Habitat Restoration and Water Quality Management

Key Projects and Practices for Streams, Riparian Areas and Wetlands in California

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Preface and Acknowledgements

This manual is a project of the Coastal Training Program (CTP) at the Elkhorn Slough National Estuarine Research Reserve. The Coastal Training Program is a system-wide program active at all 28 National Estuarine Research Reserves; the Elkhorn Slough CTP was established in 2003 to increase awareness of the importance of protecting the precious coastal resources of the Monterey Bay region and California's central coast and to educate the public and regional decision makers about conservation issues and processes.

In September 2011, the Elkhorn Slough Coastal Training staff convened the program's Habitat Restoration and Water Quality Technical Advisory Committee (TAC) to discuss ways of furthering the mission of the CTP. The committee—made up of restoration experts from the Natural Resources Conservation Service (NRCS), local Resource Conservation Districts (RCDs), and state and federal regulatory agencies, as well as restoration ecologists from the public and private sectors and monitoring experts from NGOs and scientific consortia—saw a need for guidelines that landowners, resource managers, and agency staff could use to implement habitat restoration and water quality improvement activities. It was decided to focus on a limited set of restoration and management projects, those with broad application, regional relevance, and strong scientific support for effectiveness. A number of project types meeting these criteria were identified during the 2011meeting; during subsequent focus-group discussions the list was narrowed down to the six projects included in this manual. The TAC met again in 2012 to outline a monitoring protocol to be included in the manual in recognition of the importance of monitoring for informing adaptive management of these projects.

Over the course of three years, the members of the TAC provided invaluable information about implementing the projects: how to create budgets, how to do site assessments, what kinds of experts to involve, and so on. They also provided case studies and alerted us to the resources available to restoration practitioners throughout California. In these and other ways, the members of the TAC played an invaluable role in bringing this manual into existence, and we would like to express our appreciation for their support and expertise.

The authors of this manual would also like to acknowledge the other individuals and agencies that supported the development of this manual. These include the United States Environmental Protection Agency, which provided funding; Eric Engles (of EditCraft Editorial Services), who edited the manuscript and consulted on content and conceptual issues; and Katie Bertsche who designed and produced the manual.

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Chapter 1
Introduction

Wetlands and riparian areas are transitional ecosystems, positioned physically and ecologically between terrestrial and aquatic systems. They are characterized by seasonal flooding, rich soils and diverse vegetation structure. Healthy wetland and riparian areas filter toxic chemicals and agricultural nutrients from water runoff, recharge ground water, reduce flooding, support a rich and varied flora, and provide important habitat and refugia for both aquatic and terrestrial wildlife. Acre for acre, they provide more ecosystem services than nearly any other ecosystem type in California.

Over the last century and a half, however, California has seen the degradation and loss of nearly 90% of its wetlands and much of its riparian areas. Human activities such as agriculture, vegetation removal, road building, urbanization, poorly managed grazing, and channelization have accounted for much of the loss. Areas once protected by meandering wetlands now flood more readily, and rivers and streams, no longer buffered by vegetated riparian zones, receive large burdens of eroded topsoil and pollutants. Fish and wildlife populations, once abundant, have declined to the point of nearly disappearing due to habitat loss and invasion of non-native species. During the next century, riparian and wetland ecosystems will experience additional stress from temperature extremes, droughts, increasingly variable precipitation, and shifts in the distribution of plants and animals due to global climate change.

In recent decades, Californians have invested heavily in protecting the wetlands and riparian areas that still remain in relatively natural condition, placing some of most pristine examples of these ecosystems in parks, reserves, and wildlife refuges. While these conservation efforts are critically important, they must be accompanied by restoration and conservation of the wetlands and riparian areas on public and private lands that lack official protected status if we hope to prevent further decline of wildlife populations and keep the state's natural resource base healthy and functioning in the face of population growth and climate change (Seavy et al. 2009).

Many land owners and public land managers are engaging in restoration activities. Seeing the effects of uncontrolled erosion and invasion of non-native plants, and concerned about pesticides and other contaminants making their way into waterways, they are taking steps to reverse ecological damage and clean up the waterways flowing across their land. Their small-scale efforts cumulatively can have larger effects. Unfortunately, it is not always clear how to approach restoration work, improve water quality, prevent further damage to waterways, and enhance the ecological health of wetlands and riparian areas while at the same time allowing for human uses such as agriculture and livestock grazing and addressing the uncertainties of climate change. This manual is intended to provide the encouragement and proper guidance that this work deserves.

