Creekside Plantings and Restoration in California Rangelands

Louise Jackson, Amanda Hodson, Katherine Fyhrie, Valerie Calegari

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TABLE OF CONTENTS

Habitat Restoration Practices for California Rangeland Riparian Corridors 5

Dry Creek at Audubon Bobcat Ranch, Yolo County 43

Three Creeks Ranch, Glenn County 60

Doty Ravine Preserve, Placer County 64

Riparian Habitat Restoration Planning Worksheet for California Rangelands 73

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HABITAT RESTORATION PRACTICES FOR CALIFORNIA RANGELAND RIPARIAN CORRIDORS

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1.0 INTRODUCTION

Ranches that rim California's Central Valley are important in providing most of the remaining habitat for many species that were once wide-ranging, e.g., freshwater fish, wintering birds and waterfowl, invertebrates, and mammals (Kroeger et al. 2010). Upland rangeland riparian corridors, though seasonally ephemeral, provide ecological connectivity with the large river systems in the Central Valley (Merenlender and Matella 2013). (The term 'riparian corridor' applies to waterways and the strips of vegetation flanking them). Ranchers and other types of land managers usually need some assistance to select and implement successful practices for creating, enhancing, and restoring wildlife habitat along the riparian corridors on their properties (Lewis et al. 2009). Integrated management also increases other ecosystem services, such as improved water quality, more stable stream banks and riparian soils which support hydrologic functions such as flood attenuation, higher carbon sequestration in soil and wood, and more diverse and productive plant communities (Lennox et al. 2009; George et al. 2011). During the past few years, several publications have given guidelines for habitat restoration relevant to riparian corridors in the rangelands in Central California. The purpose of this document is to summarize these guidelines for determining the most effective mix of practices and native species for stream restoration in California rangelands. It incorporates ideas from 'farmscaping', i.e., managing non-production areas to create a more biodiverse set of habitats and greater landscape heterogeneity to increase ecosystem services (Long and Anderson 2010; Robins et al. 2001; Smukler et al. 2010).

Riparian restoration requires a significant commitment from the landowner or land manager. Without adequate planning tools, the financial investment in land preparation, plant material and management can show poor returns, leading to skepticism about the feasibility of habitat restoration of riparian corridors in the grasslands and oak savannas of Central California's rangelands. Riparian corridors on ranches in the Central Valley typically occur on marginal soils without irrigation, and on rocky or steep slopes. These sites often have a history of soil erosion, livestock disturbance of stream borders, and loss of native vegetation. The survival of trees and shrubs planted in upland rangeland sites without irrigation in Yolo County is much lower (30 percent) than in lowland valley sites (70 to 80 percent) (Audubon 2005). For all these reasons, sharing information about the planning and implementation of rangeland riparian plantings is important. In particular, plant species well-suited to the heterogeneity within upland rangeland sites needs careful attention.

In recent decades, awareness and interest in management of biodiversity and ecosystem services on working lands (i.e., farms, ranches, and forests that yield food and timber and support local economies) has increased among state governmental agencies (e.g., California Department of Food and Agriculture, Water Resources, and Wildlife Conservation Board, as well as the California Resources Agency), federal agencies (e.g., Department of Agriculture's Natural Resources Conservation Service, and the United States Fish and Wildlife Service's Partners for Wildlife) as well as non-governmental organizations (e.g., Audubon California, Sustainable Conservation, California Farm Bureau Federation, and Environmental Defense Fund). There is also growing commitment among ranchers for habitat development to increase wildlife and private benefits, which ultimately contribute to public benefits such as water quality, carbon sequestration, and services rendered by pollinators and insect pest control agents (Kroeger et al. 2010). In a broader context, the ecosystem services to society from restoration projects include the avoided costs of water treatment and dredging, lower costs for health care and property damages, long-term value of protecting threatened, endangered, or rare species, and the cultural and aesthetic benefits associated with scenic views and recreational use of the land. To meet these stewardship objectives, landowners have expressed a need for more guidance to ensure cost-effective and successful projects that achieve multiple benefits (Brodt et al. 2009).

With the loss or degradation of >90% of the riparian ecosystems in California (Barbour et al. 1993), riparian restoration on rangelands has high potential for recovering wildlife and bird populations and increasing carbon storage, nutrient retention, water quality, and habitat for aquatic organisms (Kroeger et al. 2010; Tabacchi et al. 1998; Ward et al. 2003b; Young-Mathews et al. 2010). The goal of this literature review is to compile existing management and site assessment guidelines for habitat planning by ranchers, consultants, agency personnel, and agricultural producers to maximize potential success of future habitat restoration projects, given site and landowner constraints. This review focuses on the active planting and establishment of trees and shrubs along the upland rangeland riparian corridors that rim the Central Valley of California.

2.0. CALIFORNIA RANGELAND RIPARIAN RESTORATION USING NATIVE TREES AND SHRUBS

The streams, sloughs, and springs in and above the Central Valley vary widely in their timing and persistence of water. In many cases, flows in canals and sloughs that now serve as vital water delivery systems for agriculture differ hydrologically from their historical patterns (Grantham et al. 2010). Variation in the availability of water (via surface flows and groundwater) affects the vegetation that can be supported and the potential habitat that can be created in riparian corridors (Figure 1). Waterways that are perennial rather than ephemeral support more types of species. Associated with this higher biodiversity are greater productivity, carbon storage, and habitat complexity. Waterways serve as reservoirs from which beneficial organisms gradually disperse into the managed ecosystems in the landscape (Bengtsson et al. 2003, Gonzalez et al. 2009). Yet several studies have shown that habitat degradation in rangeland riparian corridors is very common in California. For example, plant and soil biodiversity in rangeland riparian corridors is only somewhat higher than along intensively-managed cropland waterways in Yolo County (Culman et al. 2010; Young-Mathews et al. 2010). While rangeland waterways had higher riparian health scores than cropland waterways using a rapid appraisal method (Ward et al. 2003b), a high abundance of invasive plant species and marginal soil quality present constraints to the successful establishment of native perennial plant species for habitat restoration in rangelands.

For a prospective restoration site, an initial assessment of the ecological status of the existing riparian ecosystems is very helpful in determining the most appropriate plant choices, restoration strategies, and management along reaches of different types and levels of degradation (Kauffman et al. 1997). The riparian corridor can then be partitioned into zones based on this initial ecological assessment: 1) areas which are relatively intact; 2) disturbed areas capable of rapid recovery; 3) disturbed areas probable to experience slow recovery; and 4) extremely degraded areas where restoration is not feasible.

FIGURE 1. Riparian corridors in grazed oak woodlands in California, with ephemeral or perennial streams.

FIGURE 2. TubeX shelters with tree and shrub seedlings in a riparian corridor in an oak woodland which was subsequently grazed by cattle. It was not feasible to use drip irrigation due to variations in microtopography, the large reach (>1 mile), distance from a reliable water source, and trampling of the drip tubing by cattle. Hand-watering and DRiWATER® were used (Table 3).

Reaches that are relatively intact are best suited to passive restoration, such as by cessation of livestock grazing. On more disturbed sites where recovery of habitat and ecosystem services is deemed feasible, decisions are usually made to restore reaches where current land use practices can be continued without large financial investments (Figure 2).

Active planting of woody plants is not necessary for passive restoration due to rapid reinvasion of native vegetation that occurs when favorable site characteristics and nearby colonization sources exist. Active restoration projects are conducted when the potential for local re-invasion and establishment of native woody plants is not feasible due to removal or disturbance (Kauffman et al. 1997). In many rangeland locations in the Coast Range and Sierra Nevada foothills of the Central Valley, historical information does not exist about native riparian vegetation, original flow regimes, or the reasons for loss of woody vegetation. Thus, active restoration projects often depend on current conditions and objectives, rather than reconstructing intact or original ecosystems (Higgs et al. 2014). The choice of plant species and management options are then set up to accommodate existing heterogeneity such as gaps, clearings, microtopography, and water flow patterns.

3.0. PLANNING STRATEGIES FOR RIPARIAN RESTORATION IN CALIFORNIA RANGELANDS

The priorities for establishing vegetation and habitat restoration on the reach of a stream vary among land managers. Aiming for multifunctional benefits is desirable, yet it increases the complexity of the design and management plan for a restoration project. Creating wildlife habitat often requires a different design and set of inputs compared to integrating other ecosystem functions such as soil and water quality, carbon sequestration, biodiversity, aesthetics, and recreation. Long-term stewardship is a big commitment, and may be perceived as more worthwhile if the investment achieves multiple ecosystem services. On the other hand, a simpler design with a more limited scope of objectives may be more viable in situations when costs are a constraint, and monitoring and post-establishment management are not feasible.

The reasons for choosing to invest in riparian restoration are diverse and numerous. Vegetated buffers not only can diminish water temperature, but also reduce sediment, phosphorus, and nitrogen (N) discharge to drainage water in agricultural areas (Osborne and Kovacic 1993). A vegetative buffer strip acts as a sponge that filters and can reduce the amount of runoff (Hubbard et al. 2004). Vegetated buffers can reduce stream bank erosion and increase water infiltration by providing a root structure that stabilizes soil (Florsheim et al. 2008). The water quality of upland rangelands is very important for entire watersheds because these areas are often the headwater tributaries for larger rivers (Lewis et al. 2002). Riparian restoration in California rangelands has been shown to improve the aquatic habitat for fish and density of native trees and shrubs and thereby increase watershed functions (Lennox et al. 2009).

It is estimated that two-thirds of California's drinking water passes through or is stored in oak woodlands (O'Geen et al. 2010). Vegetated buffers reduce pathogenic materials that contaminate waterways (Tate et al. 2004; 2006); even buffers of <2 meters width effectively filter pathogens. They also reduce nitrogen runoff through the process of denitrification, infiltration, and plant uptake (Hill 1996), but the magnitude varies according to various factors, such as the slope, the type of hydrologic flow path, and the presence or absence of a durapan that forces water to move laterally through the surface soil. For an oak woodland watershed at a research station in the Sierra Nevada foothills, where riparian corridors were relatively undisturbed, little loss of nitrate occurred via streamflow indicating net nitrogen storage in the ecosystem, highlighting the value of vegetated riparian corridors for water quality benefits (O'Geen et al. 2010).

Soil quality in vegetated buffers along creeks may increase only slowly after restoration. The accumulation of soil carbon and nitrogen depends on several factors, such as whether channels are susceptible to scouring (Smukler et al. 2010) and whether the area is grazed by livestock or not. Soil biodiversity, as indicated by nematode community composition along a lowland floodplain in Yolo County, showed no differences between restored and non-restored areas, but was higher in ungrazed zones of the creek (Briar et al. 2012). This may be because ungrazed sites provide higher vegetation cover and greater supply of soil nutrients and food sources which support more diverse groups of nematodes. The lack of effect of native vegetation restoration on trophic complexity of the nematode community may be due to slow changes in soil properties, heterogeneity in plant species establishment, or lack of colonization of soil fauna from other riparian areas due to the fragmentation of the landscape.

Attraction of beneficial insects for pollination and pest management (e.g., predatory and parasitic insects) in nearby fields is another benefit of riparian buffer strips (Steingröver et al. 2010). The Xerces Society (http://www.xerces.org/) has been collecting data for pollinators in California rangelands and recently released a booklet on habitat assessment (Jordan et al. 2014). A study of native bees in Northern California showed that both the amount and the stability of pollination services increased with increasing area of upland habitat (riparian forest, chaparral and oak woodland) which, in Northern California, is mostly provided by private ranches (Kremen et al. 2004). For some insect and disease pests, information exists on their distribution and habitat preferences in riparian corridors in California. For example, the Western Boxelder Bug (*Boisea rubrolineata*), a pest in orchards, is found on riparian maples and blackberries (UC IPM 2015a). Pierce's disease (X*ylella fastidiosa*) on grapes is vectored by the blue-green sharpshooter, (*Graphocephala atropunctata*), whose principal breeding habitat is riparian vegetation. Yet riparian corridors also provide habitat for beneficial insects, such as a tiny wasp (*Anogrus epos*) on wild blackberries that controls the grape leafhopper (*Erythroneura elegantuala*) (Folliott and DeBano 2003). Despite these examples, the ecosystem services for pest management that are provided by rangeland riparian corridors are poorly known, especially since so little is known about long distance movement of insects between land use types.

Landowners cite economic concerns as one of the main constraints to habitat restoration, despite the existence of cost-share programs (Brodt et al. 2009). High establishment costs, maintenance responsibilities and cost, and the time commitment for the design and establishment activities are problematic. In one publication on California rangelands, the private financial costs and benefits accrued by ranchers from restoration practices are quantified separately from the large set of public benefits such as carbon sequestration, water quality, and biodiversity conservation that pertain to society as a whole (Kroeger et al. 2010). One of the most important findings is that without cost-share assistance to ranchers, conservation practices on rangelands are not financially viable, i.e., net costs outweigh private benefits. The study concludes that rangeland conservation practices require the creation of markets for ecosystem services for which there is no current compensation, and that currently the decision to adopt restoration practices rests with each individual landowner (Note that information on financial costs, from this and other publications and websites, will be explained in Section 4.5 below).

While increasing the biodiversity in upland riparian corridors depends on individual landowners in California, the importance of social dimensions should not be underestimated. Adoption and diffusion of innovations are often stimulated by sociocultural processes such as neighbor-to-neighbor communication, and the prevalence of local public and private sector programs that provide technical and financial assistance (Brodt et al. 2009). Several programs in California recruit students for different phases of restoration work (Figure 3). In areas where an individual or family takes on a demonstration role in a community, their championship of restoration provides practical and useful models to other landowners. Yet, it is quite difficult to evaluate the types of benefits that are achieved through social bonds and networks, stewardship satisfaction, aesthetics, and the future option values from increased biodiversity in the landscape over the long-term (Pascual and Perrings 2007).

FIGURE 3. The costs of restoration can be mitigated by enlisting volunteers (university students, scouts, 4H members) for labor-intensive events like planting or installing irrigation.

4.0. TECHNICAL ASPECTS OF RIPARIAN RESTORATION IN CALIFORNIA RANGELANDS

Designing a riparian restoration project is often done over a period of years, with ideas and input from several different sources. Planning of the projects is often aided by staff in the USDA-NRCS, non-governmental organizations (such as Audubon California, Wild Farm Alliance, or Community Alliance with Family Farmers), and/or the local Resource Conservation District (http://www.conservation.ca.gov/dlrp/rcd/pages/index.aspx), either formally or informally. When cost-sharing is involved, agents from government agencies help to meet required criteria. To understand the permit and regulation process (such as by California Department of Fish and Game, the Army Corps of Engineers, and the State Water Resources Control Board), an excellent source to begin with is the Capay Valley Conservation and Restoration Manual (Howard and Robins 2002). Since woody species are usually transplanted, nursery owners also provide experience on taxa and genotypes for different environmental situations.

Many rangeland riparian restoration projects have been designed by landowners, and their individual experiences (both successes and failures) have rarely been documented in detail for others to learn from. But guidelines do exist, and here will be summarized from several publications that have mainly dealt with projects on farms (Howard and Robins 2002; Robins et al. 2001; Earnshaw 2004; Long and Anderson 2010; Kroeger et al. 2010). As a starting point, Lewis et al. (2009) emphasize the need for clearly stated goals and objectives that are 'specific, measurable, achievable, and time-based'. Rather than emphasize the details of the planning process here, a habitat restoration planning worksheet is included as the final document in this booklet (Fyhrie et al., Part V of this booklet).

A stepwise approach by Long and Anderson (2010) for establishing hedgerows on farms provides guidelines that are relevant for selecting, analyzing, designing, and preparing a rangeland riparian site for active restoration and planting. It is largely copied here, with some paraphrasing:

1. Farm plan for the restoration site
    a. Identify the habitat restoration goals (e.g., wildlife habitat, water and soil quality, streambank stability), decide if the project is well-suited for the site, and determine whether particular reaches at the site satisfy specific goals
    b. Consult an aerial map to examine topography, hydrology and drainage, land use types nearby, and buildings
    c. Determine potential funding sources
2. Site selection
    a. Choose sites accessible by equipment for construction and maintenance
    b. Ensure water availability for shrubs and trees for at least the first three years or until the plants have roots deep enough to withstand the summer drought
3. Site analysis
    a. Determine heterogeneity in soil type, potential flooding, and obstructions
    b. Search for high and low spots for standing water
    c. Examine potential for damage to plantings from livestock, traffic, or deep shade
4. Planning and design
    a. Draw the site to scale, showing the distribution of plant species in the planting layout
    b. Use linear plantings for the ease of equipment use, e.g., mowers, disks, or sprayers
    c. Border riparian edges with bands of native grasses, sedges, or rushes, or a single row of shrubs or trees on a berm above the water edge
5. Plant selection
    a. Choose plant species that are adapted to the microclimate and microtopography conditions at the site
    b. Avoid California native plants not suitable for standing water, as listed in Table 1 in Long and Anderson (2010). (Further details on plant environmental requirements can be found in Section 4.3)

6. Site preparation and planting
    a. Prepare soil as feasible. Whereas the recommendation for hedgerow sites is disking and shaping, this is often not possible in stream corridors
    b. Plant in fall to boost establishment
    c. Place large shrubs 15 feet apart, as compared to 7.5 feet for smaller species
    d. Space trees 20 to 30 feet apart
    e. Fertilize with compost or slow release fertilizer
    f. Irrigation depends on plant evapotranspiration and soil type, and is recommended every one to two weeks for three years for farm hedgerows, which may not be feasible in rangeland riparian locations
    g. Water tanks can be used for irrigation with pumps and drip tape. This is often not possible in steep stream corridors

7. Weed control
    a. Mulches, such as walnut shells or compost, are the most cost-effective and long-term solution for weed control
    b. Herbicide options are explained in Long and Anderson (2010) or consult the University of California Weed Research and Information Center (WRIC) at http://wric.ucdavis.edu/
8. Rodent control
    a. Plastic tree tubes installed at the time of planting help reduce gopher and vole damage
    b. Barn owl boxes will attract owls that prey on rodents
    c. Rodenticides may be necessary in outbreak years, although the risk is that non-target species such as birds also become vulnerable
9. Maintenance
    a. Yearly weed management is recommended after July when the bird nesting period is over
    b. Occasional summer watering is good for established shrubs and trees, especially during drought years
10. Costs
    a. $3847 is the estimated three-year cost for establishing and maintaining a 1000-foot-long hedgerow's shrubs, trees, native grasses and forbs on a farm in the Central Valley
    b. Weed control is the single largest expenditure ($1,065)

The steps outlined above are Long and Anderson's (2010) suggestions for establishing hedgerows on California farms, which are applicable to a range of revegetation projects. Details specifically pertaining to restoring riparian corridors follow in Sections 4.1 to 4.5.

By properly integrating plantings into the overall farm plan, installing clear signage to communicate the presence and purpose of the revegetated area, and treating native vegetation as a crop in its own right, the restoration plan should contribute to rangeland production both functionally and aesthetically (Earnshaw 2004). Sadly, one of the main causes of overall failure in native plantings is unintended destruction by tractor or work crews (Earnshaw 2004).

To prevent other causes of plant loss, i.e., from weeds, deer and rodent damage, lack of water, and over fertilization (Earnshaw 2004), and to better achieve proper location of plants and adaptation to site conditions, helpful information on technical options is provided by many sources (see list of websites in Table 1). Some publications give details on the initial site inventory, planning and design, maintenance and follow up. Others provide details on the environmental requirements of individual species. There is also scientific literature on the habitat and ecophysiological preferences for the woody shrubs and trees usually used in habitat restoration (See Section 4.3). Substantial effort is required on the part of the landowner or the restoration agency to develop a detailed farm plan using these sets of instructive but dispersed information.

TABLE 1. Some examples of websites providing information on California native plant geographic ranges, environmental requirements, potential to attract wildlife, management, and/or costs.

Organization	Website
California Native Grass Association (CNGA)	www.cnga.org
California Native Plant Society (CNPS)	www.cnps.org
Calflora	www.calflora.org
Lady Bird Johnson Wildflower Center	www.wildflower.org
The Xerces Society	www.xerces.org
Cornflower Farms	www.cornflowerfarms.com
UC Davis Arboretum	arboretum.ucdavis.edu
Las Pilitas Nursery (Santa Barbara)	www.laspilitas.com/plants/plants.htm
USDA NRCS Plants Database	plants.usda.gov/java

4.1. Soil and site preparation

The hilly rangelands in Central California often have narrow riparian corridors that contain high spatial variation in short distances along a reach. The deposition of sediment is patchy, either due to steep slopes or fluvial scouring when storm flushes occur. Compared to waterways in flatter terrain in valleys, rangeland riparian corridor sites contain more heterogeneity in soil characteristics and topography (Young-Mathews et al. 2010). As an example, a detailed analysis of two riparian corridors at the Audubon Bobcat Ranch in Yolo County showed a very large range in soil texture (up to 5-fold difference in clay content), soil total carbon (10-fold) and nitrogen (5- to 7-fold), and soil moisture (up to 5-fold) in the zone of about 75 feet from the water's edge (Table 2) (Hodson et al. 2014). The patchiness of soil and rocks is thus a major factor in designing restoration projects in upland riparian corridors. Situations with high variation over short distances and abrupt rather than gradual shifts in substrate require detailed analysis of microsite conditions and management options (Figure 4).

FIGURE 4. Variation in microtopography along a riparian corridor in California rangeland.

TABLE 2. Soil properties in the 0 to 7.5 cm depth of the soil profile at two riparian sites with seasonally dry creeks at Audubon Bobcat Ranch in Yolo County, CA. The study area at each site was located 100 m (328 feet) along the waterway within 25 m (82 feet) of the creek edge. Plant communities were dominated by manzanita *(Arctostaphylos glandulosa)*, toyon *(Heteromeles arbutifolia)*, and blue oak *(Quercus douglasii)* but also included redbud *(Cercis orbiculata)*. From Hodson et al. (2014).

