoring methods may be provided. Additional monitoring protocols, specific to Apple Valley, include the River Health Assessment performed by the project team, revegetation cover and survivorship counts, long-term/permanent monitoring transects, and condition of constructed features.

Draft monitoring timeline and responsibilities table

The schedule in **Table 3** provides a summary of the timing for which various monitoring efforts should be implemented, and the likely observers for such monitoring.

Type of Monitoring	When to Implement?	Who Should Conduct?	Recommended Procedures	Elements to monitor
Pre-Project Assessment	Within a year prior to project implementation.	SVCC or appointed individual/group	Rapid assessment for sub-reach conditions. Quantitative methods for long-term transects and cross-sections.	Channel plan, profile, and cross-section, vegetation cover and structure, benthic macroinvertebrates, fish populations, and geomorphic hazards.
Implementation Monitoring	During and/or shortly after the construction phase	SVCC staff or construction oversight team	Construction oversight form	All physical (i.e., rock structures, erosion matting, fencing, etc.) and biological treatments (i.e., container stock) should be evaluated and any deviations noted.
Effectiveness Monitoring	Structures should be monitored during or shortly after the first run-off following installation, and annually thereafter (for 3 years post-installation), and immediately after a Q10 or greater event into perpetuity. Vegetation parameters should be monitored in first growing season, 3rd season, and 5th season following treatments. Subsequently, a 10-year evaluation may be considered. Vegetation should be monitored in the peak of the growing season (late July through late August)	SVCC or appointed individual/group	"Condition of Constructed Features" form (rapid assessment), survivorship form for shrubs, line-point intercept form, Streambank Stability Assessment, Weed Survey Form, and River Health Assessment (year 5).	SVCC should prioritize which elements they desire to monitor, as monitoring all elements can be resource intensive. At a minimum, repeat photography, condition of constructed features, and survivorship counts should be conducted in the first 1-3 years following construction.
Validation Monitoring	Years 3, 5, and 10 following construction	SVCC, volunteers, or appointed group	Various, depending on target species or conditions.	Aquatic and terrestrial wildlife populations, channel geomorphology, bank erosion rates, etc.

Table 3. Monitoring Type, Timeline, and Responsibilities (example from Apple Valley)

Monitoring Methods

This section provides a summary of vegetation some of the monitoring methods available for riparian restoration projects. This is not a comprehensive list. Ultimately, site-specific conditions, project goals, resources, and other unique variables will drive the final monitoring plans necessary for a given project. Appendix A includes a static version of the monitoring forms for these recommended monitoring methods.

Vegetation Monitoring

The **rapid assessment** for vegetation is included in the River Health Assessment. Additional rapid assessment procedures can be developed as needed, but should be conducted by reach, and within hydroseres. Repeat photography should also be conducted as part of a vegetation rapid assessment, at a minimum repeating the photo points taken during the River Health assessment.

Intensive/Quantitative: The *line-point-intercept* method should be used to quantify herbaceous vegetation cover in revegetated areas. This method has repeatability across observers and over time, and is well suited for documenting revegetation results in a manner that can be used to verify if revegetation targets (i.e., 50% cover) have been met. A simple quantitative measure to document *shrub survivorship* is a shrub survivorship inventory. A sample shrub survivorship sheet is also included in the Appendix.

WEED MANAGEMENT

With regards to their impacts on native plant communities and/or social values, non-native plants (i.e., weeds) can be benign, invasive, or noxious. Weeds have long been recognized as ecologically and economically detrimental for multiple reasons, a complete account of which is beyond the scope of this document. Such invasive species have an advantage over native species in part because they lack the full spectrum of biological controls (i.e., insect predators, plant pathogens, etc.) that serve to keep their populations in check in their country of origin. As such, they are more likely to continue to spread unabated throughout a watershed by displacing native plants and forming dense monocultures, especially after the 2013 flood and subsequent restoration activity, which both provided an opportunity for invasion via disturbed soil surface conditions.