Purpose of this Manual

This reference manual serves as an introductory guide for those who want to help restore the state's wetlands and riparian zones. It outlines a set of key restoration/management projects, each of which has been shown to have the potential for significantly improving water quality, halting or reversing ecological decline, and serving as a basis for additional restoration. The more widely these projects are implemented across the state, the greater the potential for creating a healthier California—richer with wildlife, benefitting from streams that flow with more abundant and cleaner water, and more resilient in the face of climate change.

Land managers, conservationists, agency staff members, environmental consultants, and funding agencies can use the guidance contained in this manual to better understand the basic features of these projects and learn what planning needs to occur before implementing them; they can also use the information in the manual to locate additional sources of information that will help them better plan for and implement a project and to monitor project function, stream health, and water quality after the project is in place. It is also hoped that this manual will help researchers improve restoration work, help lead agency and regulatory agency staff members to more efficiently formulate reporting and monitoring criteria, and serve as a model for replication of other guidance designed to help Californians prioritize restoration work and water quality practices as global climate change effects unfold.

The projects described in this manual were chosen for inclusion because they can be used over much of the state and have broad applicability and proven efficacy. A great many other restoration projects and more general practices are available to restoration practitioners. State and federal guidelines such as the National Resources Conservation Service FOTG contain hundreds. The projects presented here make up a basic restoration "toolkit," which can be supplemented by any of the many other activities that exist. This will be a living document that will be revised as restoration priorities shift and as new information becomes available.

This manual has been designed to serve those new to restoration work as well as the experienced; it is directed primarily to landowners, land and resource managers, state and federal agency staff members, and environmental consultants. The intended audience includes employees of organizations like Resource Conservation Districts, the Natural Resources Conservation Service, and California Department of Fish and Wildlife. Other audiences that could benefit from this manual include funders, conservation lands managers, water district managers, and farmers and ranchers. This manual refers collectively to these various people as "restoration practitioners."

This manual seeks to assure the restoration practitioner that he or she is not alone in undertaking restoration work and managing water quality. A resource guide accompanying each project is designed to assist with locating the many experts and resources available. The authors hope this manual inspires and encourages readers to take action.

General Considerations in Restoration Work and Water Quality Management

When a land manager or land owner perceives a need to undertake restoration of a riparian area or wetland or to improve the water quality of a stream, it is frequently the case that the affected area or watercourse suffers from three widespread and inter-related forms of ecological decline: erosion has changed hydrological function, altered the habitat, and increased sedimentation; invasive, non-native plant and animal species have displaced natives and lowered overall diversity; and the native flora is much less diverse than it once was, with many former species simply absent. Broad and long-term restoration goals cannot be realized without giving attention to these three conditions and working to improve them. Although the projects described in this manual have much narrower goals and focused purposes than complete ecological restoration, their positive impacts are greatly enhanced when they are carried out with an eye toward understanding how they can be part of an overall effort to stem erosion, remove invasives, and restore native plants on a particular property or piece of land. In a similar way, discrete restoration projects are best considered within a long-term timeframe that takes into account the anticipated stresses of climate change.

Erosion Control

Erosion occurs when flowing water, wind, or other physical processes remove or displace soil. It is a concern in part because soil is a critical resource that does not replace itself. It may take as long as 50,000 years for an inch of soil to form. Because soil forms the basis for plant productivity, maintaining soil depth and quality are key to a site's ability to maintain itself over time and to recover from disturbance. In addition, infiltration rates, soil moisture retention, productivity, and groundwater recharge can all be significantly reduced when the upper layers of soil are removed. Erosion is also a concern because the eroded soil can have a variety of negative impacts when it enters streams or wetlands. As sediment, it alters aquatic habitats, affects water quality, and changes hydrological processes. For all of these reasons, reducing soil erosion should be a basic goal for all natural resource project managers.

Erosion control is an issue for restoration practitioners in two distinct ways. First, because erosion and sedimentation are general problems in riparian and wetland habitats, most restoration work should be designed and carried out to maximize its ability to control natural or human-induced erosional processes in the environment or repair past erosional damage. Some restoration projects (including four of the projects outlined in this manual) include erosion control among their explicit objectives; others can be designed to work in concert with erosion control measures. Second, because the restoration work itself can be a source of unintended erosion, all such work must be carried out in a way that minimizes its potential to disturb soil and deliver sediment to streams. This latter issue deserves further discussion.