Soil variable	Riparian Site 1	Riparian Site 2	Riparian Site 1	Riparian Site 2
	Range	Range	Mean	Mean
pH	7.19-8.32	6.25-8.42	7.7	0.3
EC (uS/cm^2)	42.2-253	47.9-268	100.1	52.8
MBC*(ug C/g)	146-846.2	142.4-736.4	327.7	163.5
Nitrogen (mg/g)	0.08-0.41	0.06-0.44	0.2	0.1
Carbon (mg/g)	1.1-11.4	0.8-8.5	3.8	2.5
C:N	12.8-35.9	12.6-29.9	20.5	6.8
NH_4^+-N (ug/g)	1.6-5.4	1.2-6.3	3.0	0.9
NO_3^--N (ug/g)	0-0.52	0-0.49	0.1	0.1
Moisture	0.17-0.89	0.25-0.64	0.4	0.1
Clay (%)	2.9-17.1	4.2-9.1	7.2	3.6
Silt (%)	22.1-62.2	30.2-54.7	41.6	9.8
Sand (%)	20.7-74.9	38.4-65.4	51.1	13.2

**Microbial biomass carbon*

Site characteristics affect water availability and the ability of plant roots to explore deep layers in the soil profile for water and nutrients. Soil texture (i.e., percentage of sand, silt, and clay), soil organic matter (SOM), and the presence/absence of compacted or cemented layers (such as durapans) affect root exploration for deeply stored soil water. For example, clay content is typically associated with higher nutrient adsorption and availability, but high clay content makes root elongation difficult when soil is dry. These types of constraints must be considered when planning habitat restoration projects. (See Section 4.3 for more information on the survivorship of woody plant species in relation to soil characteristics).

The best source for information about soil types and soil properties in specific locations is the SoilWeb: An Online Soil Survey Browser (http://casoilresource.lawr.ucdavis.edu/soilweb/) (Figure 5). It allows the internet exploration of areas that are mapped by the USDA-NCSS detailed soil survey data (SSURGO). With an interactive Google map, it is possible to view detailed information about map units and their components at high resolution along any stream reach in California (Figure 5). This application is compatible with desktop computers, tablets, and smartphones. Digging a soil pit in one or more zones along the reach helps to understand how the soil at a specific location differs from the features described in the soil type descriptions in the soil survey (Figure 6). Each soil type in SSURGO is characterized by one soil pit in one place in California, and while very useful, this does not allow for any site-specific features to be shown.

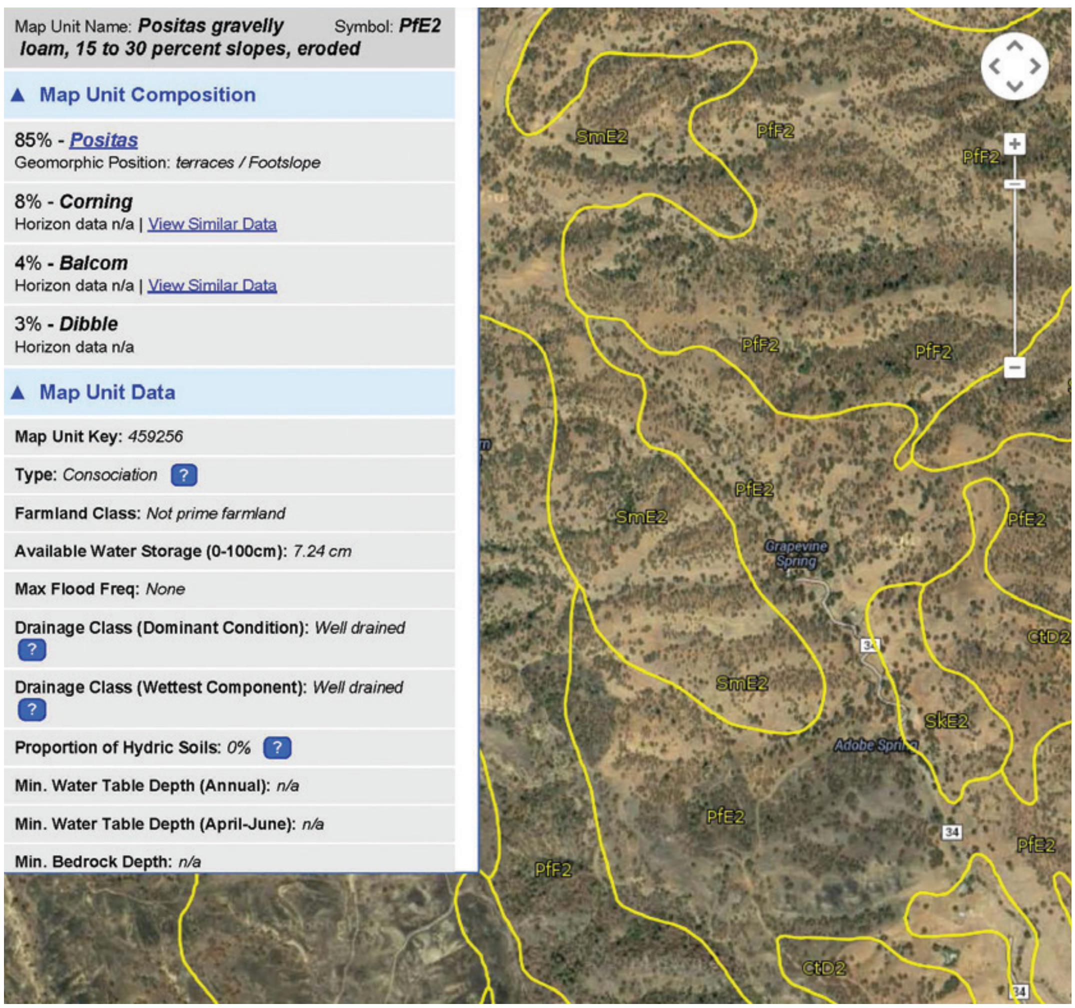

FIGURE 5. Example of a riparian corridor and surrounding soil map units as shown on SoilWeb: An Online Soil Survey. By clicking on a point in a PfE2 polygon, the information on the map unit is shown on the left. The map unit contains 85% Positas gravelly loam, 15 to 30 percent slopes, eroded, with smaller areas of Corning, Balcolm and Dibble soil types. The location is west of Winters, California.

FIGURE 6. Soil pit description and sampling along the floodplain of a rangeland riparian corridor.

Certain soil properties affect growth of native plant species in the riparian corridors of semiarid and arid western North America (Perry et al. 2012). Nitrogen availability, for example, limits riparian plant growth in at least some riparian ecosystems (Adair and Binkley 2002). Most of the plant-available nitrogen in these ecosystems comes from litter decomposition and associated nitrogen mineralization, or from sediment deposition and streamwater during floods. The seasonality of soil moisture can impact nitrogen availability by affecting litter production, decomposition, and nitrogen cycling (Adair et al. 2004; Schade et al. 2002). Lower soil moisture and decreased flooding during drought years impedes the soil microbial and stream processes that deliver nutrients to plant roots, along with causing greater water stress. The choice of plant species should therefore depend on knowledge of temporal in addition to spatial soil heterogeneity (See Section 4.3). For example, low-gradient reaches of riparian zones with finely-textured soils that become water-saturated are suitable for plants tolerant of anaerobic conditions, such as sedges (*Carex spp.*), rushes (*Juncus spp.*), or hydrophytic grasses, but would not be appropriate for cottonwoods or willows (Kauffman et al. 1997). If observations occur, however, under conditions when saturation-prone soils are uncharacteristically dry, this important aspect of soil heterogeneity may not be noted. Thus, choosing restoration sites and planning a planting design benefit from knowledge of the soil, slope, and stream channel heterogeneity along specific reaches in both wet and dry years.

In turn, riparian vegetation influences stream bank stability since plant cover and roots minimize bank erosion (Florsheim et al. 2008). Generally, bank erosion is considered as a negative phenomenon. For example, the deposition of fine-textured sediment is problematic when water flow rates are low, since habitat for aquatic organisms becomes buried. Erosion of stream and river banks is a natural geomorphic process which can also play important roles in the ecology of riparian organisms. Bank erosion from headwater areas is a source of coarse sediment that provides aquatic habitat by promoting oxygen exchange, protection from predators, and places where small aquatic animals can attach. In addition to vegetated banks, fine-sediment erosion can be held in check by other bank stabilization strategies, such as stones that are placed as miniature retaining walls within the corridor. Stone toe protection is when stones are placed longitudinally along the toe of the eroding bank, acting like a small dyke that deflects the water flow away from the bank and thereby stabilizes the bank and creates small microsites of sediment among the stones (Johnson 2003). Alternatively, stones can be distributed to create pools and riffles to slow down water movement in a severely eroding or downcutting stream. These are methods that are much cheaper than traditional steel, riprap, and cement structures. In a manual on restoration of California salmonid stream habitats, details are given on the selection and use of hard and soft materials for larger intrusive structures, which may be relevant to rapidly-eroding reaches in ranchlands (Flosi et al. 1998, pp. 7-11).

Technologies for soil preparation to overcome site constraints to plant establishment (such as very steep slopes, flooded patches, or rocky surfaces) include land movement, berm creation or contouring, soil tillage, mulches, and deep planting into pre-cored holes (Eubanks et al. 2002). Protecting young plants from flooding, for example, can be achieved by creating a raised berm or ridge. When this is not feasible, mounds can be formed around each seedling (Earnshaw 2004). Loosening the soil to encourage root exploration and improve plant establishment is often used for establishing hedgerows in croplands. In upland riparian corridors, disking and grading is possible at more level sites (Long and Anderson 2010), but it may be impossible on steeper sites due to expense or difficulty of access by heavy equipment.

Auguring deep, wide holes for planting is an alternative to disking and grading a site (Figure 7). This loosens the soil for exploration by seedling roots and disrupts hardpans that block root access to deeper layers where soil moisture is likely to be higher. Adding a small amount of compost and/or rock phosphate or bone meal to the planting hole improves nutrient availability, and the backfilled hole as well as the surrounding soil around the hole should be moist at planting time (Earnshaw 2004).

FIGURE 7. Auguring 1- to 2-ft deep holes prior to planting seedlings or acorns. The landscape view shows the slope of the terrain that permits access with the excavator/digger machinery.

4.2. Irrigation and local hydrology

Planning for adequate water for successful establishment and productivity of native trees and shrubs must reconcile the uncertainty of rainfall in California's dry summer climate with the difficulty of installing and maintaining irrigation systems along upland riparian corridors that may be distant from roads and on rugged terrain. Providing supplemental irrigation is recommended for the first three years to improve plant survival and establishment (Long and Anderson 2010), but understanding a site's soil and hydrologic conditions is also critical in planning for the short- and long-term success of a riparian revegetation project.

A river's hydrograph is a graphical illustration of the pattern of daily surface water during the year, which indicates periods that are seasonally wet and dry, and how streamflow responds to rain events. A natural hydrograph for California rivers and streams will resemble an inverted U shape with peak flows in the winter and spring (November to June), with flows that rise and fall smoothly relative to rainfall and runoff (Griggs 2009). Understanding patterns of peak flows and stream levels is important for deciding on reaches to target for restoration sites, as well as appropriate plant species. Riparian plant species are adapted to specific hydrologic conditions for survival and reproduction. Therefore, riparian natives will not naturally establish or reproduce under significantly altered regimes, and may not survive long-term if maladapted to the timing or duration of a river's flood events (Griggs 2009). More passive restoration projects are possible in riparian corridors which retain relatively natural hydrographs, while active restoration is necessary for rivers and streams with highly altered hydrographs (i.e., as a result of dam construction).

For information on watersheds throughout California, there are several websites that can be consulted for either general assessments of specific counties, or for descriptions of specific riparian corridors (Griggs 2009). These include the UC Davis California Watershed Assessment Manual (http://cwam.ucdavis.edu/), and the UC Davis ICE California Rivers Assessment Interactive Web Database (http://www.ice.ucdavis.edu/newcara/). These resources are most useful for providing relevant information on the broader spatial context of a potential restoration site (i.e., free-flowing reach miles, vegetation types, precipitation, and land use). Such criteria, in addition to specific site characteristics and heterogeneity, are crucial to successful project planning.

Fine-tuning the detailed planning of a restoration project also requires an understanding of hydrologic conditions specific to the site. Digging backhoe pits or soil auger holes at several locations across the restoration site, with guidance from a soil survey map (Access via SoilWeb interactive maps at http://casoilresource.lawr.ucdavis.edu/soilweb/), will help to identify water table depth and soil stratification patterns that may be best suited to different woody plant species (Griggs 2009). Depth to the water table can also be measured with multiple piezometers (i.e., tubes placed into the ground that reach the groundwater table), if the reach has a broad floodplain and water appears to be close to the surface. Of particular importance is the variation in the depth to the water table in winter vs. summer at various distances from the water's edge.

It is also important to note how soil textures change with depth. Layers of different soil textures occur as a result of past and present sediment movement in and along the channel, which can greatly affect the movement of irrigation water through the soil profile. Consequently, plant root growth is also affected. If coarse sediments (sand and gravel) sit above finer silts and clays, seedlings must quickly develop deep roots to reach the layers with higher water-holding capacity (Griggs 2009). In highly stratified soils, digging deep planting holes with a post-hole augur or backhoe will permit the roots to more easily develop downward in the soil profile. Observing soil texture patterns can also help guide species choice for a restoration project. For example, cottonwood and sycamore are species that grow rapidly in soils that have a high proportion of sand, while valley oak establishes well in heavier soils composed mostly of silt and clay (Griggs 2009).

Reliance on flood irrigation is not dependable in the heterogeneous channels of most rangeland riparian sites. Drip irrigation is more reliable, but the pressurization and a constant water supply can be a challenge. Stand-alone well systems are useful in remote locations where it would be too expensive or difficult to install a power line. Solar-powered pumps are increasingly available as cost-effective and durable options. But management of drip irrigation on solar wells still requires care and vigilance.

Thinking ahead to future decades, when the water supply may be even more variable than today (Moser et al. 2012), is an important exercise in planning the details and extent of the restoration project. Urban and agricultural water use is drawing down groundwater below the roots of riparian vegetation along upland rangeland streams in several areas throughout the West (Perry et al. 2012; Seavy et al. 2009). Additionally, climate change is expected to change streamflows in semiarid and arid western North American riparian ecosystems (Perry et al. 2012). Information on climate change projections for different regions of California can be found on Cal-adapt, an interactive website provided by The California Energy Commission (http://cal-adapt.org/). A general expectation is that climate change will manifest as lower late-spring and summer streamflows, which will add to the drought susceptibility of riparian organisms including vegetation during late summer and fall. Steep stream gradients or younger geomorphic surfaces with coarse-textured soils are likely to be more vulnerable to reduced water availability than ecosystems on fine-textured soils (Naiman et al. 2005). Although there are adaptation options at the landscape scale, such as securing water rights for environmental flows or implementing water conservation measures (Palmer et al. 2008), they may have more impact on the main rivers and agricultural valleys in the state, as compared to outlying smaller upland rangeland riparian corridors. Thus, planning ahead for resilience to water stress is likely to ensure the longevity of the restoration project.

Some guidelines exist for dealing with low water availability and high spatial and temporal moisture variability in rangeland riparian restoration projects. Pre-irrigation is deemed essential, and irrigation during the first two to three years greatly improves establishment (Earnshaw 2004; Long and Anderson 2010; Russell et al. 2008). As was mentioned previously, survival of trees and shrubs planted in upland rangeland sites without irrigation in Yolo County was only 30 percent, with a range from 24 to 70 percent variation (Audubon 2005). Three tree species had the highest survival rates across all the sites: blue oak (*Quercus douglasii*), live oak (*Quercus wislizenii*), and foothill pine (*Pinus sabiniana*). (See Section 4.3 for more information on the habitat preferences of these species).

Since irrigation in remote upland rangeland riparian habitats is so difficult to maintain, there is interest in other options for increasing soil moisture. For example, DRiWATER® (http://www.driwater.com/) is a patented, natural gel made of food-grade vegetable gums that gradually breaks down when exposed to soil (Figure 8 and 9). It apparently has had success among landscapers and nurseries. The product is described as follows:

> "DRiWATER® is made from 98% potable water and 2% food grade ingredients. These ingredients bind the water into a solid gel. When the gel comes in contact with naturally occurring enzymes in soil, the enzymes slowly break down the gel, releasing moisture into the soil delivering moisture to plants between 40 and 90 days. DRiWATER® is not an absorbent polymer or a wetting agent – DRiWATER® is natural and environmentally safe."

FIGURE 8. DRiWATER® gel is inserted into a biodegradable plastic tube or cardboard carton that is placed a few inches from a planted seedling, and is easily refillable. Photos are from the DRiWATER® website (http://www.driwater.com/).

FIGURE 9. Cartons of DRiWATER® gel on each side of a coffeeberry seedling.

A recent experiment at the Audubon Bobcat Ranch just west of Winters, California, has been testing the effectiveness of DRiWATER® at a restoration site, where 280 young trees and shrubs were installed in the winter of 2012 along the roadway near a seasonally dry creek (Hodson et al., Part II of this booklet). Plastic TubeX tree shelters were used to protect plants from herbivory (Figure 10). Two different water management treatments were used to maintain plantings during the summers of 2012 and 2013: some were irrigated once per month from April through September with approximately two to four gallons of water around the crown, while others were supplied with two cylinders of DRiWATER® at the same frequency. Both 2011-2012 and 2012-2013 were dry years, with only 71 cm of precipitation at the Winters CIMIS weather station (www.cimis.water.ca.gov). The distribution of plant health scores between management treatments was tested for each species by Chi squared tests. This analysis tests the null hypothesis that the relative proportions are independent between categories, i.e., that management has no effect on the distribution of observations between health score categories. Hand-delivered irrigation water was just as effective as DRiWATER® for four of the species (buckeye (*Aesculus californica*), live oak (Q*uercus wizlenii*), foothill pine (*Pinus sabiniana*), and western redbud (*Cercis orbiculata*)), and levels of survivorship were similar for both treatments (Table 3). DRiWATER® was simpler to use, since no water tank was necessary. For remote locations without road access, these results suggest that using DRiWATER® may be a preferred choice compared to other irrigation options. But there is an important caveat, which is that perhaps neither treatment in this experiment added enough water to promote plant survivorship, as there was no unwatered control, and the experimental period was exceptionally dry.

FIGURE 10. Foothill pine in a TubeX tube tree shelter.

TABLE 3. Survivorship of woody plant seedlings in December 2013, nearly two years following planting in February 2012, with either DRiWATER® or monthly hand-watering each summer month.

	% survivorship	
Native species of woody plant	DRiWATER®	Hand-delivered irrigation
Buckbrush *(Ceanothus cuneatus)*	75.0	83.3
Buckeye *(Aesculus californica)*	66.7	63.1
Live Oak *(Quercus wizlizenii)*	58.6	52.4
Foothill Pine *(Pinus sabiniana)*	93.3	82.6
Western Redbud *(Cercis orbiculata)*	68.5	77.3

4.3 Selection of plant species

Choosing species of native shrubs and trees for a restoration project in California upland rangelands requires knowledge of their habitat preferences and life history characteristics. To our knowledge, no detailed source exists for their suitability for different restoration situations in rangeland riparian corridors. Several publications give overview information. For example, CAFF (Earnshaw 2004) lists >100 native shrubs, trees, graminoids, and forbs coded as to their suitability for coastal, Central Valley, or foothill region hedgerows, and their source of nectar and pollen to hummingbirds, insect predators, parasites, and bees (This list is too long to include here). A list of species for riparian areas in Yolo County is given by Howard and Robins (2002, p. 95). Based on information from websites of the Xerces Society (http://www.xerces.org/plant-lists/) and the "Fire Effects Information System" of the USDA Forest Service (http://www.feis-crs.org/beta/), Table 4 shows species that are often used in California farmscaping and restoration projects along with some of their habitat preferences. Long and Anderson (2010) provide a list of plants that can tolerate standing water (shown as Table 5 in this report). Another approach discussed below is finding out more detailed information on candidate restoration species from botanical sources.

TABLE 4. Broad environmental requirements of some native shrubs and trees used in farmscaping and riparian restoration from the websites of the Xerces Society (http://www.xerces.org/plant-lists/ and the "Fire Effects Information System" of the USDA Forest Service (http://www.feis-crs.org/beta/). The table includes those species for which most of the information is available. NA = no available information from these websites

English name	Latin name	Water needs	Drought tolerance	N fixation	pH	Salinity tolerance	Soil
Mulefat	*Baccharis salicifolia*	moderate	low	no	6-8.5	moderate	NA
Buckbrush	*Ceanothus cuneatus*	low	high	yes	6-8.5	moderate	poor rocky
Western Redbud	*Cercis orbiculata*	low	moderate	yes	5.5-8	low	stream banks
California Fuchsia	*Epilobium canum*	low	high	no	5-8	low	NA
Toyon	*Heteromeles arbutifolia*	moderate	moderate	no	NA	moderate	well drained
Bush Lupine	*Lupinus albifrons*	moderate	low	yes	6-8	low	NA
Foothill Pine	*Pinus sabiniana*	moderate	low	no	6-8	low	dry rocky
Fremont's Cottonwood	*Populus fremontii*	high	low	no	NA	moderate	alluvial
Blue Oak	*Quercus douglasii*	low	high	no	4-8	NA	poor shallow
Valley Oak	*Quercus lobata*	moderate	high	no	6-8	moderate	deep rich
Interior Live Oak	*Quercus wizlizenii*	low	high	no	6-8	low	diverse
Narrowleaf Willow	*Salix exigua*	high	moderate	no	5-8	moderate	fluvial coarse

TABLE 5. Long and Anderson's (2010) list of woody plants for restoration sites that are or are not tolerant of standing water.