The Colorado Noxious Weed Act (C.R.S. 35-5.5-101-119) creates a legally binding obligation for the removal/control of noxious species. Through the Colorado Department of Agriculture, a list of A, B, and C species is managed and periodically updated in order to prioritize the control of priority weeds. To assist with weed management, a great variety of weed management resources is provided by these entities, including how to create a weed management plan, best management practices for weed management, and more:

Colorado Department of Agriculture website:

<https://www.colorado.gov/pacific/agconservation/noxious-weed-publications>,

Colorado State University Extension, Weed Resources:

<http://www.ext.colostate.edu/sam/weeds.html>

Weeds are classified by priority. The categories for classification are shown below:

List A weeds are non-native species whose distribution in Colorado is still limited, and for which preventing new infestations are the highest priority. Eradication of all List A species is required by law.

List B weeds are non-native species that are limited to portions of the state. Species are designated for control in regions where they are not yet widespread. Further, preventing new infestations is a high priority for the State. In areas where List B species have already become established, state noxious weed management plans are designed to stop their continued spread.

List C weeds are non-native species which are already widespread in Colorado or are of special interest to the agricultural industry. Control of these species is not required.

The most cost-effective time to manage invasive vegetation is early in a project's lifetime, before invasive plants have a chance to spread through abundant seeds or vegetative propagules. Since the initial monitoring stage has taken place, and species of concern have been identified and documented prior to project implementation, treatment of these species will occur prior, during, and after construction as needed. Consistent monitoring will take place throughout and after project implementation, which will identify whether follow-up treatments are required to address most invasive species problems.

Weed Management Recommendations

Treating invasive species is often a necessary step in restoring a riparian area to a more productive and natural condition. This will also increase biodiversity and will provide greater protection of slopes and banks. Site management should integrate a variety of restoration and management activities to control the invasion of non-native vegetation, which include:

- Selecting appropriate and diverse early- to mid-seral seed mixes with the potential to fully occupy a given area's botanical niches;
- Seeding and planting in optimal seasons, and using appropriate seeding rates and seeding methods to increase the likelihood of high vegetation cover in the early years following restoration;
- Applying appropriate levels of soil amendments, as determined by proper soil testing;
- Minimizing or eliminating the use of nitrogen, as invasive species are preferentially stimulated over native species through the use of nitrogen;
- Paying close attention to the invasive species seeds that are often present in a seed mix;
- Eliminate the presence of undesirable non-native species brought to the restoration site by heavy equipment, and via other vectors (cattle and other livestock, clothing and boots of residents and volunteers, and others)
- Pre-treating the project site to remove invasive and noxious species; and
- Developing an iterative weed management plan, informed by regularly scheduled monitoring.

Successful Revegetation

In disturbed settings, establishing desired native species is the best long-term strategy to help moderate the abundance, diversity, and distribution of undesirable weeds. Basic recommendations for the timing of successful establishment of desired native vegetation are listed in **Table 5**. This table provides acceptable windows of revegetation for low elevation sites of Colorado. However, given the elevation and poor soil conditions of Apple Valley, together with the highly managed discharge affected by Ralph Price Reservoir, it is estimated that the spring planting will have a higher chance of success than fall plantings.

Confidence of Sufficient Soil Moisture During Growing Season

Type of Material	Low	High
Seed (diverse mix)	October 1 - April 1*	October 1 - April 30*
Wetland containers**	Mar 1 - May 15 / Sep 1 - Oct 31	Mar 1 - June 15 / Sep 1 - Oct 31
Riparian shrub/tree containers	Mar 1 - Apr 15 / Sep 1 - Oct 31	Mar 1 - June 15 / Sep 1 - Oct 31
Hardwood Cuttings	November 1 - May 1*	November 1 - June 15*

* At high elevations (i.e., above 8,000'), sites may experience a longer seeding/planting window.

** At high elevations (i.e., above 8,000'), wetland planting is not recommended past September.

NOTE 1: Dates provided are not exact, but provide the general seeding window.

NOTE 2: More precise planting/seeding times will be dependent on the species in question, a variety of site conditions, and other variables.

Table 5. Optimal revegetation schedule.