Any restoration project that involves transport of materials, installation or removal of structures, vehicle access, or heavy equipment use may disturb soil, deliver sediment to streams, raise dust, or leave soil vulnerable to later erosion. These undesirable effects can be mitigated with a variety of well-known practices such as the placement of wattles. In California's Mediterranean climate, it is generally desirable to implement any restoration work before the advent of winter rains and to halt the work until rains have ceased in the spring. Each particular project calls for certain specific erosion-control measures as well, depending on the habitat and the nature of the anticipated disturbances. For some projects, effective erosion control calls for re-vegetation (see below) and protection of the soil surface until the new plants are established.

While protecting against unintended erosion during restoration work is important, care must be taken to insure that the mitigation measures don't themselves have negative side effects. If incorrectly implemented, erosion control measures can suppress native plant establishment (Keeley et al. 1981; Beyers 2004; Adams et al. 2005), introduce weeds, and obliterate the bare-soil habitat important for some species (Arnold et al. 2012; Hayes and Holl 2003). Erosion control materials sometimes include plastic netting that could entangle or kill wildlife. Therefore, erosion control experts should work with biologists familiar with the area to assure erosion control is well fitted with other biological concerns.

Invasive Species Control

Invasive species exert their negative effects both directly and indirectly (Jules et al. 2002; Skorka et al. 2010; Vitousek 1990). Invasive plants compete for resources more effectively than many natives, reproduce and disperse more rapidly, and generally lack the controls on population growth that exist for natives. They tend, therefore, to displace natives and to change habitat structure (Pavlik et al. 1993; Brown and Rice 2000). Non-native animals have similar competitive advantages over native animals, and can impact natives more directly by preying on them (Maze 2009; Wilcove et al. 1998). In general, invasive species degrade habitats, lower animal populations, and reduce floral diversity, leading to simpler, less resilient ecosystems with reduced ability to cycle nutrients and resist erosion and other forms of disturbance (Wilson et al. 1997; Adams and Pearl 2007; Hornaday et al. 2007; Pimentel et al. 2005). For these reasons, controlling invasive species is increasingly becoming one of the main tasks for restoration practitioners in California.

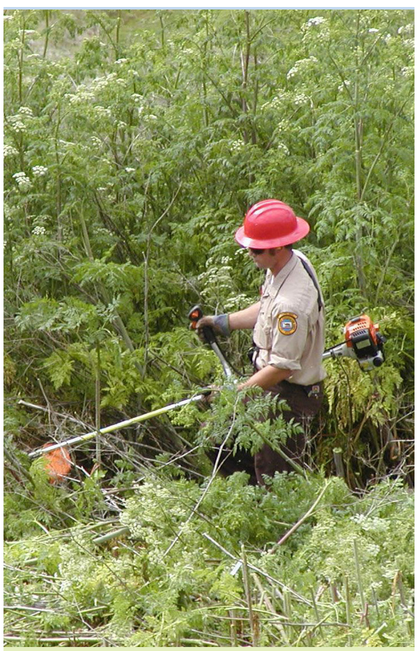

Photo: P1.1 Invasive hemlock control
Photo:ESNERR

It is clear that preventing the introduction of invasive species is less expensive than controlling their spread or removing them. Rarely is enough funding available, however, even for prevention (Leung et al. 2002). Further, many invasive species have been established for so long in many habitats all over the state that prevention is largely a moot point. Therefore, restoration work in the habitats with the most invasive species—such as California's grasslands (Huffaker and Holloway 1949), shrublands (Lambrinos 2000), forests (Blair et al. 2010), and riparian areas—almost always includes invasive species removal and control.

Invasive species control includes a range of practices (e.g., managed grazing, trapping and shooting, targeted application of herbicides, prescribed burning, manual or mechanical removal) designed to reduce the negative impacts of non-native species; the practitioner may focus on reducing the population size or density of a non-native species, lowering the number of its populations, reducing or restricting the area of land occupied by the species, or, more ambitiously, eliminating a non-native species entirely from an area. The scope and focus of the effort depends on the species, the management goals of the property, the extent to which invasives have taken hold, and various practical considerations that ultimately relate to cost.

Readers contemplating one of the projects described in this manual should be familiar with invasive species control as a general concern, and they are advised to consider in some depth how the project may interface with existing or potential efforts targeting invasive species directly. In many of the projects outlined herein, the work required as part of the installation or removal of structures creates opportunities for removal of invasive plants as part of the project. Other projects are intended to change ecological conditions in a way that make them less hospitable to the growth, spread, or establishment of non-natives, thereby creating opportunities for subsequent efforts aimed at reduction or elimination of non-natives.