English name	Latin name
Woody plants that tolerate standing water	
Cottonwood	*Populus fremontii*
Elderberry	*Sambucus racemosa*
Rushes	*Juncus spp.*
Sedges	*Carex barbarae, Carex praegracilis*
Willow	*Salix spp.*
Woody plants that do not tolerate standing water	
Buckwheat	*Eriogonum fasiculatum*
California Lilac	*Ceanothus spp.*
Coffeeberry	*Rhamnus californica*
Coyote Brush	*Baccharis pilularis*
Toyon	*Heteromeles arbutifolia*
Western Redbud	*Cercis orbiculata*

Since spatial heterogeneity is particularly high within upland rangeland riparian sites, species must be chosen according to soil characteristics and hydrology in riparian microsites, and to the annual variability in drought and floods that are likely to occur (Kauffman et al. 1997). Understanding the heterogeneity of soil and hydrological features of a site can help to plan how to minimize the tradeoffs between adequate water availability and flooding in planting design. As one example, the natural establishment of cottonwood trees (*Populus spp.*) and willows (*Salix spp.*) occurs where high flows deposit coarse-textured sediment, and seedling germination occurs in late spring when moisture is readily available and the water table is high. But establishment is vulnerable to scouring of the channel under conditions of very high streamflow during large storm events.

The native shrubs and trees used in farmscaping and riparian restoration vary in their water demands, rooting patterns, drought tolerance, and ability to withstand dry summers. One example is the rooting depth of riparian species (Griggs 2009). Along some of the more persistent upland waterways, trees and shrubs can sink their deep roots down to a permanent, shallow water table (Figure 11). These phreatophytes are present in some, but not all, upland riparian corridors. They may have been removed in the past or lost in situations when groundwater drawdown has occurred. Just above the stream channel in some riparian corridors is a shrub zone, dominated by willows (Barbour et al. 1993). Their dense branches and prolific roots trap sediment creating a natural berm which in turn supports other phreatophytes, such as cottonwoods, usually slightly above the most scoured part of the stream channel where flooding is frequent. In less disturbed locations, riparian forest has many layers (i.e., trees, shrubs, vines, herbaceous plants) (Figure 12). The species diversity of these forests is one reason why they support some of the richest animal communities in California. But depending on the channel configuration and past history, this complex forest type is often absent in upland rangeland riparian corridors. At 10 to 30 feet above the water's edge, on the natural levees above the stream, more drought-tolerant species occur. These include valley oak (*Quercus lobata*), elderberry (*Sambucus spp.*), and coyote brush (*Baccharis pilularis*), and the configuration is typically more open woodland than the forest near the channel a few feet away.

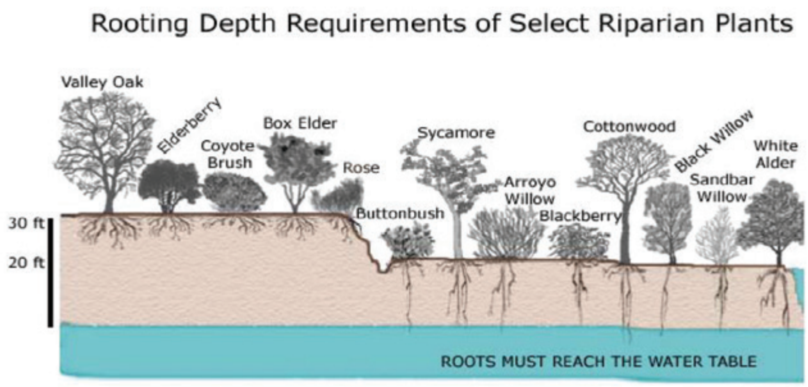

FIGURE 11. Rooting depths of selected riparian plants, according to the depth of the water table. Knowing the depth of the water table across the restoration site will help decide on the spatial distribution of species that will establish well and persist over the long-term. Excerpted from Griggs (2009).

FIGURE 12. Several layers of riparian vegetation occur along rangeland streams that are less disturbed. Almost all the species are perennials, and both deciduous and evergreen woody trees and shrubs are present.

The pioneer species (e.g., cottonwoods, willows) that require bare, moist substrates created by floods via scouring, sediment deposition, and channel movement for seed germination have strict hydrologic requirements for establishment (Perry et al. 2012). Such conditions are often not reliably present in upland rangeland riparian corridors, and the recent series of drought years highlights the unpredictability of consistent water availability. Even mature phreatophytic trees are adversely affected when water tables drop too far or too quickly, and while their roots may grow deeper to access gradually declining groundwater, they may not be the best choices for habitat restoration of the ephemeral upland riparian corridors. Using more drought tolerant trees and shrubs, such as those typically found in the plant communities of natural levees above the stream, is more likely to ensure establishment. In fact, the three tree species with the highest survival rates across the restored upland riparian sites in Yolo County (Audubon 2005) were members of foothill woodland communities (blue oak (*Quercus douglasii*), live oak (*Quercus wislizenii*), and foothill pine (*Pinus sabiniana*)) characterized by much hotter and drier regimes than riparian woodlands.

A practical set of recommendations for upland rangeland riparian corridors is to plant rushes, grasses, and sedges in the low-flow channel streambank zone (Figure 13); shrubs tolerant of inundation (e.g., willows) in the lower floodplain zone; and a mixture of grasses, shrubs, and trees in the upper floodplain zone (Howard and Robins 2002). The choice of species also depends on the existing vegetation, due to habitat preferences of different shrubs and trees. For example, in the study at Audubon Bobcat Ranch (Section 4.1 and Table 3), the establishment of buckbrush (*Ceanothus cuneatus*) was negatively affected by proximity to native perennial grasses (Hodson et al., Part II of this booklet). Foothill pine (*Pinus sabiniana*) grew better under a shaded tree canopy. Examining the details of different species' preferences and attributes can help with designating planting spots in sites where perennials are already prevalent.

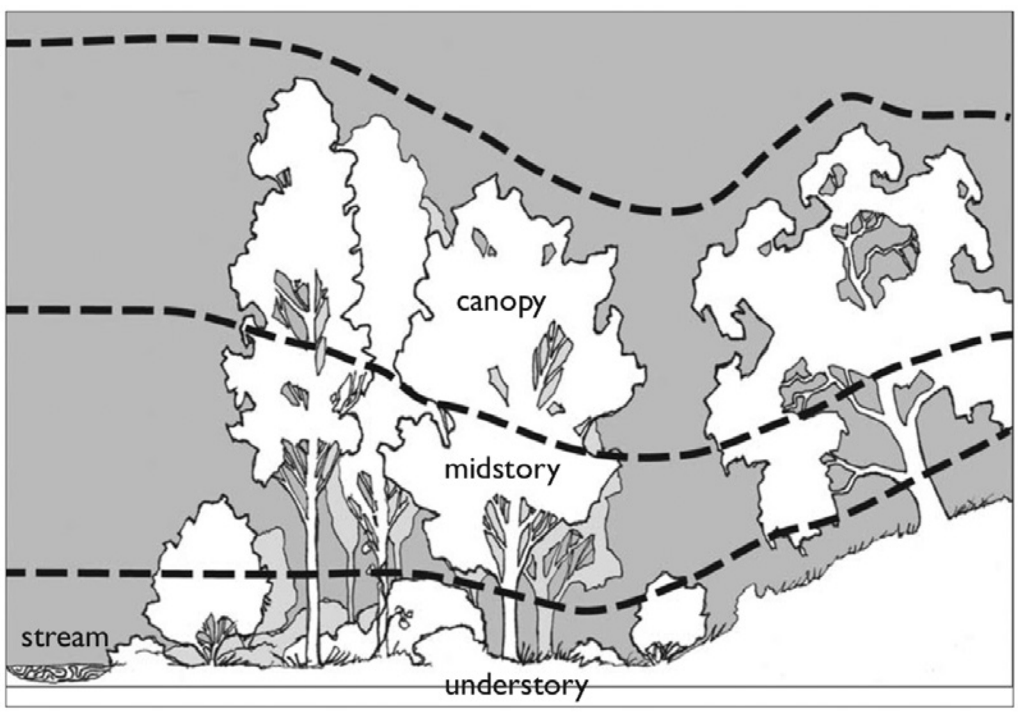

FIGURE 13. Schematic diagram of different zones along an upland rangeland riparian creek. Excerpted from CalPIF (2008).

A valuable source of detailed information on the preferred habitats, attributes and stress tolerances of native plants is the webpage titled "Fact Sheets & Plant Guides" of the Plants Database of the USDA Natural Resource Conservation Service (http://plants.usda.gov/java/factSheet). For the following native woody species, a two to five page summary on the description of the plant, its habitat, propagation, establishment and management are available:

Aesculus californica (California buckeye)
http://plants.usda.gov/plantguide/pdf/cs_aeca.pdf

Ceanothus cuneatus (Buckbrush)
http://plants.usda.gov/plantguide/pdf/cs_cecu.pdf

Cercis orbiculata (Western redbud)
http://plants.usda.gov/plantguide/pdf/cs_ceor9.pdf

Heteromeles arbutifolia (Toyon)
http://plants.usda.gov/plantguide/pdf/cs_hear5.pdf

Pinus sabiniana (Foothill pine)
http://plants.usda.gov/plantguide/pdf/cs_pisa2.pdf

Populus fremontii (Fremont's cottonwood)
http://plants.usda.gov/plantguide/pdf/cs_pofr2.pdf

Quercus douglasii (Blue oak)
http://plants.usda.gov/plantguide/pdf/cs_qudo.pdf

Quercus lobata (Valley oak)
http://plants.usda.gov/plantguide/pdf/pg_qulo.pdf

Quercus wizlizenii (Interior live oak)
http://plants.usda.gov/plantguide/pdf/cs_quwi2.pdf

Salix exigua (Narrowleaf willow)
http://plants.usda.gov/plantguide/pdf/cs_saex.pdf

More detailed physiological information, especially with respect to water use, drought tolerance, growth rates, and site characteristics, is available on the "Fire Effects Information System" of the USDA Forest Service (http://www.feis-crs.org/beta/) for the following species:

Aesculus californica (California buckeye)
http://www.fs.fed.us/database/feis/plants/tree/aescal/all.html

Ceanothus cuneatus (Buckbrush)
http://www.fs.fed.us/database/feis/plants/shrub/ceacun/all.html

Cercis orbiculata (Western redbud)
http://www.fs.fed.us/database/feis/plants/shrub/cerorb/all.html

Heteromeles arbutifolia (Toyon)
http://www.fs.fed.us/database/feis/plants/shrub/hetarb/all.html

Pinus sabiniana (Foothill pine)
http://www.fs.fed.us/database/feis/plants/tree/pinsab/all.html

Populus fremontii (Fremont's cottonwood)
http://www.fs.fed.us/database/feis/plants/tree/popfre/all.html

Quercus douglasii (Blue oak)
http://www.fs.fed.us/database/feis/plants/tree/quedou/all.html

Quercus lobata (Valley oak)
http://www.fs.fed.us/database/feis/plants/tree/quelob/all.html

Quercus wislizenii (Interior live oak)
http://www.fs.fed.us/database/feis/plants/tree/quewis/all.html

Salix exigua (Narrowleaf willow)
http://www.fs.fed.us/database/feis/plants/shrub/salexi/all.html

How should the plant community in a riparian restoration project be chosen? The basis for such choices has received a great deal of attention in the discipline of restoration ecology. Projects that carefully consider plants with complementary sets of traits in relation to environmental conditions are more likely to succeed, but inadequate knowledge of how to combine plants in mixtures can sometimes result in unexpected outcomes such as strong competition or facilitation (Eviner and Hawkes 2008). Historical information is usually paired with present knowledge of site conditions, degradative processes (e.g., loss of sediment, soil, and water quality), and practical considerations (Higgs et al. 2014). Most riparian corridors in California, however, are dramatically different from the historical ecosystem in terms of water availability, streamflows, and aquatic habitat (Moyle 2014). Moreover, there are few studies with complete lists of plant species that occur in upland rangeland riparian corridors, so that emulation is difficult (Young-Mathews et al. 2010). Choosing

plant species that increase specific or multiple ecosystem services may thus be the preferred route. For example, species with abundant fruits or seeds provide a richer wildlife habitat, whereas species with significant nectar and pollen sources support more pollinators and predatory insects (Earnshaw 2004). A goal of increasing carbon sequestration would favor long-lived trees over shrubs, with attention to microsites less susceptible to disturbance (Williams et al. 2011). Pioneer trees and shrubs (see above) would enhance bank stabilization. If groundwater drawdowns are likely in the future, it may be futile to focus on phreatophyte species whose roots must tap into the water table. Cultural objectives will also determine the species mixture, such as for Native American uses for basketry or medicinal plants, or for aesthetic beauty in locations for recreational use.

Resilience is an important objective in planning the assemblage of plants in the community. Considering the projections for climate change with anticipated variation in precipitation, it may be advantageous to plant early successional colonizer species adapted to moister conditions together with later successional species that may grow better on drier sites (Kroeger et al. 2010). Decisions to source plant materials from further south or lower in elevation, especially for the long-lived trees for which genetic variation is known to occur, should be considered. By planting a diverse set of species, and using site characteristics to match conditions for preferred microsites, some insurance may be provided against unexpected future conditions (Seavy et al. 2009).

4.4 Planting and maintaining riparian plantings

Planting should take place from late fall through early spring, except for right along the channel streambank which may be best delayed until after periods of high flow. Spacing depends on the project's goals and site heterogeneity, but plants are often more widely spaced than the recommendations for hedgerows in lowland valleys, which are given as 7.5 feet between small shrubs, 15 feet between larger shrubs, and 20 to 30 feet between trees (Long and Anderson 2010). For herbaceous plants, Long and Anderson (2010) suggest 12 to 14 lbs of seed per acre for perennial grasses and 14 to 20 lbs per acre for forbs.

For oaks, survival of planted acorns vs. seedlings was compared across several projects that used screens or tree shelters for protection (Kroeger et al. 2010). Acorn planting projects reported lower survival (33 percent) compared to seedling projects (75 percent). But acorn plantings save the time and effort of producing seedlings in nurseries.

For willows, living stakes can be made from younger shoots, trimmed, and pushed or pounded into muddy soil on the edge of a streambank (Figure 14). After roots form, the plants begin to stabilize the bank, and eventually create situations where other shrub and tree species can establish.

FIGURE 14. a) Willow stake beginning to leaf out along the stem nodes.

FIGURE 14. b) Work crew planting the stakes along a creek in Placer County.

To protect plants from herbivore browsing, fencing or cages are essential. One opinion is that 4- to 5-feet tall wire fencing is most effective (Howard and Robins 2002). By making a circular enclosure at least 3-feet in diameter around individual plants, and staking it down with rebar or stakes, the plant has space to grow out of the reach of browsing animals. If, instead, the entire area is fenced to prevent livestock trampling, erosion, and deposits of fecal matter, restoration may be more successful. A potential tradeoff for the rancher, however, is that livestock access to water may be affected if large areas are fenced off (Kroeger et al. 2010). Placing rigid, translucent double-walled plastic tubes (commonly known as treeshelters, tree tubes, or Tuley or TubeX tubes) over individual seedlings protects them from a variety of animals, including deer and cattle (McCreary and Tecklin 2001; 2005). Accelerated shoot growth of the seedlings can occur in the treeshelters. Securing the shelters with heavy metal fence posts prevents damage from cattle rubbing against them (Figure 15), but cattle and deer still clip the shoots that extend over the tops of tree shelters, which slows growth. Cages around the tubes prevent grazing.

FIGURE 15. TubeX treeshelter around a buckeye *(Aesculus californica)* secured by heavy posts and surrounded by a cage.

Weed control is considered the most difficult, challenging, and expensive aspect of restoration. Mulching with woodchips, walnut shells, compost, or weed mats is recommended around the base of shrubs and trees (Long and Anderson 2010). Mowing is often not possible in upland riparian corridors given the heterogeneous topography, but in flatter areas, weeds should be mowed after flowering has begun but before the seeds are mature. Herbicide use is usually necessary, but the different choices each come with its own set of tradeoffs, which are discussed by Long and Anderson (2010). In studies in Yolo County, prescribed burning alone resulted in short-term overall weed reduction, and significantly reduced star thistle (*Centaurea solstitialis*) populations in combination with Transline™ herbicide (Russell et al. 2008). Light grazing is considered a good option for decreasing weed competition with planted shrubs and trees. In ungrazed plots, dead litter accumulates as a dense thatch that is excellent vole habitat, and voles will often strip the bark and girdle oak seedlings (McCreary and Tecklin 2005). Invasive plant species such as medusahead (*Taeniatherum caput-medusae*), barbed goat grass (*Aegilops triuncialis*), and star thistle (*Centaurea solstitialis*) were found to increase in ungrazed plots (Bartolome et al. 2007). Thus, combining different practices (i.e., mulching, mowing, herbicide use, prescribed burning, and light grazing) is possible for weed management, but regardless of the method, frequent intervention is necessary, especially in the first three years after planting trees and shrubs.

4.5 Economic analysis of rangeland riparian habitat restoration

An assessment of the economic costs and benefits of conservation has recently been conducted by Kroeger et al. (2010). The financial benefits are more difficult to quantify than the installation costs. For example, growers report that flood and erosion control measures result in savings in labor and equipment use, and depending on the location, the reduction in downstream impacts and/or property damage, which is beneficial in terms of avoiding conflicts with neighbors and exposure to legal and regulatory actions (Kroeger et al. 2010; Tourte et al. 2003).

No cost and return studies have been conducted on projects for habitat restoration in upland rangeland riparian corridors in California. While the University of California publishes cost studies for certain conservation practices (http://coststudies.ucdavis.edu/conservation_practices/), they are currently most relevant to the Central Coast region, and none exist for planting woody vegetation along riparian corridors. Yet, they do provide estimates of costs and benefits for grassed filter strips, perennial hedgerow plantings, perennial critical area plantings, and a non-engineered water/sediment control basin (Tourte et al. 2003).

Most pertinent is the sample cost analysis for a perennial hedgerow planting of 1,000 linear feet with an 8-foot width on flat ground in the Central Coast region (Tourte et al. 2003). The costs include land preparation (cultivate and ridge up soil), a compost application before planting, a temporary drip irrigation system, and pre-irrigation before planting (Table 6). Woody shrubs of different species and heights are hand-planted, mulched with straw, and irrigated. Operation and maintenance in the subsequent five years include hand-weeding, rodent control, and irrigation. Only 8 percent of the plants are replanted during the first five years, which represents much higher survival than in studies of rangeland riparian corridor on the Central Valley side of the Coast Range (Audubon 2005).

TABLE 6. Representative estimated costs of a perennial hedgerow planting of 1,000 linear feet in the Central Coast. Material costs (e.g., compost, plants, and mulch) are $1565, whereas labor costs are $133. Adapted from Tourte et al. (2003).

Management activities	Estimated costs
Installation (Year 1)	
Land preparation (rip and disc)	$35
Compost application	$28
Set up irrigation system, pre-irrigate and establish	$522
Plant perennial shrubs	$1669
Mulch around plants	$109
Installation Costs Subtotal	$2363
Annual Operation and Maintenance (Year 2-5)	
Irrigation to maintain	$17
Replant to maintain	$140
Hand weed around plants	$268
Rodent control by trapping	$90
Annual Operation and Maintenance Costs Subtotal	$515
Interest on operating capital @ 7.4%	$40
Total	**$2918**

In another example of costs for a perennial hedgerow of 1,000 linear feet planted in the Central Valley, Long and Anderson (2010) estimate the costs for three years as $3847. One difference from the coastal study (Table 6) is that native grass and native forb seeds are also planted, and the weed control is 4-fold higher than in the Central Coast project ($1065) (Tourte et al. 2003). Weeds in stands of native grasses are more difficult to control than under canopies of shrubs and trees. The Central Valley project also included labor for site analysis and design ($253). In fact, if the full costs of planning by the landowner and staff from the USDA-

NRCS or a non-governmental organization were included, labor has been estimated at an additional $10,000 for an oak restoration project of similar magnitude at Bobcat Ranch in Yolo County (Kroeger et al. 2010). Kroeger et al. (2010) do recognize, however, that costs could be significantly reduced if the hourly value for these labor inputs were lowered. The difference in labor costs may have been largely due to paying employees for project design, whereas many rancher-driven projects do not consider this as a specific cost. Some of the opportunities for obtaining financial and technical assistance from the federal government are shown in Table 7.

TABLE 7. Government programs that offer payments and technical assistance to ranchers for projects related to conservation and habitat restoration. Adapted from Griggs (2009).

Program Name	Description	Incentive
Conservation Stewardship Program (CSP) <http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/>	Voluntary program to help farmers and ranchers maintain and improve current conservation projects, and adopt new conservation activities.	Annual payments over a 5-year contract with option to renew; payments increase for higher conservation performance.
Environmental Quality Incentives Program (EQIP) <http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/>	Voluntary conservation program for farmers and ranchers to implement structural and management practices to improve environmental quality.	Financial and technical assistance; one to 10 years and up to 75% cost share.
Conservation Reserve Program (CRP) <http://www.fsa.usda.gov/FSA/webapp?area=home&subject=copr&topic=crp>	Assistance to farmers and ranchers who take environmentally sensitive land out of production and plant resource-conserving species.	Cost sharing, annual rental payments, and technical assistance; 10 to 15 years.
Agricultural Conservation Easement Program (ACEP) <http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/easements/>	Farmers and ranchers can sell easement of lands for habitat restoration, including wetlands and riparian corridors.	Financial and technical assistance

5.0 EVALUATION OF THE SUCCESS AND FAILURE OF RIPARIAN RESTORATION IN CALIFORNIA RANGELANDS

Monitoring for and evaluating success of riparian restoration projects in rangelands is problematic. The theoretical framework and tools exist (see below), but consistent, high-quality data sets are still scarce. This lack of information could foreseeably limit future adoption of riparian restoration practices in California rangelands by limiting landowner interest and investment into riparian restoration. Agencies, too, may be hesitant to contribute to the costs of site preparation and implementation when so little is known about the factors contributing to the success and failure of riparian restoration projects. When monitoring is carried out and the results are made available, it is possible for people to share experiences and learn from others' efforts, especially when a common set of monitoring tools are used (Ward et al. 2003a). Thus, the following aspects of monitoring procedures are considered: why monitoring is a crucial part of a restoration project; an overview of current information; key points for designing monitoring plans; challenges for implementing monitoring programs; and some promising directions for future projects.