SITE PROTECTION

In addition to being aware of the negative effect invasive plants can have on desired native vegetation, land managers should consider the impact domestic livestock and wildlife can have on newly planted vegetation.

LIVESTOCK AND WILDLIFE CONTROL

Unmanaged impacts from livestock or wildlife in a revegetation site can be devastating to newly established plant materials. As such, livestock should be excluded from the restored site for a period of four to five years after establishment. If livestock access to water is critical, offsite watering (i.e., stock ponds or tanks) or hardened water crossings should be used to reduce impact to revegetation areas during the grazing season. For areas where livestock is a concern, a grazing management plan will be essential (Washington State Department of Fish and Wildlife et al., 2003). Once riparian vegetation is well established, livestock grazing can resume as part of a well-managed grazing plan. When managed correctly, livestock can have beneficial impacts to riparian and adjacent upland plant communities.

Waterfowl can also cause significant damage to a new planting. Various types of fences, tape, rope, wire, and balls can be effective protective measures. In moderate to high recreation areas, human traffic (i.e., fishing, boating, picnicking, etc.) can cause substantial bank erosion in treated areas. In many cases, adequate signage and temporary exclusion fencing can help alleviate these impacts.

While development of a proper grazing management for a site is beyond the scope of this report, the following strategies are provided to influence grazing management and several will be employed to help minimize grazing impacts:

- A combination of fencing and hardened water crossings, when designed correctly, can allow for grazing in a floodplain while providing access to water and protecting restored vegetation. Once vegetation is established (four to eight years), properly managed seasonal grazing patterns (i.e., deferred rotation) can occur in riparian areas with minimal damage to vegetation.
- Protective cages (wire mesh, plastic mesh, etc.) can be applied to protect key individual plants until their roots are well established and their leaves and stems are high enough to be safe from grazing animals, or robust enough to sustain moderate levels of grazing.
- Chemicals such as hot pepper spray (6% hot sauce and 92% water), deodorized predator (i.e., fox, wolf, or coyote) urine, and other manufactured products have proven effective at reducing herbivory by deer and to some degree elk. Typically, such chemicals should be applied monthly or bi-monthly (depending on precipitation and season) to maintain effectiveness.
- Plastic collars (i.e., corrugated pipes with a vertical slit) can be used around the trunks of trees such as cottonwoods to reduce damage from rabbits, gophers, and other animals. In areas where below-ground herbivory is expected, collars should be installed one to two inches below grade, and extend 16 inches above grade.
- A slurry of cement and paint can be applied to the trunks of woody vegetation to discourage beaver predation.

Site Maintenance

Maintenance is the collection of actions taken to help ensure a given stream restoration project performs as designed and attains project objectives (NRCS, 2007). Maintenance is closely tied to management, and involves the initial set of planned activities as well as unplanned activities following project implementation. If lack of maintenance becomes chronic, substantial efforts may be required to correct failures in structures or other design elements. Active and frequent maintenance can often result in reduced “reconstruction” costs down the road.

Maintenance is most beneficial in the first three to five years following planting, with the exception of the occurrence of significant (i.e., 50 years or greater) flood events. Excessive flood flows soon after planting can cause substantial erosion and slope failure, resulting in unacceptable soil and plant loss. Such areas may need to be replanted, inter-planted, or reinforced by other means. Other maintenance efforts may include: (a) placement of large

woody debris and other toe protection treatments on banks to redirect water away from the established areas, (b) invasive species management, (c) supplemental irrigation, and (d) fencing.

By understanding the range of post-construction stressors (floods, drought, wildlife, human traffic, etc.) that can potentially impact the bioengineered streambanks of Apple Valley, the design process is likely to develop optimal treatments necessary to minimize post-construction maintenance needs.

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APPENDIX A – MONITORING FORMS/DATA SHEETS

1. Noxious Weed Report/Inventory Form
2. Photography Point Monitoring
3. Stream Resilience (AKA River Health) Assessment
4. Streambank Stability Assessment
5. Line-point Intercept
6. Shrub/Tree Survivorship Datasheet