The science and practice that has developed around the topic of invasive species control is exceedingly complex and in a constant state of flux. Most readers of this manual need only a passing familiarity with its basic principles; for those wishing to inform themselves in greater depth, we provide the following areas of exploration:

- There are many invasive species; each poses a different level of threat and this level can vary by region. Priority lists for invasive plant species exist and are coded by region for California (Bay Area Early Detection Network 2010; California Invasive Plant Council [CalIPC] 2011).

- Many land and resource managers develop a comprehensive invasive species control plan to help prioritize the control of some species relative to others and to guide everyday work to maximize impacts.

- A rigorous monitoring program is often used to control the spread of invasive species in a particular area and to detect the introduction of new populations. In many places throughout the state, Weed Management Areas serve as regional invasive species control networks within which managers share information about recent outbreaks and detection methods (see "additional resources").

- Controlling existing populations of invasive species sometimes requires restoring the structural components of a system, which typically involves re-vegetation with native plants (see below). The shading provided by replanted native trees, for example, can help control some plant invasions (Holl and Crone 2004).

- Since many invasive species are essentially "here to stay," many managers focus on mitigating their effects than trying to eliminate or control them. An example of mitigation is adding movement corridors for wildlife as a way of combatting habitat fragmentation (Gelbard and Harrison 2003; D'Amore et al. 2010).

- Effective invasive species control often requires stakeholder engagement. Many restoration practitioners have been surprised when stakeholders have expressed concerns about the use of chemicals or the aesthetic impacts of removing non-natives. Such surprises can be avoided through public engagement or education (Selge et al. 2011).

Revegetation with Native Plants

Some native plants can re-establish in an area, or recover their more-natural population sizes, when pressure from competing non-natives is removed or other restoration activities create more amenable conditions. However, many natives lack the dispersal mechanisms necessary to reestablish quickly enough (or from great distances) to prevent the re-growth of invasive plants or the erosion of open soil (Seabloom et al. 2003). And even if propagules are present, they may not exist in large enough numbers to support re-population. It is for these reasons that it is often necessary to "jump-start" the regrowth of native vegetation through deliberate replanting with native plants (a.k.a. revegetation).

Photo P1.2 Revegetation of uplands with native seedlings Photo: ENSERR

Although the replanting of an area can be an effortful and expensive process, it usually needs to be done only once. If the planted seedlings survive and establish, they provide safe sites for the establishment of other native plants (Kettenring and Adams 2011), either by serving as nurse plants (Badano, Perez et al. 2009) or by changing the local conditions.

Revegetation is also an important tool in the effort to control invasive species: by creating shade and competition, revegetation can help reduce the growth of non-native species (Kettenring and Adams 2011; Iannone et al. 2008). The seeds of Jubata grass (*Cortedaria jubata*), for example, germinate less readily when light at the soil surface is reduced (Drewitz and DiTomaso 2004).

In general, revegetation it often a critical facet of restoration because it helps to ameliorate harsh environments, capture naturally dispersing seeds, and protect seedlings while they establish. Revegetation can help protect and maintain soils by providing soil cover and supporting biotic activity (Bochet et al. 2010). By protecting and maintaining soils, revegetation also helps to maintain watershed processes, reducing sediment movement and increasing infiltration and groundwater recharge (Prieto et al. 2012).

Effective re-vegetation with native plants requires a thoughtful approach to selecting the right species with the correct genes. Revegetation with certain native plants can hinder the establishment of other native species (Dale 1991). Picking the wrong suite of species may fail to reduce erosion or to nurse the establishment of other native species (Brown and Rice 2000; Bochet et al. 2010). Using native plant propagules not collected locally can threaten the success of the project or negatively impact locally adapted genepools (McKay et al. 2005).

Climate Change

During the next century California can expect significant changes in temperature and precipitation due to the effects of climate change. Extreme drought as well as extreme rain events may become the new normal and fire seasons are predicted to become more intense. These threats to sensitive habitats and wildlife must be part of the natural resource management equation. Restoration practitioners must plan for resiliency and be prepared to adapt in response to the unknown changes that will occur in California ecosystems as a result of future climate change and related disruptions.

Resiliency is the ability of an ecosystem to recover from disturbance without losing its essential characteristics. All ecosystems have some degree of inherent resilience, but restoration practitioners can increase the resilience of ecosystems in very clear ways. Ecosystems with native vegetation, a high level of biodiversity, natural hydrologic regimes, and limited human-caused disturbance or pollution are always more resilient ecologically than the degraded ecosystems that are usually the targets of restoration. In this way, the enhancement of resilience may be seen as one of the major goals and aspects of restoration work.