5.1 Monitoring is crucial

Monitoring helps the private landowner decide if their goals are being met, and in addition, demonstrates how public benefits accrue as a result of the project. If such data were available, then resource professionals would learn more about riparian processes and management interactions, and in turn, provide this information to land managers and conservation planners (George et al. 2011). Eventually, stories on successes and failures will accumulate as monitoring becomes more commonplace, which could help minimize risks and generate enthusiasm for greater investment in restoration.

Adoption of certain rangeland conservation practices is often costly to implement (e.g., channel stabilization or native plant establishment) and higher cost shares are needed to make them economically viable for landowners (Kroeger et al. 2010). Economists maintain that it is essential to quantify the economic value generated by the ecosystem services provided by a particular practice in a specific location in order to justify monetary investment. Thus, for conservation payments for rangeland riparian restoration to increase in the future, monitoring the effects of restoration projects compared to baseline conditions is the essential basis for evaluating ecosystem services. Over the long-term, a series of well-documented projects will presumably support an increase in financial and technical assistance for landowners by governmental and non-governmental organizations (Kroeger et al. 2010). A common set of monitoring tools to observe and document changes in land, water, vegetation and wildlife habitat in a consistent manner across sites is recommended by Ward et al. (2003a), as this would facilitate the process by which landowners and resource professionals could exchange information and problem-solving approaches.

FIGURE 16. Assessing species composition at Audubon Bobcat Ranch (Courtesy of Phil Hogan).

5.2 California rangeland riparian restoration monitoring studies

While restoration of vegetated riparian corridors may be perceived as an affordable and easy-to-maintain tool for California rangeland managers to increase ecosystem services, such as reducing runoff into local watersheds, sequestering carbon in soil and wood, and providing wildlife habitat, little monitoring data actually exists on the costs of specific projects or on ecological outcomes (George et al. 2011; Kroeger et al. 2010). As has been mentioned earlier, some results do exist on various types of benefits that have occurred in specific studies of vegetated riparian corridors on California rangelands, such as nutrient retention (Briar et al. 2012; Smukler et al. 2010), reduction of pathogens in stream water (Tate et al. 2004; Tate et al. 2006), and carbon sequestration based tree density (Smukler et al. 2010; Young-Mathews et al. 2010). Overall, however, the results are inconclusive in terms of the effectiveness of specific restoration practices on different aspects of environmental quality, and especially on quantifying the time frame in which benefits may be expected to accrue.

There appears to be only one survey that has assessed a number of different attributes of a set of riparian restoration sites on California rangeland (Lennox et al. 2007). Across 102 riparian revegetation sites in Marin, Mendocino, and Sonoma Counties, both passive restoration methods (grazing management and fencing) as well as active techniques (planting and/or structural changes to the channel or berms) were beneficial to plant communities and wildlife (Lennox et al. 2007). Active restoration methods accelerated the achievement of benefits associated with tree canopy cover and bank stability in the first 10 years after projects began, but the benefits of both methods converged after 10 to 15 years for most variables related to vegetation cover and aquatic habitat. There were three belt transects per study site, which

included four classes of landforms (e.g., channel and bank) per transect, two or more plots per landform, and three quadrats per plot. The sampling consisted of 36 attributes related to channel, pool, bank, and radiation measurements, as well as density and cover of vegetation classes. Total woody vegetation density and total canopy cover increased with project age, peaking at 15 to 25 years after restoration occurred. Fish habitat quality also improved, which was quantified using metrics such as increasing pool depth. Exotic shrub density increased as well, especially Himalayan blackberry (*Rubus discolor*), which led to the authors' recommendation to maintain active control of exotic shrubs during the first few years after management to avoid homogeneous, dense patches that become prohibitively expensive to remove later on.

The rangeland Conservation Effects Assessment Program (CEAP) synthesis, led by the NRCS, evaluated how well current scientific literature nationwide supports hypotheses for several riparian practices in rangelands (Spaeth et al. 2013). This extensive evaluation of riparian rangeland conservation practices also shows a lack of monitoring studies, and reports inconsistent or inconclusive results for many habitat management practices. There was only weak or inconclusive evidence for seven of their hypotheses, including: 1) "uncontrolled riparian grazing decreases habitat for riparian mammals and sage grouse"; 2) "woody plant control decreases undesirable species"; 3) "prescribed fire increases the diversity of flora and fauna"; 4) "upland woody plant management decreases erosion and increases streamflow"; and 5) "carbon sequestration can be enhanced through establishment and maintenance of woody species".

While this seems to cast a disparaging view on riparian rangeland restoration, a more appropriate conclusion is that the lack of monitoring studies and the variability among these heterogeneous rangeland environments currently make sound scientific conclusions nearly impossible.

5.3 Key points for designing monitoring plans

Several sets of guidelines exist for monitoring changes in grazing or restoration regimes (Clewell et al. 2000; US EPA 1995; Ward et al. 2003a; Lewis et al. 2009). These monitoring plans all require technical expertise in rangeland management, ecology, and/or hydrology. While landowners and land managers can learn these tools, they must first perceive that the effort and outcome is worthwhile. Additionally, rigorous monitoring as outlined in these guidelines may be impossible for a landowner who is already busy with more urgent demands, so an individualized monitoring toolkit may be the best solution for determining whether or not their goals are being met.

Because so much of the effort and cost of riparian restoration are currently borne by the landowner in California, they must be satisfied with the outcome. Therefore, defining the landowner's goals for a specific project is an essential component of project planning. Once these goals are clearly defined, monitoring plans can be tailored accordingly. This can form the basis for adaptive management that better obtains the desired goals over time. Regardless of the approach, the aspects discussed below are regarded as necessary components of a monitoring plan (Clewell et al. 2000; Lewis et al. 2009; US EPA 1995; Ward et al. 2003a).

PRE-PROJECT MONITORING. On the actual site or reach of the intended project, measurements on parameters such as water quality, groundwater elevation, and vegetation should ideally be collected for a year or more before the project begins in order to form the baseline for comparison over time. These data may also point out conditions which could necessitate alterations in project goals or design.

REFERENCE ECOSYSTEM. Some projects may have a target ecosystem for which the restoration project is intended to resemble over a period of years. This might be relatively undisturbed sites or even a pre-disturbance condition if it is known. It may be difficult to identify comparative ecosystems that serve as restoration targets. In some cases, the reference may serve as a template, but often riparian corridors have become so disturbed that the reference only serves as a rough guideline.

PERFORMANCE CRITERIA. The success of a project depends on the attainment of specific objectives, outcomes, or endpoints identified during the planning process. Some of the objectives will be relevant to goals for the ranch as a whole, and others will refer to a specific riparian reach or to the prevalence of a given species. Certain criteria may be set on a specific timeline, such as one-time events occurring at the beginning of the restoration project. These can include objectives such as structural changes (i.e., road removal), planting, or installations. Others, such as invasive species removal, are carried out repetitively. Cultural objectives are also recommended as criteria (Kroeger et al. 2010) and include publicity, celebrations, or participation of stakeholders in implementation and monitoring.

Performance criteria are used to evaluate whether a specific state in ecosystem recovery has occurred, as an indicator of whether a corresponding objective was successfully achieved. The actual monitoring that is carried out depends on who is involved in a restoration project, and how and why it was established. As an example, with pollinator habitat as a priority, monitoring is oriented to changes in conservation actions that encompass the site and landscape features relevant for bee movement and colonization, and the specific attributes of foraging and nesting habitats for bee abundance and diversity (Jordan et al. 2014). For government funded projects, agencies may have strict rules for meeting funding requirements, e.g., quantitative analysis of beneficial designated uses of a water resource, measurement of numeric water quality parameters, and narrative assessments of water quality that directly promote the protection and sustainability of a specific water resource (US EPA 1995). If the labor and measurement costs for monitoring are included in the project, detailed quantitative monitoring standards will be possible in order to definitively show whether objectives have been met, or if non-compliance warrants enforcement or legal sanctions (Clewell et al. 2000; US EPA 1995).

For rangeland restoration projects initiated by ranchers with little or no outside funding, performance criteria are more focused on assessing short- and long-term trends intended to inform adaptive management of the restored area (Ward et al. 2003a). These criteria may include species distribution, litter layer depth, channel shape, or flooding frequency.

Ward et al. (2003a) suggest a monitoring protocol to assess a standardized set of performance criteria for riparian corridors. Periodic visual and quantitative assessments of physical parameters, vegetation, and habitat are made along permanent transects according to established monitoring tools (Table 8). A grazing management survey is also included in order to track how grazing may be implicated in observed changes in the riparian corridor. The suggested monitoring program is somewhat involved and requires a specific set of equipment, training, and technical expertise; it is primarily intended for rangeland management or restoration professionals in advisory roles who want to provide high quality feedback to land managers for future adaptive management decisions. See Table 8 for a summary of the data collection worksheets and assessment tool examples provided in the appendices.

TABLE 8. Summary of suggested monitoring protocols provided in appendices of Ward et al. (2003a) (adapted from Appendix A).

Assessment	Parameter quantified	Appendix
BLM Proper Functioning Condition[a]	Hydrologic function	C7
UCCE Riparian Health Assessment for Rangelands[b]	Hydrologic function; aquatic habitat quality	C6
Greenline Protocol[c]	Width of riparian area; change in greenline vegetation composition; regeneration of woody species along greenline	C5, C8, C9
Fish habitat quality[d]	Length, width, and depth of pools, riffles, and runs; substrate assessments	C3[e]
Physical parameters[d]	Water temperature; air temperature; canopy cover; width and depth of channel	C3[e]
Grazing management survey	Management goals; ongoing restoration and monitoring efforts; management practices and costs; livestock interactions with riparian corridor	C1[e]

[a] *Visual assessment tool. See Prichard et al. (1998).*
[b] *Visual assessment tool. See Ward et al. (2003b).*
[c] *Quantitative assessment. See Winward (2000).*
[d] *Quantitative assessment. See MacDonald et al. (1991) pp.109-132.*
[e] *Blank data collection worksheet.*

Lewis et al. (2009) provide a worksheet intended to guide restoration professionals through the process of designing a personalized monitoring plan for riparian revegetation projects. A suggested list of published references outlines appropriate quantitative monitoring methods for a variety of performance criteria. These include all of the criteria found in Ward et al. (2003a) in addition to others, such as survival and establishment of planted vegetation, bank stability, and habitat use estimates. Data collection worksheets, however, are not provided.

Landowners with little capacity for monitoring activities may choose to utilize a set of visual assessments of vegetation or the stream channel, photographs, or use changes in their management practices for flood control, road grading or new fencing materials as indicators of performance criteria. If time and labor are in short supply, brief notes on visual changes or management activities can still serve as useful records for planning other projects. For example, adapting one or more of the worksheets from the Ward et al. (2003a) monitoring plan, or from the methods listed in Lewis et al. (2009), would take only a couple of hours each year. These

worksheets may also serve as a template that can be tailored to a specific landowner's needs and goals. For agencies and NGOs who may wish to compile outcomes of landowner projects for wider distribution, even rough notes and worksheets will be useful if compiled over a 10 to 20 year period.

DATA COLLECTION PLAN. Once a project's goals are defined and performance criteria are identified as appropriate indicators of success for the achievement of those goals, then a data collection plan for monitoring the project's success can be designed. Setting up a timeline and worksheet for a project's performance criteria is the best way to determine how a sampling design can be implemented, and to evaluate if monitoring is actually feasible in terms of time and labor. Revisions will most likely occur in order to find the most efficient way to illustrate the achievement of project goals. Continuity is important; it is better to downscale the data collection plan than abandon it mid-way through the project's life.

5.4 Challenges for implementing monitoring programs

ACCURATE DOCUMENTATION OF RESTORATION OF ECOLOGICAL INTEGRITY. Even well-developed test methods and field assessments may not be able to capture the full set of changes during a restoration project, especially if some types of biota are seasonally or intermittently present, such as certain species of birds and fish (US EPA 1995). Likewise, water quality may fluctuate with streamflow. Changes over time, as used by Lennox et al. (2007), may be a good choice if reference ecosystems are unavailable or unfeasible as templates for performance criteria.

ERROR AND BIAS DUE TO HETEROGENEITY IN TIME AND SPACE. One of the main aspects of uncertainty of outcomes from rangeland riparian restoration projects is that site conditions differ widely, and are often heterogeneous within particular reaches as well. An issue that must also be considered is that monitoring itself can affect the integrity of a site, such as by trampling aquatic habitat and disturbing bank edges. Lack of funding for detailed and frequent monitoring makes it less possible to demonstrate changes in performance without high levels of error and bias in the collected data. The benefits of a particular project may be inaccurately evaluated if the monitoring plan is unable to capture natural fluctuations in water quality and biological indicators over time and space.

COMPILING AND PUBLISHING MONITORING DATA. In principle, technical publications should serve as a way to compile monitoring data, but it is difficult to collect data rigorous enough to stand up to scientific review. This may be one of the reasons why so little published documentation exists. Perhaps a 'case-study' approach to riparian rangeland restoration projects could evolve, in which landowners' experiences are compiled in a framework that provides information on successes and failures, and is made accessible through websites or other outreach materials to a wider community of interested stakeholders. Because one practice or set of practices is not suited to the biophysically diverse riparian habitats in California rangelands, such an approach could at least provide ideas for a flexible mix of practices relevant to specific site conditions and landowner management objectives.

DISCONNECT BETWEEN RESEARCH COMMUNITY AND LAND MANAGERS. As Spaeth et al. (2013) point out in their synthesis of the rangeland CEAP, the research community has rarely conducted long-term studies on rangeland restoration, and the USDA has not provided much funding for monitoring implementation of conservation practices. Management decisions for conservation projects take place over long time frames whereas most scientific experiments span only a few years, and sometimes only one. Researchers with the capacity to conduct quantitative assessments must engage more directly with landowners and policy makers (Figure 15), so that they collect information that is both useful for adaptive management and for the basic understanding of wildlife and ecological processes in California's upland riparian corridors.

FIGURE 15. Range manager and researcher discuss grazing and restoration strategies.

5.5 Promising directions for improved monitoring

Several points emerge as promising directions for enhancing the monitoring capacity and information exchange regarding successes and failures of riparian restoration projects on California rangelands:

- Consider monitoring as a fundamental aspect of a restoration project, so that benefits become more evident to landowners, government agencies, NGOs, and the public, which in turn could stimulate greater investment in the future.
- Find new ways to distribute information (as attempted in this document) on benefits, practices, and monitoring for projects in riparian rangeland corridors.
- Develop sets of performance criteria suited to different types of projects, which typically have different goals, such as those with: 1) large-scale extent and government-funding; 2) local-extent and involvement of rangeland management professionals; and 3) minimal funding and led by landowners.
- Attempt, with time, to elucidate more conclusive outcomes for practices that are conducive to establishment of native plants, removal of invasive species, and improvement of habitat and water quality.
- Bridge the gap between scientists, rangeland management professionals, and policy-makers, so that they can better serve the landowners who develop and maintain riparian management plans which provide public goods and ecosystem services.

Several factors that would contribute to this agenda are: greater collaboration amongst stakeholders, more attention to site and project specificity, and careful consideration of the level of scientific rigor that is required for performance criteria in order to develop high quality information on successes and failures of riparian restoration practices.

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DRY CREEK AT AUDUBON BOBCAT RANCH, YOLO COUNTY

ENVIRONMENTAL AND SOIL FACTORS ASSOCIATED WITH SURVIVAL OF RESTORATION PLANTINGS

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1.0 INTRODUCTION

The purpose of this study, which was funded by a NRCS Conservation Innovation Grant, was to assess how site, soil, and water management factors affected the success of restoration plantings of several native woody species along a riparian corridor. The study site was in the foothills along the west side of the Sacramento Valley in Yolo County, California, at the Audubon Bobcat Ranch. The plantings were made in the winter of 2011/2 and their establishment period occurred during the severe drought that began in 2011. The objectives of this study were to:

a. Evaluate the survival of several species of woody plants planted for riparian restoration.

b. Assess environmental factors conducive to establishment of woody plantings.

   iii. Categorize habitats at the restoration site with field indicators (e.g., soil characteristics and plant community composition) and commonly-used remote sensing (e.g., elevation, slope, hydrologic, and soil type) indicators.

   iv. Determine which, if any, environmental factors were associated with successful establishment of different species of woody plantings.

c. Compare the effects of manual irrigation vs. a soil-applied gel, DRiWATER®, on survival of woody plants. DRiWATER® gel is a possible management option to overcome site water constraints in hilly terrain where installation of irrigation is difficult or prohibitively expensive.

Assess how site, soil, and water management factors affected the success of restoration plantings of several native woody species along a riparian corridor.

This report is also intended to provide insight into methods that may be useful for monitoring the success of plant establishment in riparian restoration in rangelands. Many such projects are implemented by landowners, as occurred here, without an experimental design conducive to conventional statistical methods. To meet this challenge, a variety of statistical methods, including multivariate approaches and multiple regression, were used for data analysis. Based on these results, suggestions for planning and monitoring of landowner-driven restoration projects are discussed.

2.0 METHODS

2.1 Planting installation

The Audubon Bobcat Ranch (headquarters located at 38°31'57"N, 122°02'18"W) is located in western Yolo County, California, USA, in the Coast Range Mountains. This is a Mediterranean-type climate with cool, wet winters and hot, dry summers. The mean annual rainfall is 57.9 cm, and maximum and minimum temperatures are 24.4 and 9.5°C, respectively, in the nearest town (Winters, CA; Western Regional Climate Center, 2012). The grazed woodlands along the riparian corridors are composed of both deciduous and evergreen woody species, but decades of cattle and sheep production have undoubtedly reduced the density and cover of shrubs and trees compared to the more protected stands in riparian corridors on steeper slopes (Hodson et al. 2014).

In January 2012, 280 restoration plantings were installed along 2134 m (7000 linear feet) of stream corridor along Dry Creek, which varied in slope, aspect, soil characteristics, and density of surrounding native trees and shrubs. The planted area was approximately 65 ha (160 acres). In total, there were 280 plantings of container stock, acorns, and seeds in the study. Species

of container stock used in the planting included buckbrush (*Ceanothus cuneatus*), redbud (*Cercis orbiculata*), and foothill pine (*Pinus sabiniana*). Acorns of the evergreen interior live oak (*Quercus wizlizenii*), the deciduous blue oak (*Quercus douglasii*), the deciduous valley oak (*Quercus lobata*) species, as well as seeds of buckeye (*Aesculus californica*), a summer-deciduous species, were also planted. To prepare the acorns, they were rinsed in a weak solution of bleach to deter any bacteria or mold before putting them in vermiculite and refrigerating from collection in the fall until planting.

In January and early February, 2012, after rain events, 30 cm (1-ft) deep holes were mechanically augured, then herbicide (glyphosate (*N*-(phosphonomethyl)glycine; Roundup®) was sprayed in a 1-m dia circle around the hole. The seedlings or acorns were planted into the holes, which were re-filled with soil, and the 1-m dia circle around the plant was mulched with crushed walnut shells. Each plant was surrounded by a TubeX tree protector held in place by rebar to protect the young plant from rodent herbivory and grazing by deer and cattle. (It should be noted that some additional plantings were made of acorns and mulefat cuttings, but these were not labeled nor protected, so were not included in the study).

The DRiWATER® gel material was encased in plastic tubing in the soil at 10 cm below the surface, and exposed to the soil starting in early April, 2012. DRiWATER® is water held together in a gel by food grade binders, which releases moisture slowly over time. It is packaged in 0.27 L (9 oz.) cylinders. Paired plantings of the same species, where one plant had DRiWATER® and the other did not, occurred on roughly half of the restoration site (west fork of Dry Creek). For each treated plant, two cylinders of DRiWATER® were placed diagonally in contact with the upper 10 cm (4 inches) of soil once per month during the dry season (April through September) of both 2012 and 2013. For plants without DRiWATER®, ~8 to 16 L (2 to 4 gallons) of water per plant were slowly poured around the perimeter of the tube with a bucket once a month starting in late May and concluding in September. This was called the hand-watering method. On the headwaters of the east fork of Dry Creek, which is generally steeper, DRiWATER® was used on all the plants, due to concern about water runoff rather than percolation.

Cattle were grazed in the 65-ha planted area during the winter of 2013. During December there were 300 stocker steers weighing approximately 550 to 650 lbs that grazed the area in groups of 75 in one week intervals each upon delivery to the ranch. No livestock grazing occurred in 2012 or earlier in 2013.

2.2 Metrics of plant success

The success of plant establishment was assessed in late November 2012 and early December 2013. Two metrics of plant success were used: plant height and plant health scores. For redbud, the number of meristems was also used as a metric of plant success, but for other species, meristems were too numerous (e.g., buckbrush) or insufficiently variable (e.g., live oak) to count. Height was measured in cm, and the health score was rated with integers on a scale from 0 to 3. On this scale, 0 signified that the plant was dead, with leaves or branches dry, and the roots not anchored to the soil. The rating 1, or 'barely alive', signified that plant roots were still anchored to the soil, while dry leaves may have been present, the stem was pliable and the plant still showed some signs of life. The rating 2, or 'alive', meant the plant was doing fairly well, with some new growth of buds or leaves. The rating 3, or 'thrive', was for plants with many green leaves, elongated stems, and few or no dying shoots or meristems.

In some cases, plants were absent, and if the surrounding tubes and soil were disturbed, we reasoned that animal herbivory might have killed the plant. These disappeared plantings (34 in total) were counted in survivorship calculations but not in multiple linear regressions to explain plant height or habitat classifications based on health score, since there was no height or health score to measure, and their disappearance was likely due to factors that could not be ascertained. When shoots had been clipped off at the level of the top of the tube, grazing damage was noted.

2.3 Environmental data

Site information was collected for each planting, and included 32 variables measured through soil physical and chemical analysis, vegetation surveys, and geographic information system (GIS) data derived from remote sensing (Table 1).

Soil data	Type
POXC (mg C kg^{-1})	Numeric
pH	Numeric
EC (µS cm^{-1})	Numeric
Clay (%)	Numeric
Silt (%)	Numeric
Sand (%)	Numeric
Fine silt (%)	Numeric
Very fine sand (%)	Numeric
Fine sand (%)	Numeric
Medium sand (%)	Numeric
Coarse sand (%)	Numeric
Soil N (%)	Numeric
Soil C (%)	Numeric
Litter (g 78 cm^{-2})	Numeric
Soil moisture (g g^{-1})	Numeric
Rock (%)	Numeric

Vegetation data	Type
Annual cover (%)	Numeric
Perennial herbaceous cover (%)	Numeric
Tree cover (%)	Numeric
Bare soil cover (%)	Numeric
Surface rock cover (%)	Numeric
Nearest tree species	Categorical
Perennial species (2 m dia. plot)	Categorical
Distance to main channel (m)	Numeric
Distance to nearest tree (m)	Numeric

GIS data	Type
Elevation (m)	Numeric
Slope (°)	Numeric
Aspect (degrees from east)	Numeric
Profile curvature (1/meters)	Numeric
Tangent curvature (1/meters)	Numeric
Flow accumulation (pixel count)	Numeric
Aspect (degrees from east)	Categorical

TABLE 1. Data collected about the environmental characteristics of 280 restoration plantings at Audubon's Bobcat Ranch in California.

Cover of annual and perennial herbaceous vegetation, bare soil, and rocks was surveyed around each planted shrub or tree over four days in April 2013. Cover was estimated visually for a 2 m (2.2 yd) dia concentric circle starting 0.5 m (0.51 yd) away from each planting's protective tree tube (for a total area of 23550 cm^3). This was to avoid sampling the surface that had received herbicide and walnut shell mulch (1963 cm^3). The identity and percent cover of any shrubs and/or trees in the canopy layers of the plot was also recorded. The shortest linear distance from the planting's location to the main stream channel as well as the distance to the nearest tree was measured.

The GPS coordinates for each of the 280 plantings was input into a GIS. For each point (pixel), a digital elevation model was constructed (10 m resolution) and derivatives of elevation calculated using Geographic Resources Analysis Support System software (GRASS v 64). These included slope, aspect as determined from clear-sky solar radiation summed over a calendar year and modeled from a digital elevation model (Beaudette and O'Geen (2009), slope curvature (which determines the pathway of water and was used in the flow accumulation calculation), and water flow accumulation (an estimate of the amount of overland flow that traverses a point). Flow accumulation is expressed as cells, measuring the number of upstream pixels that drain into a particular cell.

Leaf litter was collected near each planting in January 2013, from a 10-cm (4 inch) dia circle 60 cm away from the base of the protective tube (outside the rim of walnut shell mulch). Litter was air-dried. Soil samples were taken below the litter sample (5 cm dia) at 0 to 10 cm (0 to 4 inches) depth. Soil was mixed by hand and a 100g subsample was stored at 4°C until processing. In the laboratory, soil moisture was determined gravimetrically. Air-dried soil was ground and sieved through a 2-mm screen. Laser diffraction for particle size distribution (total sand (52.6 to 2000 µm), coarse sand (500 to 1000 µm), medium sand (250 to 500 µm), fine sand (125 to 250 µm), very fine sand (62.5 to 125 µm), silt (2.2 to 47.9 µm), and clay (0.04 to

2.0 µm)) was done according to Eshel et al. (2004). Soil type was determined using the USDA-NRCS Soil Survey Geographic Database (Soil Science Staff 2006). The soil type was a Positas gravelly loam in the Mollic Palexeralfs series.

Soil organic matter pools were characterized using two methods. For total soil carbon (C) and nitrogen (N), mass loss after combustion was used (Chatterjee et al. 2009). The labile pool of organic matter (Wander 2004) was characterized using permanganate oxidizable carbon (POXC) following the methods of Culman et al. (2012) and Weil et al. (2003).

2.4 Data analysis

Cluster analysis was used to determine if there were different habitat categories to which each individual plant's location could be assigned based on soil, vegetation, and topographic data. Ward's hierarchical cluster analysis of all quantitative numeric variables was used to identify five distinct groups representing different types of habitat (based on Euclidean distance matrices). To see if plants tended to survive better in some habitats than others, the distribution of plant health scores was compared between habitat categories and watering strategies (DRiWATER® vs. hand-watering) with chi squared tests of independence (or Fisher's exact test when there were less than 5 observations in each category). In 2012, plant heath scores of 0 (completely dead) were rare, comprising only two plantings, so all analyses used the other health categories. Plantings were much more likely to be missing entirely, and were therefore excluded from analyses, since mortality could have been due to multiple, non-ascertained factors. Analyses thus focused on the remaining 224 site locations.

The distribution of plant health scores was compared between habitat categories and watering strategies.

For the multiple linear regressions used to examine the environmental variables that best explained plant height, height data from both 2012 and 2013 were used. As will be described in the results section, the 2013 plants had suffered an unusual drought, many were barely alive, 30% were missing or dead, and most had suffered browsing. For the plantings in both years, missing plants were excluded from the analysis. The two plants that were dead but still present had suffered substantial browsing by herbivores and were also excluded. The 32 environmental variables were too many to put into one model, so the data set was first split into soil, vegetation, and GIS/remote sensing categories (Table 1). For descriptive data such as vegetation of the surrounding community, categorical data were coded as dummy variables, for example, if a mature blue oak was present it was marked as 1, whereas absence of mature blue oaks was coded as a 0. For each category, normality, and heterogeneity of variances were checked graphically and variables were transformed when necessary. Colinearity/covariance of variables was checked by PCA and Pearson's correlation matrices, and when two variables were found with an R value >0.9, only one was selected for the model. These were generally multiple indicators of the same variable. For example, since soil C and N cycling are tightly linked in these ecosystems (Hodson et al. 2014), they were highly correlated, and only soil C was selected for inclusion. The best explanatory variables from each category were then used to generate a final model for each species. Model variables were selected for each category using best subsets regression using the 'leaps' package in R version 3.1.1 which compares all possible models for a given set of predictors (Lumley 2009). The model with the lowest adjusted R^2 was selected.

Since many variables were non-normally distributed, Spearman rank correlation matrices were used to examine relationships between plant height in both years and all habitat factors measured.

3.0 RESULTS

3.1 Survivorship

Of the 280 plantings, 87% survived their first summer (2012), and 69% survived their second summer (2013), even though 2012 and 2013 were some of the driest years on record, with the area receiving less than one quarter of its average rainfall in 2013. This coincided with several plants changing from 'barely alive' status in 2012 to 'dead' in 2013. The percentage of plants in the 'dead' category increased for all plantings from 2012 to 2013 with the highest increases in mortality for redbud and buckeye (Table 2). For example, 27% of all plantings and 38% of buckeye seedlings were in the dead or missing categories in December 2013, whereas previously in November 2012, only 2% and 16% were dead or missing. The only two species that experienced less than 25% mortality by the second year were buckbrush and foothill pine. The percentage of 'alive' buckbrush plantings actually increased between the two years, as plants that were thriving in 2012 decreased in health status ratings but did not die. No species showed more than 15% in the 'thriving' category in 2013, although one-third to half of the plantings of all species was still alive. The exception was buckeye, which was less vigorous than the other species and had 56% 'barely alive' plants.

In both years plants experienced heavy grazing by herbivores. In 2012, 40% of all intact (not missing) plantings were noted as having browsing damage, but none of this was due to cattle which were not allowed into the area until 2013. The most frequently browsed was buckbrush, accounting for 30% of all browsed plants, followed by buckeye and redbud, which both accounted for 25%, respectively. Live oaks were never browsed, although this was probably due to the fact that most were rarely tall enough to become exposed above their protective tubes. In 2013, 80% of all plants had experienced browsing damage, which was evenly distributed among the species, after live oak was excluded.

Acorns of live oak, valley oak, and blue oak were planted, but only live oaks were included in analyses. No valley oak acorns germinated and blue oak numbers were too small for statistical analysis. Nine blue oak acorns were originally planted, and of these, 7 germinated. Five of these were still alive in 2013.

Species	Plants	% Dead or missing		% Barely alive		% Alive		% Thriving	
		2012	2013	2012	2013	2012	2013	2012	2013
Buckbrush	59	6.1	23.7	27.1	15.3	42.4	45.8	23.7	15.3
Buckeye*	50	16.0	38.0	36.0	56.0	46.0	6.0	2.0	0.0
Live Oak*	60	28.3	51.7	21.7	5.0	35.0	31.7	15.0	11.7
Foothill Pine	53	0.0	11.3	26.4	49.1	49.1	34.0	24.5	5.7
Redbud	58	1.7	27.6	29.3	20.7	51.7	51.7	17.2	0.0
All species	280	11.4	30.7	27.9	27.9	44.6	34.6	16.8	6.8

TABLE 2. Percent of restoration plantings in each health category during 2012 and 2013 at the Audubon Bobcat Ranch restoration site in California. Percentages were calculated by dividing the number of plants in each category by the total number of plantings (280) at the onset of the survey in 2012. Those plants that died or were missing in 2012 were included in the calculations for 2013. Note that assessments were made in the fall of each year. *Buckeyes and oaks were planted from seeds/acorns, but these seedlings are referred to as plantings here and in the rest of the document.

3.2 Habitat categories

The data on soil, vegetation, and topography (Table 1) for the 224 planting locations were used in cluster analysis to assign each planting to a habitat category. Five habitat cluster groups were distinguished, ranging in size from 34 to 53 plantings, and each differed substantially in the soil and substrate variables used to profile them by cluster analysis (Table 3). For ease of distinction we gave the clusters names based on substrate, which by no means encompasses all the environmental factors that separate them, but at least provides an indication of differences. Cluster 1, which we named the 'high soil organic matter' group, was high in soil POXC, %N, %C, and water content, and had high content of very fine sand and abundant leaf litter. The 'rocky' group (Cluster 2) was high in coarse sand fractions and volume of rocks (% rocks) in the soil, and many rocks were observed on the soil surface. Although the rest of the cluster groups were all loam soils based on particle size analysis, Cluster 2 classified as a sandy loam. Cluster 3 ('low pH and EC') had low pH, EC and water content. Otherwise, values for soil %C, %N, clay, silt, sand, moisture, and litter were in the mid-range measured in the project. Cluster 4 was high in silt, but was 'intermediate' in almost all other categories. The 'high clay' group (Cluster 5) included plantings that occurred on soils with high clay content, neutral pH, and low soil %C.

These habitat clusters also differed in vegetation and topographic variables. The 'high soil organic matter' group of planting locations (Cluster 1) was close to the nearest tree, with high tree cover and leaf litter, and fairly close (median of 5 m) to the stream channel with moderate slope with flow accumulation (the amount of water estimated to flow over the location based on topography) and aspect values signifying less steep areas that faced in northeasterly directions. The 'rocky' group (Cluster 2) of plantings occurred in locations closer to the stream channel, with intermediate slope, aspect, and flow accumulation, and little tree cover. The 'low pH and EC' group (Cluster 3) was in locations far from the stream channel (median of 8 m), with substantial bare ground and low cover of annual plants. The median cover of annual plants was only 48%, and tree cover was only 1.9%. Although the planting locations in Cluster 4 tended to be 'intermediate' with respect to substrate, this group was distinctive in its higher elevation (indicating the east fork of Dry Creek), flow accumulation, and aspect indicating south-facing slopes (median of 258 degrees). Cover of annual plants was high (median >74%) for Cluster 4 and for the locations of plantings in the 'high clay' group (Cluster 5). The 'high clay' group tended to be far from a tree, with little bare soil or rocks on the least steep slopes (median of 2.8 degrees), at moderate elevations and thus toward the east fork of the creek.

	1-high soil organic matter	2-rocky	3-low pH and EC	4-intermediate	5-high clay
POXC (mg C kg^{-1})	836.8	449.2	494.3	593.1	531.3
pH	6.6	7.1	6.6	6.9	7.0
EC (mS/cm)	91.7	74.8	62.8	89.2	74.8
Clay (%)	7.2	7.7	10.3	8.8	13.0
Silt (%)	40.7	33.9	38.6	42.1	42.9
Sand (%)	52.0	58.3	51.4	49.0	44.1
Very fine sand (%)	16.9	16.0	14.8	15.9	13.3
Fine sand (%)	15.4	17.0	14.6	14.2	12.6
Medium sand (%)	16.5	20.0	18.4	16.3	15.0
Coarse sand (%)	0.9	2.5	2.6	0.9	0.6
Soil N (%)	0.22	0.11	0.12	0.13	0.12
Soil C (%)	2.83	1.23	1.57	1.64	1.24
Litter (g)	1.04	0.30	0.50	0.33	0.20
Water content (%)	0.22	0.11	0.12	0.13	0.22
Annual cover (%)	65.0	70.0	48.0	74.5	85.0
Perennial herbaceous cover (%)	1.2	0.3	0.8	1.3	0.1
Tree cover (%)	14.8	0.9	1.9	2.4	0.7
Bare ground (%)	25.0	30.0	45.0	20.0	14.8
Surface rock (%)	0.0	1.5	0.0	0.5	0.0
Distance to channel (m)	5.0	3.0	8.0	4.0	8.5
Distance to tree (m)	7.0	9.0	9.0	8.0	15.0
Elevation (m)	108.4	118.7	113.5	132.4	121.5
Slope (degrees)	7.76	5.33	5.29	6.88	2.80
Aspect (degrees)	41.78	244.01	246.80	258.76	235.33
Flow accumulation (cells)	7.02	8.72	7.55	81.23	12.33

- soil
- vegetation
- remote sensing variables

TABLE 3. Characteristics of habitat groups at the Audubon Bobcat Ranch restoration site in California, as identified using Ward's hierarchical cluster analysis. Date are expressed as the median from 224 restoration plantings. Brown are soil, beige are vegetation, and tan are remote sensing variables. Those variables that had medians very close to 0 (perennial herbaceous cover, and tree cover) are expressed as means.

The five habitat clusters contained slightly different species of woody plantings (Figure 1), although the landowners apparently made no intentional decision to allocate seedlings of different species to different habitats. The 'high soil organic matter' group of plantings (Cluster 1) included 48 plants and was composed of similar distributions of each species (22%), except for buckbrush (10%). Cluster 2, the 'rocky' group, contained 36 plantings; it did not include any plantings of foothill pine, but plantings of other species were otherwise evenly represented. In contrast, Cluster 3, the 'low pH and EC' group, was dominated by pine plantings (45%), as well as live oak (30%), and contained 34 plantings in total. Plantings in Clusters 4 and 5, the 'intermediate' and 'high clay' groups were 53 and 41 plants, respectively, and contained all species, but with slightly less live oak in Cluster 4, and slightly more redbud and buckbrush in Cluster 5.

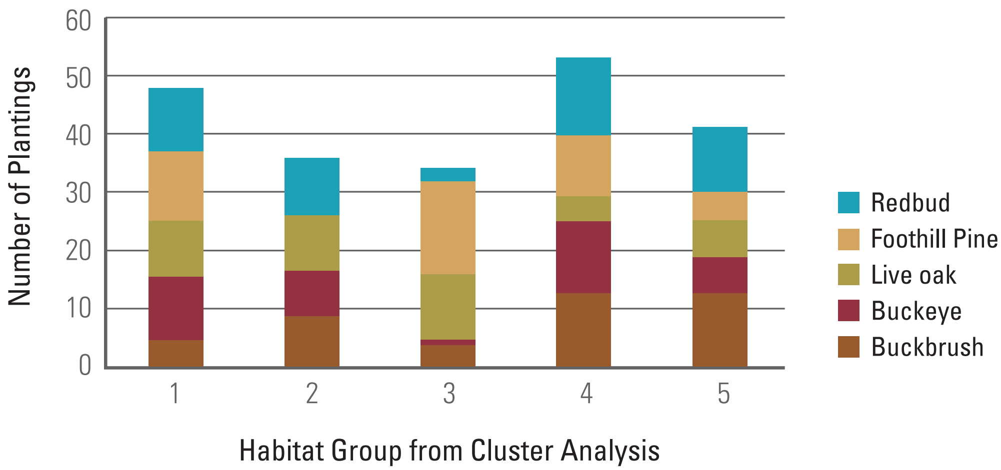

FIGURE 1. The number of restoration plantings in each habitat category identified by cluster analysis at the Audubon Bobcat Ranch in California. Colors correspond to the species composition of plantings assigned to each cluster using Ward's hierarchical cluster analysis.

3.3 Survival by habitat

Habitat affected restoration success, based on plant health scores of plantings in the five habitat clusters. In 2012, for the 224 plantings categorized as either 1 ('barely alive'), 2 ('alive'), or 3 ('thriving'), distributions of health scores differed among the habitat cluster groups (X^2 = 19.2, df = 8, P = 0.01). When the 'alive' and 'thriving' categories were combined, distributions of health scores also differed among habitat groups (Figure 2; X^2 = 12.4, df = 8, P = 0.01). The cluster with the highest proportion of 'alive' plus 'thriving' plantings (86.6%) was Cluster 3, the 'low pH and EC' group, which was somewhat distant from the stream channel with low cover of annual grasses and trees. Cluster 3 had the most 'thriving' plantings (35%) and the least 'barely alive' plantings (14%).

The two clusters with the next highest proportions of plantings that were either 'alive' or 'thriving' were closest to the stream channel (≤ 5 m away). Cluster 1, the 'high soil organic matter' group with high cover of trees and perennial herbaceous plants (75.5%), and Cluster 2, the 'rocky' group (70.2%) closest to the channel with higher coarse and medium sand fractions.

Plantings generally did poorly in the two groups that occurred at the higher elevation part of the creek in locations with high cover of annual plants (Figure 2). The 'intermediate' and 'high clay' groups, Clusters 4 and 5, had the lowest proportions of plantings that were 'alive' or 'thriving', 56.3% and 58.7%, respectively. In these groups, the proportion in the 'barely alive' category was more than three times higher than in the 'low pH and EC' group, i.e., 43.6% for the 'intermediate' group and 41.3% for the 'high clay' group.,

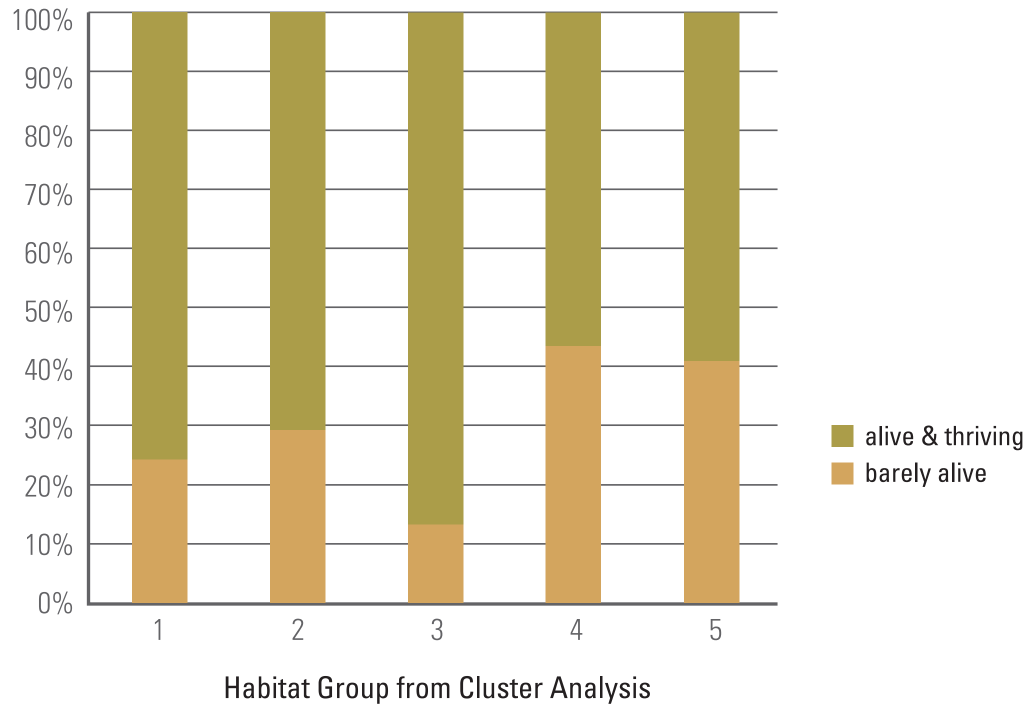

FIGURE 2. Distribution of plant health scores of restoration plantings between habitat group categories identified using Ward's hierarchical cluster analysis at the Audubon Bobcat Ranch restoration site in California. Plantings were categorized as either 'barely alive', 'alive' or 'thriving'. Here the number of 'alive' and 'thriving' plants have been summed.