But doing restoration work with climate change in mind is more than just a matter of increasing the resilience of habitats and ecosystems. By increasing the chances of damaging floods, stream-drying droughts, and plant-killing freezes and heat waves, climate change challenges restoration practitioners to consider events that may pose threats to any installed or constructed infrastructure and may change a habitat's structure relatively quickly. For these reasons, restoration practitioners must consider questions such as these: Can the streambanks withstand the "100-year floods" that may occur every decade? Are buffer zones wide enough? The culverts big enough? Are the pieces of large woody debris adequately anchored? Might flooding cause the course of the stream to shift? What areas of vegetation may die off during a long drought and how will this affect the ecosystem?

The long-term directional changes in environmental conditions—warming and drying—that are already occurring as part of climate change may pose the most serious challenges because the responses of species and ecosystems are largely unknown. Nevertheless, a number of generalizations offer some guidance. Many revegetation projects should use the most drought-tolerant species available. Projects that store water and recharge aquifers—such creating a pond for trapping stormwater (Project 4)—might be considered to have high priority. Since many animal species are likely to shift their ranges, it may be wise to consider how restoration might facilitate migration to and from a particular habitat or area.

A number of resources are intended to help restoration practitioners design restoration projects that enhance the ecological function of degraded or damaged areas in a manner that prepares them for the consequences of climate change. Notable among them is Point Blue's Climate-Smart Tool Kit. Restoration practitioners are encouraged to seek out these resources and to tap the experts as they undertake any of these projects.

Photo P1.3 Aerial view of the Elkhorn Slough Photo: Keith Ellenbogen

The Overall Planning and Management Context

It is expected that among the readers of this manual there will considerable diversity in experience, knowledge of restoration practices, professional role, and motivation for implementing restoration projects. Some readers will know the land for which they are responsible with an intimacy difficult for others to appreciate; others will have only general knowledge of the land and its issues, at least at first. Some readers will be working within the confines of agency regulations and management plans whereas others will have relative freedom to implement restoration activities as they choose, within the constraints imposed by local, state, and federal laws. Because of these and many other differences, each reader will be implementing the projects outlined in this manual within a unique context. At one extreme, a project might be the first of its kind on a privately held ranch for which no formal management plan exists; at the other, a project might be one of many inter-related ones undertaken on public land under a long-term management plan.

Photo P1.4 Improving tidal flow as part of a larger effort to improve water quality Photo: ESNERR

The authors have attempted to accommodate these variations among readers and in the contexts within which they work by avoiding hard-and-fast assumptions about how the projects are being approached. It is necessary, however, to discuss up front two issues for which it is impossible to avoid basic assumptions that do not fit the circumstances of all readers.

Choosing a project. Some readers will know exactly which project they want to implement before they open the manual for the first time. They may have noticed a particular problem—such as livestock damaging a riparian area during the dry season—and already know at least the basic outlines of the solution. Other readers face a more general, more widespread, or less-clearly-defined problem (such as a long-term decline in water quality) and know only that some kind of ecological restoration is called for. Since the latter type of reader requires an initial step (choosing a project) that the former type can simply skip, the authors assume that the latter situation is the baseline. Readers who have made their choice of project ahead of time may, as suggested, skip any beginning steps that seem superfluous—or, perhaps, treat them as a process of confirming that their choice is indeed the appropriate one.

The project as part of a larger restoration effort. In many contexts, a long-term management, watershed, or restoration plan guides the choice and implementation of specific restoration projects. When such a plan exists, carrying out one of the projects in this manual is merely one piece of a much larger puzzle. Given that this is not always the case, however—and that when it is the variables are complex and impossible to predetermine—the authors have chosen to assume that the projects in this manual will be implemented in isolation. This means that when a management or restoration plan exists, it is up to the reader to work out the ways in which the implementation of one these projects articulates with the plan or larger restoration effort and with other projects. When no such plan exists, on the other hand, the reader is encouraged to engage in the big-picture thinking and planning that might lead to one of these projects being the starting point of a longer-term and broader-scale effort to restore a longer reach of stream, a larger portion of a property, or a more extensive area of habitat.

Carrying out a Project: An Overview

Regardless of land ownership status, planning history and scope, the extent of impacted habitat, and other factors discussed above, implementing a restoration or water quality management project involves a complex series of steps that begins well before any dams are removed, trees placed, or fences installed. Chapter 2 describes some of these steps and the thinking that goes along with them. After the project's infrastructure is installed, it must be maintained and its functioning monitored relative to the initial goals. Chapter 3 describes these and other post-implementation practices. The following outline is presented to help the reader understand how these two phases fit together with project implementation to make up a typical project in its entirety.