3.4 Success of plant species

Multiple linear regression models of factors associated with plant height in 2012 showed that for some plant species, soil and vegetation attributes in the planting location were important, while for others, plant height was more affected by topographic variables (Table 4). For example, buckbrush height was positively associated with pH (P=0.02), clay (P=0.06), very fine sand (P=0.05), and coarse sand (P=0.06), and tree cover. But it was negatively associated with the cover of perennial herbaceous vegetation (P=0.01), which was mainly the bunchgrass, *Stipa pulchra.* In contrast, taller pine height was associated with site topographic factors such as higher slope (P=0.04), aspect (i.e., south-facing) (P<0.01), flow accumulation (P<0.01), but also higher annual vegetation cover (P<0.01) but low % rock visible on the surface (P=0.02).

For buckeyes, greater height was associated with greater distance from trees (P=0.07), lower tree cover (P=0.06), and higher soil water content (P=0.09). A higher percentage of annual plant cover (P<0.01) and bare ground (P=0.03) were negatively related to buckeye plant height; both factors may be indicating a sensitivity to low moisture. For live oak, regression models indicated that only higher elevation explained plant height well (P=0.03; Adjusted R^2=0.15, P=0.02, df=38). This may have been associated to a general trend in habitat changes on the eastern part of the site, which was at slightly higher altitude.

For the 2013 data, multiple linear regression models of most species were weak and inconclusive with none of the 32 variables relating well to plant height of redbud, buckeye, or pine. Buckbrush height, however, increased marginally with the presence of mature blue oaks within 2 m distance (P=0.06) and hand watering as opposed to DRiWATER® (P=0.06; Adjusted R^2 0.19, df=33). Spearman rank correlations revealed some relationships between soil and vegetation variables and the plant height of individual species as well. For example, in 2013 buckbrush height increased with the cover of mature trees (P<0.01, Rho=0.43, n=46) and their proximity (P<0.01, Rh =-0.44, n=46), while height in 2012 was weakly associated with higher pH (P=0.07, Rho=0.24, n=55).

In 2013, pine height was correlated with cover of perennial herbaceous species (P<0.01, Rho=0.37, n=49) a relationship that was not observed in 2012. For redbud in 2013, the number of meristems increased with soil N (P=0.03, Rho=0.34) and litter weight (P< 0.01, Rho=0.43, n=40) and higher health scores were also associated with higher soil N (P=0.03, Rho=0.34), while no relationships were found with these factors in 2012. Live oak height in 2012 increased with soil N (P=0.05, Rho=0.31, n=40), but not in 2013.

Environmental variable	Buckbrush height (cm)	Foothill Pine height (cm)	Redbud height (cm)
pH	*		
Clay (%)	*		
Coarse sand (%)	*		
Fine sand (%)	*		
Soil N (%)			*
Litter (g)			**
Perennial herbaceous cover (%)	↓↓	**	
Annual cover (%)		**	
Tree cover (%)	**		
Surface rocks (%)		↓	
Slope (°)		*	
Aspect (degrees from east)		**	
Flow accumulation (pixel count)		**	

soil

vegetation

remote sensing variables

TABLE 4. Habitat characteristics associated with plant height (cm) of 224 restoration plantings at the Audubon Bobcat Ranch in California as indicated by multiple linear regression models. Brown are soil, beige are vegetation and tan remote sensing variables. Symbols indicate either a positive (*) or negative (↓) effect. One asterisk indicates P values: P=0.02-0.06; two asterisks indicate P<0.01. Models for buckeye and live oak were less conclusive and are not included here.

3.5 Effects of watering method

In examining the effect of water delivery methods on overall establishment, most restoration plantings were equally likely to succeed with DRiWATER® as with hand-watered only during the hottest months (May through September). The only plant species for which DRiWATER® seemed to have any effect on health score distribution was buckbrush, for which plants were more likely to be either 'alive' or 'barely alive' with the DRiWATER® in 2012 (P=0.08, Figure 3), but less likely to be 'thriving'. Multiple linear regression models for live oak in 2012 indicated, contrastingly, that plant height increased slightly with hand-watering instead of DRiWATER® (P=0.07). Aside from these instances, there were no statistically significant differences between plant health score distribution and plant height due to watering strategy in either year.

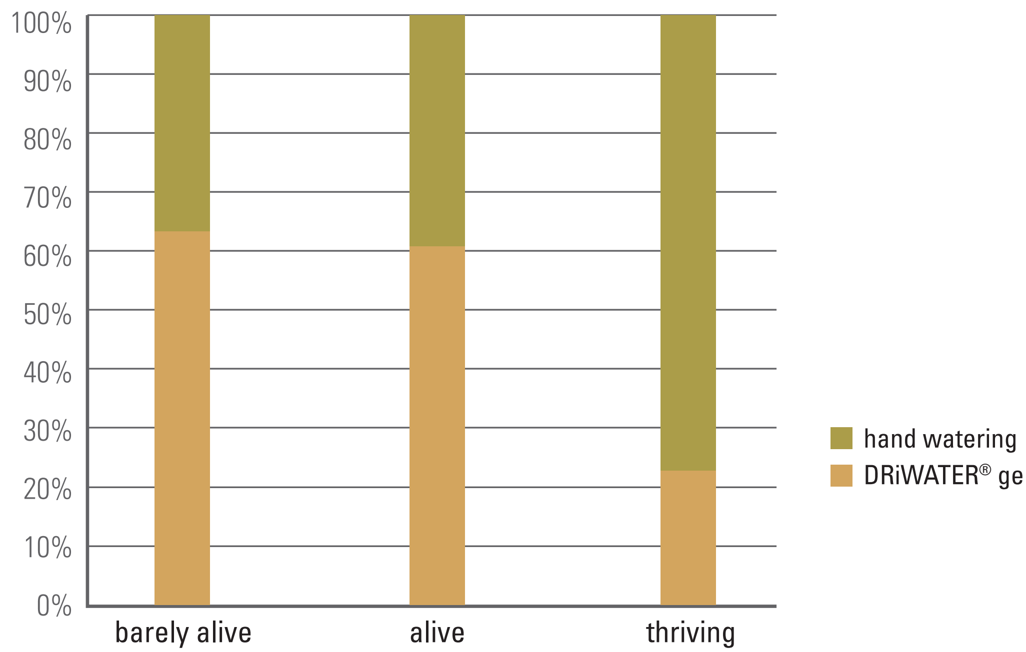

FIGURE 3. The distribution of plant health scores for buckbrush between two management options, DRiWATER® gel or hand watering once a month.

4.0 DISCUSSION

Despite the severe drought, the survival of woody plantings was surprisingly successful. Few plantings died *in situ* during the first-year establishment period. Missing plants could have been lost to a number of factors including animal damage. By the second year, 27% of all plantings were dead or missing. The careful planting methods with excavation of a deep hole in the soil, well-anchored protective tube, and monthly watering or use of DRiWATER® gel during the dry season may explain the successful plant establishment. But it is not possible to determine which aspects of these methods were most crucial for survival. Nor was it possible to know if the strong grazing pressure was from deer, cattle, or both. But deer may have been the cause of much of the browsing damage, since even 2012 damage was high, when no cattle were present.

4.1 Species comparisons

Buckbrush and foothill pine emerged as the woody plants that were the strongest survivor species. They were the only species with less than 25% mortality during the second year. For buckbrush, sites with higher pH and higher sand fractions, and some tree cover were favorably associated with plant height in 2012. In 2013, height was related to the cover and close proximity to mature trees, and more specifically to having a blue oak within 2 m. But no consistent effects of site position (i.e., slope, distance to channel, etc.) were apparent.

Buckbrush height decreased in the presence of perennial herbaceous vegetation, which was mainly the drought-tolerant bunchgrass, *Stipa pulchra*. It may be that competition for water between the woody shrub and the bunchgrass occurred, since both species have long, overlapping growth periods.

For foothill pine, the other very hardy species in the study, greater height was mainly associated with topographic factors. Higher slope and flow accumulation indicate site conditions where the deep root system of this large, long-lived species may reliably access moisture at depth. In contrast to buckbrush, height was favorably associated with perennial herbaceous vegetation in 2013. And pine height in 2012 increased with higher cover of annual vegetation. Herbaceous vegetation may also benefit from higher flow accumulation, as both life forms are typically water-limited in California grasslands. By 2013, if the conifer seedling's roots had gone deeper than the root system of the bunchgrass, direct competition for water and nutrients would have been reduced.

For live oaks, only half of the acorns planted in 2012 resulted in viable seedlings after two years of drought, but of the seedlings that survived, more than 10% were 'thriving' in 2013. Likewise, half of the blue oak seedlings survived until 2013. The protection of the plastic tubes to create a low level of browsing may have contributed to the success of these plants. Higher elevation and soil N were related to greater height of live oak, but data were not consistent in both years.

Redbud and buckeye, which are deciduous, suffered greater mortality in 2013 than buckbrush and pine, which are evergreen. Site preferences for redbud were locations with higher soil N and litter, based on measurements of height, number of meristems, and health scores. For buckeye, favorable sites would have had higher soil moisture, and/or lower competition for soil moisture.

Overall, these results indicate that buckbrush and pine are the least risky choice of woody species to transplant as seedlings for riparian restoration. But acorns of live oak and blue oak also were remarkably successful, especially given the relative ease of propagation. With better knowledge of species' site preferences, then even greater survival would be expected. For redbud and buckeye, more must be learned about their site preferences, and whether more frequent watering may be necessary to increase survival.

4.2 Habitat classifications to aid restoration planning

This study shows that soil, vegetation, and topographic variables can together indicate the locations along a waterway that are most likely to support establishment of native perennial shrubs and trees. For planning a restoration project, these results suggest that the terrain within 5 m (5.5 yd) of the stream channel is generally conducive to high survival, as were habitats with low pH, EC, annual cover and substantial bare ground. While the latter had the highest number of 'alive' and 'thriving' plants, it must be noted that the nearly half of the plantings in Cluster 3

were foothill pine, a species which is known to prefer these rather unique ecological conditions. So this may not be definitively the ideal habitat for all restoration plantings, but rather for certain species. Among these three habitat types, plant species should be chosen to match the heterogeneity in soils and ecological conditions, as discussed above (see Section 4.1).

Slightly above the stream channel, sites with mature trees, high soil organic matter arising from surface litter and decomposing roots, and high soil N, labile C, and EC also had higher cover of perennial herbaceous plants (Cluster 1). With normal rainfall, the high soil quality in this habitat type may have been more conducive to survival and growth of plantings. During the study period, however, competition with roots of mature trees and perennial grasses for water and nutrients may have been intense. Likewise, rocky sites closer to the stream channel (Cluster 2) also would have normally been more supportive of seedling establishment, because they would have received intermittent streamflow, which was absent during the study. Thus, it may be most realistic to conclude that no definitive ranking of Clusters 1, 2, and 3 can be made for restoration success in terms of habitat quality, due to the severe drought during the study.

Less favorable for seedling survival and growth were Clusters 4 and 5, the 'intermediate' and 'high clay' habitats that tended to be at the higher elevation part of the creek (indicating the east fork of Dry Creek). These groups of sites had high annual cover but otherwise differed in tree cover, distance from the stream channel, and cover of perennial herbaceous plants. Thus, it is difficult to explain which factors contributed to the poor establishment of plantings, and more information on larger scale factors may have been needed in the data set. The landscape in this part of the creek drainage was a more open flat valley, as opposed to a stream channel with hills on each side further downstream. This larger scale topography was not captured in the set of measurements in the study. But there may have been cooler temperature and moister humidity regimes in the more protected part of the creek that supported better establishment of plantings.

To determine and describe habitat types, this study used several indicators of site, vegetation, and topographic characteristics that are costly or not readily available to ranchers, land managers, and rangeland professionals. Soil tests are expensive if sufficient samples are taken to represent the heterogeneity at a site. In fact, another aspect of the project not mentioned so far is that infrared spectroscopy was a rapid, inexpensive method (Calderón et al. 2011; 2013) to able to identify conditions conducive to plant establishment, such as a high labile soil organic matter and soil C. While GIS-based data are publically available, it takes some skill to use and interpret. Despite these constraints, many of the habitat indicators in this study could be ascertained with field evaluations, such as litter as an indicator of soil organic matter, or cover of perennial grasses or mature trees as an indicator of habitat suitability (or unsuitability) for different species.

4.3 Effects of watering strategy

DRiWATER® was as effective for survival and height of plantings as hand watering once a month during the summer. It is also easier to manage in remote sites, because the cylinders can be transported on an ATV or in a backpack. Buckbrush was the only species for which hand watering produced a marginally significant increase in plant height, as compared to DRiWATER®. Although there was no unwatered control in the study, and the distribution of the plants was somewhat different in each of the habitat types, these results do indicate that DRiWATER® is a viable management option to improve the survival and growth of restoration plantings in rangeland riparian zones.

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THREE CREEKS RANCH, GLENN COUNTY

CHET VOGT, LANDOWNER AND RANCHER

SITE VISIT: November 25, 2014

INTERVIEWED BY: Louise Jackson (UC Davis) and Valerie Calegari (Audubon California)

PROPERTY DESCRIPTION

- 5 mi x 2 mi, approx. 5000 acres
- Main valley (Green Valley) is surrounded by ridges, many with steep slopes. Gravelly Ridge to the east is owned by Vogt up to its top.
- Of the ranch's land surface, 40% is grassland, 30% is savanna and woodland, and 30% is chaparral.
- Oak woodlands are mainly composed of blue oak, manzanita, and ceanothus, with some gray pine on the rockier upper slopes.
- Four creeks run through the ranch. Mad, Poison, and Clover run across the ranch, SW to NE. Briscoe enters the property in the S and runs NE then N, along the E side of the ranch toward Gravelly Ridge.
- 22 soil types, with serpentine in Green Valley in the center of the ranch.

History

Chet Vogt and his wife, Angela, at Three Creeks Ranch in Glenn County

In 1992, when Chet Vogt bought the ranch, it was one big field. The ranch had been badly abused, and he knew of only one patch of native perennial bunchgrasses. The degraded land required time, money, ideas, and the input of many people in order to recover. The initial five years showed little progress. Today, the property has fences along each riparian zone, and cross fences divide the land into many small pastures. There are 32 pastures, each grazed separately, with short rotations and longer rest periods. The riparian zones now have more gravel bars, vegetation, and most likely slower peak flows during storm events. Angela Vogt has counted 90 different bird species on the ranch, and according to Chet this is much higher than on neighboring ranches according to a surveys conducted by Point Blue Conservation Science. The restoration of the ranch has included several different types of projects (see below), and has been helped along by staff of UC Cooperative Extension and the NRCS, funding from federal and state programs (e.g., CSP, WCB and EQIP), and a long-term commitment to work that improves the quality of the land.

Vogt's Main Strategy for Habitat Restoration

- Start with developing a plan for the ranch based on landowner's answer to the question: "What do I want this ranch to be and look like?"
- Set up restoration activities with a mindset that recognizes that there is a better way to manage land than in the past, and that education in ecology and land management will help you decide what to do and why.
- Manage for "Happy Land" (Chet Vogt's term), or land that supports cattle grazing, provides environmental benefits and is sustainable, economically and ecologically, over the long term, using a variety of practices that are prioritized and fine-tuned according to the opportunities and problems that arise.

Vogt's Philosophy for Restoration on Three Creeks Ranch

- "Good things happen." Passive restoration is more relevant to his objectives than active restoration. For example, after Chet Vogt works on his streams (as described below), sediment is trapped in places that then permit the establishment of grasses, sedges and trees that stabilize stream banks, raise the water table, and provide wildlife habitat.
- "Land is for the benefit of grazing, and grazing is for the benefit of the land." Like most ranchers in the area, Chet Vogt removes the cows and bulls in summer (when there is inadequate feed and water) and moves them to permanent pasture in Modoc County. He does not run stockers, which do best on ranches with higher quality feed.

Photo, previous page: *Riparian corridor on Three Creeks Ranch, showing willows that now re-occupy the stream banks. Fences keep cattle out of a wide zone along the creek. The riparian corridors are grazed briefly each year.*

Management

STARTING POINT: Chet Vogt began the restoration projects near the entrance of the ranch, close to the headquarters, then continued with the middle part of the ranch, and lastly worked in the most southern area. The first project was a pond behind the house, and it was carried out with PL566 funding (which was the precursor for NRCS EQIP) for the upper Stoney Creek drainage.

WATER: Pipelines, troughs and tanks are fed by springs. There are no solar or electrical pumps because the topography allows for gravity-fed water transport. The high mineral content of the water tends to plug the lines, which are buried a few inches below the soil surface. Searching for and breaking up clogs is time-consuming.

In the fenced riparian corridors, he has graded some channels to spread the water outwards, thereby trapping sediment that would have moved downstream during high flows. Chet Vogt used large boulders to build rock structures that serve as small dams that trap sediment above and below the dam. Native willows, cottonwoods, sedges, and other streamside plants have moved onto the creek banks in these areas without the need for planting or irrigation.

In the riparian corridors of Briscoe Creek, for example, the gravel bars are coming back and willows are establishing. Because the riparian zone is only grazed once a year, trampling by cattle of the gravel bars is minimal. Chet Vogt sees more regeneration of native plants, such as sedges, upstream compared to 22 years ago when he arrived. Cottonwoods, willows, and redbuds are coming in on their own.

ROADS: Chet Vogt has "manicured" roads to be self-draining. By out-sloping edges, erosion is minimized and ditches do not occur.

FENCES: He uses wildlife-friendly rebar-post barbed wire fences around the various fields, and uses electric fencing for cross fencing. He uses electric fencing for the cross fencing as it is more affordable and he is able to train cattle to avoid it. On the permanent fences, the upper wires are not barbed, enabling wildlife to safely cross fencelines. To build the fences, he used contract labor partially funded by government grants.

Chet Vogt's Advice on Restoration

"Restoration of California ranchland requires a long-term commitment. You must have a goal and stay with it for the time required. Different places have different timelines. Different goals have different timelines."

LIVESTOCK: Before construction of the elaborate fencing system, the cattle congregated in Green Valley, where soils and grass production are poor. The cattle now stay in a given pasture for two weeks at a time, after which that pasture rests for about 160 days. Every three days, at some place on the ranch, animals are being moved with a quad (and horses at times) then two days are spent cleaning up and finishing the move. The livestock are rotated in a counter-clockwise movement through the ranch except for the summer, when they are transported to Modoc where Chet Vogt has a forest service permit. Not only is the feed very poor and water limited on Three Creeks Ranch in summer, tar weed is so prevalent that the animals become covered with black goo.

Despite the ranch's degraded conditions in the past, there is no yellow starthistle today. Perhaps the soil is not deep enough or the pH unsuitable for it. At the time of purchase, medusahead thatch was a problem on the ranch. Chet Vogt has managed the property so that there is now what he considers a healthy amount of medusahead. Animals graze it along with the other grasses and so medusahead thatch does not accumulate. Chet Vogt was able to train the cattle to eat medusahead by treating it with molasses until the animals became accustomed to it. Grazing each pasture three times a year also keeps it under control. Medusahead in the vegetative stage is adequate forage, so periodic grazing before flowering is actually beneficial for the cattle.

Every fall, Chet Vogt runs half his herd (200 cows) on 25 acres of rolling terrain, and feeds them rice straw mixed with anhydrous ammonia. The animals are fenced out of the riparian corridor. During this time, the remaining 200 cows are on forest service land in Modoc County.

BRUSH REMOVAL: It has been possible to open up more grazing land by removing manzanita, chamise, and ceanothus shrubs, which form nearly impenetrable thickets over 10 feet tall. This was done by chaining, burning, and herbicide application for two years in a row. Oak establishment and ceanothus shrub encroachment begins soon afterwards, necessitating a second season of management.

Cattle are concentrated in one small field (25 acres) during the fall, without access to the riparian corridor. They are given supplemental feed and water pumped into troughs.

PLANTING NATIVE PLANTS: On this ranch, seeding of native perennial bunchgrasses has been only marginally successful. The balance of "killing what you don't want and keeping what you do want" is difficult. The process used to establish native grasses was to use Roundup on an entire field and then drill seeds of seven native perennial grass species (e.g., purple needlegrass and melics) into the bare ground. Now, three years later, there are patches of perennials that seem to have been selectively ungrazed. The animals apparently prefer annual grasses, and since they are taken off the land before the annuals are overgrazed, some perennial grass plants have survived.

At one site on the ranch which was planted according to the methods described above, native grass seedlings emerged in the first year, but only persisted on a one rocky knoll in one section of that site, surprising due to the low water-holding capacity in such microsites. While the establishment of native bunchgrasses is due to habitat conditions and/or yearly weather conditions, it it is difficult to know what factors were most important for success in this instance.

Although no oaks have been planted on the ranch, there are blue oak seedlings up to 1-foot tall in several of the fields. Their survival may be due to the fact that the livestock are removed when the feed quantity of annual grasses declines, leaving behind the oak seedlings that are less desirable as forage. In areas of dense blue oaks, Chet Vogt thins the forests in order to encourage the health of remaining trees.

In a few locations along riparian corridors, willow stems were cut and placed directly in the soil, but the main regeneration has been passive. During this long drought, Chet Vogt is noticing that willows are dying.

OTHER ACTIVITIES: Elementary students from Willows School District visit the ranch each year. Chet Vogt stated that other ranchers have visited the ranch, but are uncertain and somewhat skeptical about how they would use these passive restoration methods on their land. For this reason he focuses on elementary student education.

DOTY RAVINE PRESERVE, PLACER COUNTY

JUSTIN WAGES, LAND MANAGER; PLACER LAND TRUST, LANDOWNER

SITE VISIT: March 11, 2015

INTERVIEWED BY: Louise Jackson (UC Davis) and Valerie Calegari (Audubon California)

PROPERTY DESCRIPTION

- 427 acres along Doty Ravine northeast of Lincoln.
- Perennial stream with salmon habitat in the western foothills of the Sierra Nevada.
- Protected since 2005 through Placer Land Trust's West Placer Habitat Protection Program.
- Multiple on-going restoration projects in riparian, floodplain, and vernal pool grassland habitats
- Of the ranch's land surface, 75% is valley grassland with vernal pools, 10% is riparian corridor, and 5% is oak savanna.
- The surrounding landscape is grazed rangeland and irrigated pasture with scattered residences.
- The dominant tree and shrub species in the riparian corridor are cottonwood, sandbar willow, Goodding's willow, white alder, Oregon ash, box elder, California black walnut, blue oak, valley oak, and Himalayan blackberry.
- Soils: Xerofluvents (drainageways with 100% hydric soils) along the creek; Ramona sandy loam on the adjacent floodplain with Alamo variant clay in the depressions; and Redding and Corning gravelly loams on the nearby terraces.

History

The Doty Ravine Preserve is owned by the Placer Land Trust. It was acquired as a mitigation property for a Roseville development project, and the specific purpose was to protect vernal pools and Swainson's hawk habitat. In 2005, when the land was obtained, the riparian zone was very degraded, with eroded banks, and a dense thatch of medusahead, an invasive annual grass, in the floodplain. The degradation was due to poor livestock management. Historically, the land was used for dryland grazing, with some irrigated pasture. There had not been any cross-fencing or fencing for riparian protection. Trees had been reduced to lower density than either above or downstream on the same creek.

Justin Wages at the Placer Land Trust's Doty Ravine Preserve

Much of the floodplain is usually dry despite its proximity to the creek due to a levee built prior to 1937 on the south side of the creek. In years with normal precipitation, the creek usually overflows into the floodplain at least once during the winter. Remnants of a flood-style irrigation system for irrigated pasture were available for the restoration project.

The main project along the Doty Ravine riparian corridor occurred in the fall of 2008, when Westervelt Ecological Services and High Ranch Nursery planted 5,000 California native trees and shrubs in a 20-acre restoration site located along Doty Ravine. In preparation for the planting, two years were spent on the removal of invasive species and land preparation (see below). Developing reliable irrigation to establish and maintain the young plants has taken some experimentation. There has been huge improvement in cover of woody plant species, and native grasses, sedges, and rushes have grown well. Wildlife, such as wood ducks and otters, has increased. This restoration area was excluded from cattle grazing during the establishment period. Flash grazing is now being reintroduced into the project area to reduce herbaceous cover, and has been a great success. The recent cattle operation benefits from the high quality of forage at a time when the rest of the preserve has lower quality forage (fall or late winter). The land trust is now reaching its long-term goal of improving the land by utilizing better livestock management and new scientific information on grazing and restoration. Four years of drought, however, has been very problematic, as it has changed the water flow in the creek and adversely affected plant growth.

Riparian Floodplain Restoration on Doty Ravine Preserve (2008 California Regional Water Quality Control Board – Supplemental Environmental Project (SEP)). On the left is from the 2006-7 season showing dense thatch of medusahead. The right-hand photo from 2015 shows trees planted in 2008.

Other projects are underway for specific purposes, and some will be described briefly below:

- Use of a native sedge to discourage Himalayan blackberry and other invasive plants along the creek.
- Enhancement of bulrush wetland to attract Tricolored Blackbirds.
- Encouragement of beaver dams near levee-removal areas to promote floodwaters in historic floodplain.
- Upland grassland restoration on the stream terraces using native annual and perennial grasses and native wildflowers for attracting and maintaining honeybees and other pollinating insects well into the summer.
- Embankment plantings of drought-tolerant perennials, such as ceanothus, blue elderberry, and coyote brush, to reduce erosion and increase wildlife habitat.

Support for these restoration projects has come from the California Regional Water Quality Control Board, National Resource Conservation Service (Wildlife Habitat Incentive Program) and the US Fish and Wildlife Service (Partners for Fish and Wildlife Program). The bee project was carried out in collaboration with UC Davis and Project Apis m. Doty Ravine Preserve is closed to the public, but there are numerous ways that people can visit, utilize, and support the preserve. These include annual trainings for US Fish and Wildlife employees, field trips for college and university classes, academic internships for college students, scout camping trips, volunteer service for conservation such as by Americorps, Girl Scouts, Boy Scouts, and as a source of information for the Placer County Conservation Plan. A small endowment generated through conveyance fees from mitigation of area home sales provides minimal funds for management each year.

Placer Land Trust's Main Strategy for Habitat Restoration

- "Placer Land Trust is dedicated to quality of life through the protection of wide open spaces, wild places, local farms and ranches, natural playgrounds, and the links that connect us to them." (http://www.placerlandtrust.org/about-plt/our-mission/)
- Combine multiple goals: watershed protection, working landscapes, and wildlife protection.
- Create opportunities for people to connect with each other and the environment.

Placer Land Trust's Philosophy for Restoration on Doty Ravine Preserve

- Maximize the Doty Ravine Preserve's habitats for biodiversity and resilience, to benefit the greatest number of species and the human communities downstream, with a mindset for what the future may hold.

- Learning landscape: protect the land in perpetuity while continually evolving the practices used for protection and stewardship, and share the results with a larger community.
- Active restoration: Keep livestock out of sensitive riparian areas and re-plant the degraded areas with native plants to protect the health of these ecosystems. Utilize livestock for future maintenance of the riparian zone by harnessing the power of short duration but high intensity grazing during the late winter months.

Management

First, the management time sequence and details of the main riparian floodplain restoration project are described. Then specific topics (e.g., water, fences, brush removal) for restoration and planting native perennials are dealt with separately, using some information from the main riparian project, and some from other smaller projects on the floodplain and embankment nearby.

Justin Wages' Advice on Restoration

"Choose plant species that you know will do well in specific places. What is found nearby? Plan for your irrigation! Plan for everything taking much longer than you expect."

MAIN PROJECT ALONG THE DOTY RAVINE RIPARIAN CORRIDOR: The 20-acre restoration project along the creek and its adjacent floodplain began with removal of invasive plants in 2007 along with constructing a 5-strand barbed wire fence to exclude cattle. A thick thatch of medusahead covered about 80% of the land surface and large patches of Himalayan blackberry were scattered around the site. Prior to restoration the site looked much like a golf course during winter months with very low statured annual grasses which quickly dried up. The site transformed into a weed field with very little forage value during the first year. There were no perennial grasses and little of the biodiversity usually present in floodplain habitats. Westervelt Ecological Services contracted with a local grazer to use livestock to reduce invasive and non-native vegetation in an effort to prepare the site for planting in the fall of 2008. The remaining patches of blackberry were masticated with tractors using flail mowers. Seeds from native trees existing on the site were collected and contract grown at High Ranch Nursery. These plants would later be used during the restoration process.

In the fall of 2008, Westervelt Ecological Services and High Ranch Nursery mapped the hydrology of the 20-acre site to better assign plant species to appropriate habitats. A hydrologic-based topographical map was created and plants were assigned to regions of the site where they had the best chance of successful establishment and growth. Some earth movement occurred to create small oxbows (20 to 30 feet long and approximately 4 feet deep) within the floodplain but well outside of the creek channel. There was no grading along the creek. This helped avoid triggering certain permit requirements which would have increased project costs. All appropriate permits including cultural surveys were granted prior to construction. The idea was that oxbows would help retain flood water longer into the growing season and thereby support a wider diversity of plant and wildlife species. The plan was designed to utilize the old remnant flood irrigation system that was historically used for irrigated pasture.

The 5,000 plantings included sedges, trees, and shrubs, including species such as valley oak, blue oak, live oak, Oregon ash, box elder, California sycamore, Fremont's cottonwood, California black walnut, California wild rose, blue elderberry, California wild grape, coyote brush, and Santa Barbara sedge. Planting holes were dug using a tractor-mounted auger. This made planting much easier and more efficient, and allowed plant roots to tap deep into the ground quickly because of reduced soil compaction. Fertilizer packets were added to the soil as it was backfilled, and a 3-foot TubeX plastic shelter tube and ground cloth were placed around each seedling.

The existing flood irrigation system was used every few weeks or as needed to maintain soil moisture, and saved the cost of installing a new system. Unfortunately, the excess water resulted in a massive growth of herbaceous cover (grasses, non-native sedges, and other weeds), making managing the site much more difficult. These plants provide excellent cover for voles and gophers, both of which exacted a heavy toll on the restoration plantings. The site was flash grazed by sheep to reduce herbaceous plant growth. While largely successful at reducing the coverage of invasives, the sheep were quite destructive to desirable plants and restoration plantings. Sheep would rub on tree shelters which often broke the seedlings or the stake holding the TubeX shelter in place. They also browsed the tops of any trees/shrubs growing out of the tree shelters.

Grazing was eliminated from the project site after the sheep problems, and mechanical mowing and weed-eating were used instead. In hindsight, Justin Wages feels that mowing is a less expensive and easier way to control invasive plants, assuming the restoration plantings are planted in rows much like would occur in an orchard. Due to seedling mortality, these rows will eventually become uneven and wavering, which looks much more natural. As was explained above, flash grazing by cattle has been recently adopted once or twice per year in the fall or late winter. But this is only possible due to more secure fencing around the creek and the entire restoration area.

This first project was fairly successful. Thousands of trees and shrubs are well-established on the floodplain. Justin Wages estimates that more than 60% of the plantings survived (less than 40% mortality). Willow, cottonwood, sycamore, wild rose, and sedges were particularly successful. Box elder and oaks also established well, though the oaks grew more slowly. A non-native but non-invasive rush species also increased and provides habitat for rabbits that attract Northern Harriers and other hawks. But there were some problems that arose directly and indirectly from flood irrigation. It caused vigorous weed growth, as explained above, and these fast-growing annual species competed with the slower-growing native plantings. In addition, the dense coverage of annual plants protected voles that were able to crawl under the ground cloth and nest in the TubeX shelters and girdle young trees and shrubs. Justin Wages estimates that 70% of the tree and shrub mortality (or approximately 25% of the total plantings) resulted from vole damage. If the area surrounding plantings are kept relatively clear of tall vegetation, vole damage would likely be reduced as predators such as hawks and coyote would have much easier views of and access to voles.

WATER: Irrigation is the management factor that Justin Wages believes is most important for successful establishment of plantings of native perennials along creeks and floodplains. Failed irrigation is very costly in terms of site preparation, staff time, and plant materials.

The remnant irrigation system for irrigated pasture consisted of underground pipes and risers that brought water to the surface. The system was mapped out and the risers were repaired. The source of the water was the creek, which has never dried out even during drought years. The topography allowed for gravity-fed water transport which effectively maintained soil moisture throughout most of the site. Alternatively, one could create berms or checks between planted rows and apply water much like for an orchard, but this is a very inefficient and wasteful method of irrigation.

A few years ago, during the period of flood irrigation on the floodplain, a main line burst underground. An accidental wetland was created on the floodplain that is now habitat for Black Rail, a secretive, mouse-sized bird of shallow marshes and wetlands. It is a California threatened species.

Drip irrigation with emitters at each plant was used for a subsequent project for planting riparian native woody species in 2011. Each seedling was in a 3-gallon pot that was imbedded in the soil for four years and subsequently became very root-bound. The drip system was gravity-fed from an 1100-gallon water tank. The tank was periodically filled using a generator and an old well. Unfortunately the well failed and the drip system was abandoned. Hand watering took place throughout most of the next few summers. While plantings near the creek did well, nearly half of the plantings in the project were lost during the current drought.

Outside the main riparian area, a more recent project is the planting of native perennials on the upland terraces 15 to 20 feet above the main creek, above a small water channel. Three irrigation methods were tested: hand-watering, DRiWATER® (http://www.driwater.com/) gel that gradually releases moisture when exposed to soil, and portable rotating sprinklers. Justin Wages thinks that DRiWATER® in paper cartons is effective for a one-time application. Since cartons fall apart and leave a vacant hole, roots dessicate when exposed to the air. Using PVC-plastic sleeves, though more expensive, is better for replacing the gel intermittently during a long-term drought. The rotating sprinklers have two sprinkler heads each with an approximately 40 to 60 foot throw. They are fed by a portable sprinkler pump attached to a 100-gallon tank carried in the back of a pick-up truck.

ROADS: No new roads have been made.

FENCES FOR LIVESTOCK: At the preserve, livestock grazing occurs outside the main 20-acre restoration project. A 5-strand barbed wire fence is recommended by Justin Wages as a boundary fence to keep cattle out of lush grass stands or edges of the creek in the restoration area. A 4-strand, high tensile electric fence was used for the majority of the riparian exclusion fencing because it was less costly and more wildlife-friendly. However, the electrified fence can be problematic as a livestock barrier. If, for example, dense tall grass shorts out the electric fence, livestock will break through.

LIVESTOCK: While the main restoration site has not been grazed until very recently, livestock grazing occurs on most of the rest of the preserve. Early on, in the non-restoration areas, there was an opportunity to compare a management-intensive vs. an open grazing approach to assess the effects on invasive plants. In the management-intensive approach, cattle were moved through a series of paddocks to intensively trample and graze each area. Plants were allowed to grow before cattle were reintroduced. On the other side of the creek, the lessee left the cattle in an open grazing regime without any paddocks. Surveys of cover of plant species in May, 2009, showed that the coverage of medusahead decreased on both sides of the creek, but the reduction was more pronounced with the intensively managed paddocks on the north side of the creek. When medusahead is reduced in the adjacent grazed areas, the neighboring restoration area is less likely to be reinvaded. Grazed plots contained higher coverage of native grasses and forbs, and lower coverage of invasive species than ungrazed, control plots.

Subsequently, the grazing regime in the non-restoration areas has become less management intensive through the better overall condition of the preserve, the use of new fencing to create more paddocks, and additional water sources (i.e., solar-powered water pumps and new troughs). From the rancher's point of view, the solar-powered pump systems also provide electricity that can feed an electric fence, which saves the time and the effort of dragging a solar panel and battery out to the area to be fenced. Rental prices are adjusted to compensate the rancher for their extra workload and loss of animal productivity when performing prescribed grazing services or because of a loss of acreage during restoration projects that exclude grazing. The fees collected from grazing contracts are put back into a fund that pays for future preserve enhancements and infrastructure maintenance and repairs.

BRUSH REMOVAL: Himalayan blackberry along the creek edges was the main target for brush removal. Given the proximity to the stream, tractors and flail-mowing were not an appropriate. The project was mainly completed by volunteers from AmeriCorps. They removed the blackberry using a mixture of long-pole hedge trimmers, machetes, and lopers. These efforts were followed up by applications of herbicide (mainly glyphosate and triclopyr) where appropriate and according to herbicide prescription. No fire was used.

PLANTING NATIVE PLANTS: Planting and establishing native perennial plants has already been described above for the project on the main creek's floodplain. Several other small projects for establishing native trees and shrubs have been carried out at the Doty Ravine Preserve during the past nine years. The following information is from these smaller projects. The focus is on certain species and methods in specific types of locations, such as on the floodplain, along the creek edge, or on embankments above the floodplain.

For native woody species contained in 3-gallon pots on the floodplain (for which a drip irrigation project was described above), drought may have been the main deterrent to survival, since plantings near the main creek channel had higher survivorship. The most successful species were California sycamore, box elder, Oregon ash, and willows. Of the three willow species (arroyo, Gooddings, and sandbar) that were planted, sandbar willow had the highest survivorship and growth, although all did quite well. Valley oak was poorly suited to this method, probably because the roots coiled in the pot and did not form a taproot that could access deep soil moisture.

Planting willow stakes was a way to stabilize the creek bank, and create more secure habitats for other native trees and shrubs. From well-established willows, younger shoots with a width of 0.5- to 1-inch are cut near the base of the plant, noting the top and bottom of the shoot. The shoots with many nodes and meristems are most desirable. The side branches are trimmed, and the living stakes, are soaked in water, then are pushed or pounded two feet deep into muddy soil. These stakes eventually take root, and then other perennial species can be planted nearby. The willow branches need to be thinned periodically to reduce competition and let the other species thrive.

The Santa Barbara sedge, also known as valley sedge or white root, is another species that has been useful for bank stabilization. It produces prolific rhizomes that anchor soil and also allow the plants to spread rapidly. Planting this sedge on the edge of the Doty Ravine creek has deterred invasive plants such as poison hemlock. It has been planted to replace Himalayan blackberry, which initially dominated much of the bank, and once established, keeps out the blackberry.

A planting of Santa Barbara sedge on the edge of Doty Ravine Creek (foreground) with Himalayan blackberry on the far edge of the creek. The native sedge prevents the non-native Himalayan blackberry from spreading.

On the upland terraces that occur 15 to 20 feet above the creek and floodplain, Justin Wages recommends planting native perennials on the zone from the toeslope and footslope, and not on the steepest part of the embankment, or on the top of the embankment, unless a dependable irrigation system is available. Successful perennial plantings on the gentler slopes of the terraces included coyote brush, willow, lupine, and blue elderberry, but they all have required hand-watering through the drought. Ceanothus "Ray Hartman" was browsed by deer in the absence of metal cages around the TubeX shelters. In one area, where the toeslope meets a swale where water temporarily accumulates, Scirpus rushes and cattails were already present. Plantings of Santa Barbara sedge and creeping wild rye are now proliferating along the channel.

In the TubeX shelters around plantings, Justin Wages has found that woody stems and trunks develop better in tubes that are no more than three feet tall. When buying the cheaper, flat version, use duct tape or zip ties to augment the snap closures. In hindsight, Justin Wages would prefer to have used the pre-formed round shelters. The shipping costs for the round version are much higher. To support the shelters, he suggests using a 1-inch x 2-inch wooden stake on the inside of the shelter, rather than a bamboo pole, which breaks easily, causing the shelters to fall over. Sturdy metal wire cages (4 feet diameter x 5 feet tall) around the TubeX shelters were essential if using livestock grazing for weed management. Justin Wages suggests using a minimum of three T posts per cage.

MONITORING: For the main riparian restoration project, photographs are taken at specific photo point locations every year, and compared with photographs at the time of the initial baseline conditions. A descriptive overview with specific changes, such as losses of an old oak tree or effects of drought, is made each year. The observed changes are compared with the property's management plan, as a basis for adaptive management.

OTHER ACTIVITIES: As explained above, the Doty Ravine Preserve welcomes many types of people and organizations, consistent with the Placer Land Trust's commitment to engaging the community in environmental education and restoration. Through grants and cooperation with state and federal agencies, and connections with universities and colleges, this small property offers a unique demonstration of viable riparian restoration practices.

RIPARIAN HABITAT RESTORATION PLANNING WORKSHEET FOR CALIFORNIA RANGELANDS

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INTRODUCTION TO THE WORKSHEET

When it is time to start thinking about a habitat restoration project, you and the rest of the people involved in the management of your property should start by asking yourselves, “What do we want for our land and how do we want to get there?” This worksheet is intended to help landowners and land managers with decisions about installing restoration projects that establish native plant species along creeks in California rangelands.

The general framework for this worksheet consists of an Objectives Phase and a Design Phase. The Objectives Phase begins by determining your long-term vision for the property as well as your goals for the restoration project. To help you outline the goals of your project, this worksheet uses the concept of ecosystem services in its widest sense. Ecosystem services are the benefits that an ecosystem provides. This concept goes beyond food, water, and environmental quality, and includes other benefits such as recreational or aesthetic value (blocking the view of a neighboring golf course, for example), or increasing the land’s resale value. The worksheet first asks you to choose a category of ecosystem services of foremost importance, and later helps you decide on specific interventions and practices to meet your goals. Before making decisions about specific restoration practices, however, you will consider the available funding and other resources (e.g. landowner funds, grant or public funds, volunteer or staff time, materials, existing biodiversity, etc.) available to implement a project. The Design Phase lays out clear steps for ensuring that the project accomplishes your goals and contributes to your overall vision for the property.

A five-step planning process (Figure 1) is invoked to: 1) Clarify objectives; 2) Identify resources; 3) Re-evaluate priorities after considering resource availability; 4) Configure a specific project; and 5) Reconsider how well the proposed project addresses goals identified in the Objectives Phase. This worksheet is not intended to provide a comprehensive project plan; instead, it will guide you through a thought process which should help ensure that your project maximizes available resources and takes you closer to your long-term goals. It should be used in conjunction with a concrete, detail-oriented design.

OBJECTIVES PHASE

1. Goals: What is our ranch's vision for our streams and their functions?

Provisioning	Regulating	Cultural	Supporting
Water and food for humans and livestock	Clean water	Aesthetics	Site integrity and quality for future generations
	C storage	Stewardship	
	Wildlife habitat	Eco-tourism	
		Heritage	

2. Resources: What support do we have for the project?

Human	Social	Financial	Physical	Natural
Knowledge	Agency support	Savings or credit	Equipment	Native vegetation
Experience	Land tenure	Government subsidies	Road access	Soil quality
Family effort	Local help		Reliable irrigation	Source of endemics

3. Re-evaluate: Refine our goals based upon existing resources

DESIGN PHASE

4. Design: Configure the restoration project to meet our ranch goals

Choose the type of interventions	Create potential layout and design
Passive restoration	Spatial extent and distribution
Active restoration	Habitats included
Channel grading	Timing of operations
Berms and small dams	Zonation of plantings of native species
Invasive removal	Wildlife interventions
Woody plantings	
Seeding native grasses	

5. Reflect: How well does our restoration plan address goals, work within available resources, and deal with obstacles?

FIGURE 1. Diagram for the riparian habitat planning worksheet for California rangelands, showing an Objectives Phase and a Design Phase. The idea is for you to work through the five steps sequentially; each is numbered on the diagram. The arrows follow the conceptual pathway. For example, Step 1 on goal setting is revisited after re-evaluating the available resources (Step 3). The Design Phase begins after Step 1 (goals) and Step 2 (resources) have been re-clarified. The actual design (Step 4) consists of choosing the types of interventions and practices, then creating a potential layout and site design. Step 5 has you reflect on goals, resources, and obstacles, in order to continue refining the actual design (Step 4) before it is implemented.