1. Understand the Problem
a. Identify the conditions of greatest concern
b. Examine the whole context
c. Define goals and objectives
d. Choose the project that will best advance the goals

2. Form the Project Team
a. Identify and engage stakeholders
b. Assemble experts
c. Define roles and responsibilities

3. Plan and Prepare
a. Assess resources and capacity
b. Analyze the site
c. Anticipate potential concerns
d. Draft an implementation plan
e. Estimate costs and create a budget
f. Complete environmental review and permitting

4. Implement
a. Acquire materials
b. Carry out construction

5. Manage Adaptively
a. Maintain the project site
b. Monitor project function and impact
c. Report monitoring data
d. Adapt management and/or structures in response to monitoring results

Related Resources

- The California Invasive Plant Council (CalIPC):
  http://www.cal-ipc.org
- Weed Management Area information:
  http://www.cal-ipc.org/WMAs/
- Local Resource Conservation Districts:
  http://www.conservation.ca.gov/dlrp/RCD/Pages/CaliforniaRCDs.aspx
- National Resource Conservation Service:
  http://www.nrcs.usda.gov/wps/portal/nrcs/site/ca/home/
- California Water Quality Monitoring Council:
  http://www.mywaterquality.ca.gov/monitoring_council/index.shtml
- California Wetlands Portal:
  http://sfei.org/projects/3032
- Point Blue Conservation Science, Climate Smart Restoration Principals:
  http://www.pointblue.org/our-science-and-services/conservation-science/habitat-restoration/climate-smart-restoration-principles/
- Point Blue Conservation Science, Climate Smart Tool Kit
  http://www.pointblue.org/our-science-and-services/conservation-science/habitat-restoration/climate-smart-restorationtoolkit/
- California Climate Change Portal:
  http://www.climatechange.ca.gov/
- A U.S. Fish and Wildlife Service issues related to climate change:
  http://www.fws.gov/home/climatechange/

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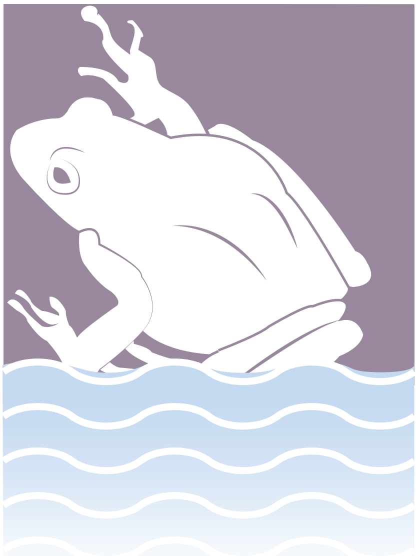


Chapter 2
Getting Ready to Implement a Project

The key to success in carrying out a restoration or water quality management project is adequate planning and preparation. It is difficult to overstate the importance of knowing, at the outset, why the project is being undertaken, how it will be carried out, where it will be sited, how much it will cost, who will be involved in the effort, what materials will be used in its construction, and so on. To give restoration practitioners some idea of what's involved in laying the groundwork for a project, this chapter provides guidance on accomplishing the first three steps outlined in the previous chapter, from *Understand the Problem* to *Plan and Prepare.*

Because the six projects outlined in this manual are all very different from each other, and because the unique aspects of each site and its management and ecology add further variation, this chapter must remain at a general level of specificity. As with the projects themselves, practitioners will need to seek additional information and be ready to adapt the guidelines to their own circumstances.

This chapter is addressed to the single individual assumed to have the greatest responsibility for carrying out the project. Depending on circumstances, this "you" could be the project manager, the restoration practitioner, the land manager, the landowner, or a person combining any of these roles. It could also be two or more people working in partnership.

Understand the Problem

This initial step involves investigation, analysis, and clarification. Depending on your role and circumstances, you may want other people—such as stakeholders, colleagues, or consulting experts—to assist you with the decision-making and other work that may be required (if that is the case, the authors recommend that you take a look ahead at the *Form the Project Team* step). At the other end of the spectrum of possibilities, you may already understand the problem well and have a good idea of which project you want to implement.