LANDOWNER/LAND MANAGER QUESTIONNAIRE

In going through the steps of this questionnaire, it may be helpful to keep checking the diagram in Figure 1. It shows the five steps of the Objectives and Design Phases, and arrows indicate when it is desirable to revisit a past step and reassess the goals and feasibility a second (or even third!) time.

From now on, and in Figure 1, "we" refers to you and the other people involved in the management of your property. "We" is the chosen pronoun here to recognize that when restoration is a group effort, the project benefits from a diversity of viewpoints, knowledge, and technical skills. The resulting project will then lead to greater buy-in and overall satisfaction along the path to implementation and into the future.

OBJECTIVES PHASE:

1. **Goals:** What is our ranch's vision for our streams and their functions?

Overview on goal setting: *Examine our vision for the ranch and its streams.*

- What is our long-term vision for our ranch?________________________________

- Do we have a long-term vision for our rivers and streams?________________________________

- Why do we want or need to restore a particular stream?________________________________

- How do we see a restoration project contributing to our vision for our ranch?________________________________

Ecosystem services approach: *To prioritize desirable outcomes from stream restoration on our ranch, use the ecosystem services concept of 'nature's benefits'.*

- Think of ecosystem services as all of the benefits that can be provided by nature. Check the broad categories that are most important to the vision for the stream and the ranch, and also the specific issues that seem particularly essential. These will become the goals for designing a restoration project. Add notes here on explanations or rationale.________

    A. Products provided by the ecosystem (provisioning services)

    ☐ water for livestock ☐ forage production for livestock ☐ water for humans

    ☐ food for humans (i.e. fish or wild plants) ☐ firewood ☐ building/craft materials

B. Environmental benefits gained by regulating or modifying the ecosystem (regulating services)
   ☐ water quality ☐ carbon storage ☐ wildlife habitat ☐ waterfowl habitat ☐ fish habitat
   ☐ erosion prevention ☐ reduction of sedimentation ☐ habitat for beneficial insects
   ☐ forage for pollinators ☐ pest control ☐ flood abatement ☐ air quality ☐ weed control

C. Aesthetic, stewardship, recreational, and other non-material benefits from the ecosystem (cultural services)
   ☐ aesthetics ☐ mental/physical health benefits ☐ eco-tourism ☐ spiritual benefits
   ☐ stewardship of the land ☐ cultural heritage ☐ educational value

D. Long-term value of the ecosystem, land, and property (supporting services)
   ☐ long-term soil and water quality ☐ long-term integrity of the land ☐ long-term profitability

- Are there any other goals that are not listed here?____

- What ecosystem services from a creekside restoration project are the priorities for our vision for the ranch?

Existing conditions and land use: *Evaluate constraints and possible changes that could affect our goals for stream restoration.*

Land use

- What types of activities take place on the ranch (grazing, irrigated pasture, ORV use)?________________

- Do we want to continue all these uses?____
- What other uses would we like to see carried out on this property?____________________________

- Would any of these activities or uses affect our objectives for stream restoration?____________________

- Consider what our target ecosystem will be. Do we have a direct reference in the nearby landscape, or will we be building a novel ecosystem? ____

Land tenure

- Who owns the property?____
- Are there any deed restrictions or other agreements associated with the property (conservation easements, rights of way, oil or gas extraction rights, leases)?____
- Are there any constraints on stream restoration?____

Existing disturbance

- Are any of the following types of disturbances affecting the potential restoration site(s)?
  ☐ Bank erosion ☐ flooding ☐ overgrazing ☐ trampling by livestock ☐ invasive species ☐ landslide
  ☐ damage to riparian vegetation from a dropping water table ☐ fire ☐ past mining ☐ past logging
  ☐ loss of aesthetic benefits ☐ not sure ☐ other____________________________
- Add any other disturbances and clarifying notes here.____________________________________
- In what ways could existing disturbances and land degradation affect our stream restoration goals? ____________

2. **Resources:** What support (people, agencies, tools, materials, biodiversity, soil quality, etc.) do we have for the project?

Human resources: *Identify potential sources of knowledge, innovations, networks, and labor.*

- Of all the landowners and/or managers, who is most committed to seeing the project through to completion?____
- What are our sources of knowledge and innovation for the stream restoration project?____________________
- Who are the people in our community who could help design, install, maintain, and/or monitor the success of this restoration project? *Some ideas: employees, partners, family members, friends, contract labor, potential volunteers (e.g. Americorps, scout troops, high school students, local clubs or other social organizations, universities or colleges, religious organizations*____

- Expand the answers to the questions presented above by filling in this table:

Who?	**How many?**	**Time frame?**	**Where would they fit in best?**	**Special skills?**
My kids	*2*	*Summers, weekends until 18*	☐ design ☑ install ☑ maintain ☐ monitor	*gopher hunting*
			☐ design ☐ install ☐ maintain ☐ monitor	
			☐ design ☐ install ☐ maintain ☐ monitor	
			☐ design ☐ install ☐ maintain ☐ monitor	
			☐ design ☐ install ☐ maintain ☐ monitor	

Social resources: *Consider agencies, organizations and other professional connections who could lend advice or support in some way.*

- Is it possible to receive technical support or assistance from an outside organization for this project? ☐ Yes ☐ No
- If so, list the outside organizations:
- What kind of support (e.g. design, installation, etc.) might they offer?
- Who could help with land tenure decisions, easements, and regulatory issues? *Some ideas: local Resource Conservation District (RCD), Natural Resource Conservation Service (NRCS), non-governmental organizations (NGOs) e.g. Audubon California, California Association of Family Farmers, or Wild Farm Alliance, local land trust, county office of the University of California Cooperative Extension*

Financial resources: *List the potential sources and amounts of funding, and any constraints on using funds.*

- What sources of funding (e.g. landowner, public grants, NGOs, endowments, earned income) exist for this project?
- Is there a time constraint for using any of this funding? ☐ Yes ☐ No
- If so, identify time constraint:

- What is the approximate budget available to carry out this project? ____________________

Tools and equipment (physical resources): *Think about the tools, equipment, and infrastructure are already available, and those that are needed to achieve the long-term goals.*

Irrigation

- Is there a reliable water source for irrigation at the potential restoration sites? ☐ Yes ☐ No
- Are the potential restoration sites amenable to drip irrigation? ☐ Yes ☐ No
- Are there other options for irrigation at the potential restoration sites? ____________________

____

____

Equipment

- What useful equipment, tools, and/or supplies are already on the ranch? *Some ideas: heavy equipment for site preparation/channel grading/berm formation, planting supplies, hand tools, scrap materials, on-site nursery, power augur for planting holes, weed control equipment (backpack sprayers, ATV sprayers, weed eaters, mowing equipment), fencing materials for protecting plantings (T-posts, rebar, wire fencing, tree stakes, tree tube shelters), source of compost for soil preparation, water trucks, water tanks* ____________________

____

____

____

____

Natural resources: *Describe the vegetation, water resources, and soil quality on the potential stream site(s).*

Vegetation

- Are there native and/or other desirable species present at the site(s) or in surrounding areas already? ☐ Yes ☐ No
  If yes: what type, how many, distance from stream, approximate age, and evidence that they are reproducing effectively? ____________________

____

____

____

____

Hydrology and soil

- What is the seasonality and abundance of water in the stream at the potential site(s)?____________________
- Are there areas of standing water? When, where, and for how long?____________________
- Does the stream have a relatively natural hydrograph or is it altered?____________________
- What is the general condition of the soil, such as gravelly, sandy or fine-textured, easily erodible, deep organic litter layer?____________________

- Does the general condition of soil vary visually across the site(s), and if so, how?

- Elaborate on any of the following, given that this information is available: soil types, pH, soil organic matter content, level of compaction, texture, depth and location of stratified layers, level of heterogeneity, rockiness, etc.

- For the potential site(s), describe the condition of the stream bank and its potential for erosion (height and slope of bank, history of erosion, presence of undercuts, amount and type of vegetation present, livestock exclusion).

Other

- What other natural resources exist? *Some ideas: boulders useful for streambed alterations, timber for building structures or as a source of woodchips for mulch, plants from which seeds or cuttings could be taken*

3. **Re-evaluate:** refine our goals based on existing resources

Limiting resources: At this stage, careful re-assessment of existing and needed resources is essential for achieving appropriate scope for a potential restoration project.

- Identify the most limiting resources/assets from Step 2 above: *human, social, financial, physical, natural*

- Think about ways to increase access to these resources. Get creative, but be realistic.

- Add any new ideas under Step 2.

Other restrictions: Check about other types of restrictions that might be encountered before starting to draw up any defined plans.

Land tenure and regulatory restrictions

- Based on land ownership, easements, and other laws, are there any legal restrictions that may affect the project?

- Are there regulatory permits to obtain before starting the project?

Physical and natural resource restrictions

Accessibility

- Is there existing road access to the site(s)? ☐ Yes ☐ No
- Is the site accessible to heavy equipment, such as a backhoe or tractor? ☐ Yes ☐ No
- Other notes about accessibility? *Some ideas: very steep or rocky, only accessible by foot, remoteness from main access areas, near a permanent water source for irrigation* ____

Vegetation

- Are there invasive species present at the site(s) or surrounding areas that may require control prior to and/or after installation? ☐ Yes ☐ No
- If so, what are the invasive species? Describe density and level of establishment, as well as patchiness along the stream reach of the site(s). ____

Hydrology and soil

- In which specific locations will earth-moving, berms, or other types of site engineering be necessary? ______________
- What aspects of hydrology and soil distribution may affect the choice of plant species and the overall design and management practices for the project? *Some ideas: patchiness of soil types and drainage, locations along the reach where passive restoration is possible vs. more disturbed locations where active restoration is necessary, storm flow hindrances to plant establishment, likelihood of change in water table depth, flooding frequency and location* ________________________

Other

- Can we identify any offsite (especially upstream) factors over which we don't have control, but which may affect the project vision and goals? *Some ideas: sources of pollution/sediment/debris, heavy water use, invasive aquatic/riparian species* ____

- Are there site conditions which could affect the establishment of planted species? *Some ideas: changes in deep shade as a project matures, potential for damage from livestock or wildlife, changes in storm flows and flooding as a result of climate change* ____

Reconsider and refine goals: Review our objectives and priorities, and determine any adjustments that would make the project more feasible and successful

- Revisit objectives and priorities. Considering resources and limitations, think about the following questions, and amend goals as necessary: Which goals can't be compromised? Which immediate goals are most important to the long-term overall goals? Do goals need adjustment? What scale of project is most likely to succeed? What measurable outcomes can be defined? ____

- Go back to step 2 and record any changes in the goals. Include additional thoughts there, or use a separate sheet of paper if necessary.

4. **Configure** the restoration project to meet our ranch goals

Outline of project objectives: Write a 1- or 2-page project outline as a summary of the Objectives Phase.

- What key aspects of the restoration project must be outlined to start the design phase? In a separate document, develop your own outline, or use this one as a template. Short answers and bullets are probably sufficient at this stage.

  A. Background

    1. Desire or need to restore a particular stream
    2. Contribution of the stream restoration project to our vision for our ranch
    3. Ecosystem services to be increased by the project
    4. Site overview: possible locations and their land use types, land tenure, and existing disturbance levels

  B. Resource availability

    1. Main source of knowledge, innovations, networks, and labor
    2. Agencies and organizations likely to be contacted for support
    3. Potential funding sources and amounts
    4. Irrigation and equipment currently available
    5. Existing natural resources that will help the success of the project

C. Limitations

1. Land tenure and regulatory restrictions (if known)

2. Physical and natural resource restrictions

D. Site map (described below)

Site choice and mapping: Examine each potential site on the ranch, and decide where the stream restoration project will be most feasible and successful.

- What are the key resources and important limitations at the potential site(s) on the ranch? Outline pros and cons of each potential site in this table, referring back to Steps 2 and 3 above.

Potential site for the restoration project	Key resources at this site	Important limitations at this site
Stream site 1		
Stream site 2		
Stream site 3		

- Is a particular site favored overall by available resources and existing limitations? ______________________________
____

- Would a restoration project at this site adequately achieve our goals and overall vision? ________________________
____
____

- For the most viable site, what stream reach will be the focus of the restoration project? *Some ideas: Consider different reaches on this stream that have different levels of degradation severity. Should the project focus only on the most disturbed areas of a reach? Or is it more cost effective to focus on less degraded areas that may need less intervention for restoration? Are there areas that should be excluded from the project because they are too degraded to restore in a cost-effective manner?*
____
____

- Define specific boundaries for the restoration project, both along and beside the specific reach of the creek. Hand-draw a map of the reach to scale if that is sufficient, or use GPS and GIS mapping tools if this will increase precision and accuracy. Create a separate document for this map.

- Map the existing vegetation, soil types (such as using SoilWeb of the UC Davis California Soil Resource Lab along with more detailed on-site observations), especially problematic areas, and other relevant site features. Show (or overlay if you have GIS) this information on the map of the project's boundaries.

Team: Determine who is on the team for this project and what their roles will be. Your selection of restoration practices will partly depend on the number, commitment, and continuity of people involved.

- Who will manage the project and what roles are expected of different people? *Some ideas: Who is the project manager? What about the people who will be doing the installation labor? What about maintenance and monitoring?* ______

- Identify the structure for making decisions about design, spending, implementation, and management. Who is in charge of what? *Some ideas: If there are multiple project managers, it may be easier for complications and confusion to arise and this question becomes much more important to consider.* ______

- How will you contact individuals or community groups that may be able to contribute ideas, experiences, or labor to the project? ______

Decide on restoration practices: Each intervention and practice chosen should directly address the restoration goals. They should all integrate into a cohesive whole.

Many options exist for choosing interventions, management, and maintenance of a restoration project. At this stage, it may be helpful to read and explore the information available for California rangeland creek restoration. The first chapter of this booklet, "Habitat Restoration Practices for California Rangeland Riparian Corridors," is one place to start. It includes references to relevant reports and websites. An example of a concrete, detail-oriented design for active restoration with native plants in a farm hedgerow (Long and Anderson 2010) is excerpted in that chapter.

Candidate practices

- Since the target ecosystem is our baseline for the types of interventions and the specific restoration practices, will passive or active (or both) restoration practices be used? ______
- How closely does our site already resemble the 'target ecosystem', and are minor or major changes in land use and management necessary? ______
- What practices seem to be good candidates for meeting our objectives? Describe/define here with as much detail as possible: ______

Physical interventions

- What physical interventions are necessary to meet restoration goals on their own, such as bank stabilization, or creating meanders that reduce the risk from high storm flows? ______

- What physical interventions (soil amendments, etc) may be necessary in order for biological communities to succeed? ____
____
____

- How will the need for physical interventions differ along the reach of the stream? *Some ideas: physical interventions along banks that deal with soil erosion, soil compaction, bank stabilization, adding boulders and gravel, and effects on flow paths* ____
____
____
____
____

Biological interventions

- What are the ecological requirements of the plant species that we hope to incorporate into the design of the restoration project? Consider upper and lower canopy tree species, shrubs, vines, grasses, rushes, sedges, and forbs.
____
____
____
____

- What plant species will be included to improve wildlife habitat, especially for certain species of birds or mammals? *Some ideas: If improving wildlife habitat is a high priority, specify which particular species we hope to increase at the site. If bank stabilization is a major goal, which plant species will most likely successfully establish regardless of flooding or a long-term drought?* ____
____
____
____
____

- How will specific activities for plants and animals differ along the reach of the stream? *Some ideas: drought and flooding tolerance of native plant species, whether to seed or transplant native grasses and forbs, when to plant seedlings or seeds (e.g. acorns) of woody shrubs and trees, when to use plug transplants and cuttings, inoculation of nitrogen-fixing bacteria for leguminous species, fish stocking, installation of owl boxes, nest boxes and perches, removal of non-native species, use of mulch/detritus spreading for small animal habitat, weed control and/or improvement of soil quality* _____
____
____
____
____

Select practices

- Drawing from various sources of information, what combination of practices will effectively achieve the goals of the project? (insert in table below)
- What are the available resources to support each practice, and ecological requirements of species to be used? (insert in table below)
- Indicate the most viable practices to satisfy our goals given our available resources and restrictions? (insert in table below)
- Record your decisions here:

List of candidate restoration practices	What goal does this contribute to?	What kind of resources and support are available?	Notes on ecological requirements of any species to be used

Finalize details: Designate the restoration practices on the site map.

- Make a schematic diagram of exactly where each restoration practice will be applied. Make a new map, or add to the existing site map. Be as specific as possible and annotate the map with explanations for the rationale for managing different zones of the reach in unique ways.

Make a timeline and a budget: Each restoration practice will consist of a set of activities that may be time- or weather-dependent, and will differ along the reach. The budget must account for the intermittent needs for labor and supplies, which will be most demanding during the first two to three years of the project.

Think about what needs to happen for each restoration practice to be carried out, and the timeline for the different activities needed to implement each restoration practice with as much flexibility as possible. For example, if the expectation is that native species will increase via passive restoration, it may first be necessary to control invasive plants, which could involve controlled burning, mechanical interventions, or herbicide applications.

- Make a list of specific activities for each of the restoration practices decided upon along different reaches of the creek. Estimate the distance (or area) along the reach for each restoration practice.

Practice 1.	
Length/acreage:	Activities and frequency:
Labor needs:	Supplies:
Timeline:	Cost (by year):
Practice 2.	
Length/acreage:	Activities and frequency:
Labor needs:	Supplies:
Timeline:	Cost (by year):
Practice 3.	
Length/acreage:	Activities and frequency:
Labor needs:	Supplies:
Timeline:	Cost (by year):

Plan for monitoring: A monitoring program will help to assess the success of the project and contribute to adaptive management decisions in the future. Use the restoration goals as a basis for a monitoring program. Be realistic about what is feasible: an over-ambitious monitoring plan may have to be abandoned if time and resources fall short. *(For ideas on different monitoring possibilities, see the final section of the first chapter of this booklet,"Habitat Restoration Practices for California Rangeland Riparian Corridors").*

- What is the purpose of the monitoring data? How will the information be compiled, and how will it be presented and used? *Some ideas: Are data for personal use only, or are there other objectives for distributing the results, or requirements from a funding source? What expertise will be needed for data collection?* ____________________________

____

____

____

____

- Who will be responsible for carrying out monitoring activities? ____________________________

____

____

- What observations or data will be collected? ____
____
____

- How often will they be collected? ____
____
____

- Determine appropriate record-keeping techniques for the criteria that will be measured over time. Describe briefly here. *Some ideas: Data sheets that can be used consistently over the years would be helpful. Will a personalized data sheet be created, or will an existing form be used? If data sheets are not used, how will records be kept consistently? If electronic, where will they be housed and what happens when technology changes? (Can anyone read a floppy disc today?)* ________
____
____
____
____

- Which preliminary photographs and quantitative measurements will be taken as a baseline? *Some ideas: baseline bird survey, list of plant species and their cover (along different areas of the reach if possible), soil biota such as nematodes to indicate biological soil quality* ____
____
____
____
____

- Establish permanent photo points where consistent photos will be taken during data collection. Mark them on the site map and, if possible, mark them physically at the site as well. *Some ideas: A painted T-post, GIS coordinates, iconic site features such as a large boulder*

5. **Reflect:** How well does our restoration plan address goals, work within available resources, and deal with obstacles?

During the design process: Keep the following questions in mind, and refine our design, timeline, and budget accordingly.

- Are the overall and specific restoration goals being directly addressed?
- Do the chosen restoration practices meet the ranch objectives and make sense given available resources and limitations?
- Are the goals specific, clear, and measurable? How will success of the restoration project be defined, whether the results are conceptual or quantitative?
- Think short-term and long-term. Is the timeline reasonable? How committed is the team of people involved, and what kind of resources can be reasonably assumed for long-term maintenance and monitoring?

Follow-up: Think about ways that our project can inform and lend support for rangeland riparian restoration in California.

- How might successes (and failures) be shared with other ranchers and land managers?
- Can we use this project to create support for existing programs that provide funding and other support for this kind of work? Can we tell success stories for agencies such as NRCS, California Department of Fish and Wildlife (CDFW), and the Wildlife Conservation Board (WCB)?

RELEVANT PUBLICATIONS

Clewell, A., J. Rieger, and J. Munro (2000). *Guidelines for developing and managing ecological restoration projects.* Tuscon, AZ: Society for Ecological Restoration International. < http://www.ser.org/resources/resources-detail-view/guidelines-for-developing-and-managing-ecological-restoration-projects#4 >

Lewis, D., M. Lennox, and S. Nossman (2009). Developing a monitoring program for riparian revegetation projects. University of California Extension: UCANR publication 8363. <http://anrcatalog.ucdavis.edu>

Lutes, D.C., R E. Keane, J.F. Caratti, C.H. Key, N.C. Benson, S. Sutherland, and L.J. Gangi (2006). FIREMON: Fire effects monitoring and inventory system. Fort Collins, CO: USDA Forest Service Rocky Mountain Research Station General Technical Report RMRS-GTR-164-CD. USDA Web site, <http://frames.nbii.gov/projects/firemon/ISSv3_Sngl.pdf>

U.S. Environmental Protection Agency (1995). A decision making guide for restoration. Chapter 4 In EPA 841-F-95-007, *Ecological Restoration.* Washington, D.C.: U.S. EPA Office of Water. <water.epa.gov>

Ward, T.A., K.W. Tate, and E.R. Atwill (2003). *Guidelines for monitoring the establishment of riparian grazing systems.* University of California Cooperative Extension: UCANR publication 8094. <anrcatalog.ucdavis.edu>