Identify the Conditions of Greatest Concern

The ecosystems on any piece of land that has been subject to anthropogenic modification are no longer functioning "naturally." Since agriculture, grazing, housing development, stream channelization, flood control measures, grading, interference in the fire regime, growth of invasive species, and other human impacts are so extensive and widespread in California, you can simply assume that the wetlands or riparian areas under your responsibility are no longer in a natural and wild condition and that their ecosystems do not function as they did 200 years ago. If your goal is to restore them to a hypothesized pristine state, you could direct infinitely large amounts of time and resources at the effort and still fall far short of reaching that goal.

In restoration work, therefore, it is important to target your efforts at what is in greatest need of attention. Beyond the general concept of ecological health (or, in this case, its absence), there is no objective standard for "greatest need"—it is very much dependent on your specific situation.

One key consideration is whether your land (or part of it) is dedicated to human uses such as agriculture, grazing, or recreation. If that is the case, restoration directed primarily at returning ecosystems to a more "natural" state is likely to be both unrealistic and contrary to some management goals. Instead, you will probably want to focus on conditions that are detrimental to the land's human uses and which, when remediated, will also benefit wildlife and water quality.

It may also be the case that "external" factors play a strong role in determining what is in greatest need of attention. Downstream water users may demand that poor water quality be your greatest concern; a regulatory agency might do the same for conditions unfavorable to an endangered species on the land. Stakeholders frequently influence what restoration should focus on as well: fishers may want you to focus on conditions that have caused a fishery or fish population to decline, hunters on those that have been detrimental to waterfowl.

Even when circumstances have focused your attention on a particular problem like poor water quality or erosion, it is desirable to be aware of all of the ecological conditions that might be considered undesirable and which could, through restoration work, be improved. This awareness is important because the elements of ecosystems are always interconnected: a project intended primarily to improve poor water quality is likely to have positive impacts on a variety of other ecological conditions. Problems are rarely isolated, and their priority as targets of restoration increases with the number of other problems that might be ameliorated through the same solutions.

Because many problems are not only interconnected but also causally layered, it is important to have clarity about what leads to what. Many problems have both proximal and ultimate causes; effective solutions depend on addressing the latter. This is made easier if you are careful to distinguish the many layers of causation. See Figure 2.1 for an example.

Examine the Whole Context

Because the interconnectedness of ecosystems extends outward geographically, most problems or conditions of concern will have causes or contributing factors that exist outside of the immediate vicinity. Nitrates deposited in rainfall or particulates originate from far away urban or agricultural areas; adjacent agricultural land or other land subject to intensive human use can be a source of non-point-source pollution, invasive plant propagules, or sediment; wells in nearby properties can lower the water table; upstream neighbors can add coliform bacteria to stream water. Even if you have little control over factors such as these, it is important to be aware of them in fashioning solutions. It could also be the case that a neighbor contributing to a problem could become a potential ally or partner in solving that problem (see *Form the Project Team* below).

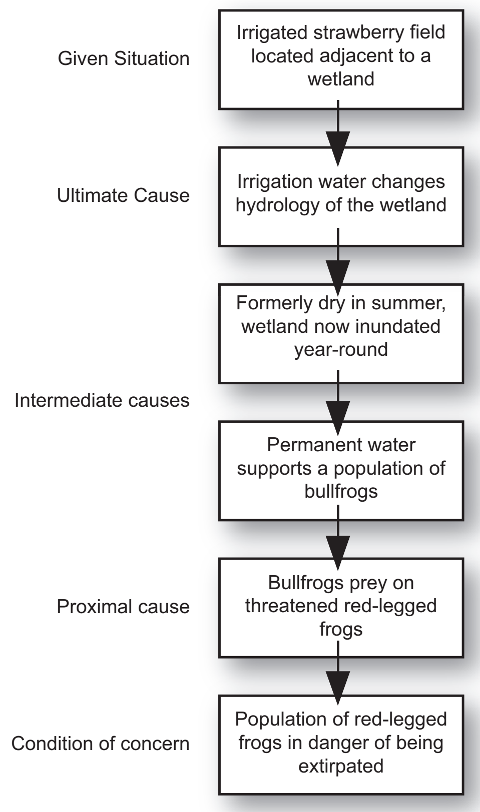


Figure P2.1. An example of a condition of concern (or problem) having multiple layers of causes. A restoration solution that addresses the "ultimate cause" may have the best chances of success.

The larger context of a problem also includes such factors as applicable laws and regulations, the land use history of the property, land use plans that may be in effect, and global factors such as climate change and its possible impacts on future sea level rise, salt water intrusion, coastal erosion, drought, precipitation, and the chances of flooding.

If a watershed plan, restoration plan, or management plan exists for the property, it is likely that the broader context was examined as a part of drawing up the plan. If that is the case, you may only need to refer to the relevant parts of the plan.

Define Goals and Objectives

To a large extent, the goals of restoration flow directly from the identified conditions of greatest concern. A problem of poor water quality, for example, clearly means that the primary goal of restoration is improvement of the water quality. But there is more to goal-setting than simply changing the way you express an identified problem.

First, goals can be developed that take into account that the problems identified as primary are related to other problems that can be remediated at the same time. For example, in dealing with the problem described in Figure 2.1 (predation of threatened native frogs by introduced frogs) it may be possible to address several other problems associated with the juxtaposition of a wetland and a strawberry field, such as movement of weeds or animals into the field from the wetland, shading of the field by trees at the margin of the wetland, and nitrate pollution of the wetland by agricultural runoff. Each of these problems could be the subject of a stated goal. Further, goals can express desired end results that can be realized only over long or very long periods of time. If a management plan, restoration plan, or watershed plan is in place, these larger or longer-term goals may be the same as those in the plan, or they may integrate tightly with them.

Second, the setting of goals can also involve objectives; these are more specific than goals and can therefore be connected to measurable outcomes. For example, for a general goal of improving water quality, some possible corresponding objectives are "nitrate levels remain below 0.02 ppm" and "pH does not fall below 6.8." It is important that objectives be realistic and based on well-established parameters for ecological health. A set of well-conceived objectives can serve as an important touchstone during the planning and implementation stages of the project, and then again during the adaptive management stage (described in Chapter 3).

Choose the Project that Best Advances the Goals

A discrete restoration project, like any of those outlined in this manual, is a strategy for solving a particular problem or set of related problems. In that sense, you choose a project after you have identified the problem and outlined the goals associated with alleviating the problem. The authors acknowledge, however, that you may have had one particular project in mind all along and that the process described above serves mainly as a post hoc justification for implementing that project.

If you haven't settled on a particular project, the problem-identification and goal-setting processes described above should make the choosing of a project much easier. In fact, the project that best advances your goals may by this point be so obvious that it hardly seems like a choice. If, for example, you're a farmer with strawberry fields adjacent to a wetland, establishing a buffer zone between the two (Project 5) is clearly the way to go. At the other extreme, choosing a project may require an involved process of collaborative deliberation and possibly more investigation.

It is important to recognize that one possible end result of identifying the problem, considering the context, and defining goals is a decision that the best solution is something other than implementing one of the projects in this manual. These projects have broad utility and application, but they represent only a small proportion of restoration and water quality management possibilities. Your problem may very well call for other kinds of solutions.

It is also possible that the best way to address the conditions of greatest concern on the land for which you are responsible is to implement multiple projects. Then, a primary issue becomes how to order the projects in time. In many streams, for example, improving fish habitat and water quality requires both removing in-stream barriers (Project 1) and placing large woody debris in the stream (Project 2). Which of these should be carried out first?—it could make a big difference.

Implicit in the choice of project is, in most cases, a choice of site as well. This means that the location of the project is tied up in the process of deciding which project to pursue. When this is not the case—such as when any of various riparian habitats could be fenced to exclude livestock or many different reaches of a stream could benefit from emplacement of large woody debris—deciding on the exact site or sites for implementing the project must be made part of the process of selecting which project to implement.

The project-based approach to restoration reflected in this manual is admittedly piecemeal. Although working incrementally to effect small, local improvements in ecological health is generally dictated by real-world constraints, it doesn't mean that you must be resigned to seeing only small, local results. A single project can have enormous benefits—which is the premise behind a manual outlining only six relatively small-scale projects. But this can be true only if the project is well chosen to address the problems at hand and is well matched to the unique situations of the local context.

Form the Project Team

Photo P2.2 UCSC volunteers remove invasive Ice Plant at Elkhorn Slough National Estuarine Research Reserve. Photo: ESNERR

Although some restoration projects can be implemented at a small enough scale for a single person to manage the entire process from problem identification to post-installation management, it is more typical for a project (or larger multiple-project restoration effort) to be too big and complex for one person to handle. Many aspects of a project require special expertise or certification, and more general tasks such as overall management, record-keeping and accounting, regulatory compliance, and stakeholder outreach are often so complex and time-consuming that they are best accomplished by multiple individuals. For these reasons, many projects are best carried out by a team of people working together.

As with any team, the members must share a sense of common purpose and a commitment to cooperation. Beyond these basic requirements, the project team will vary in its size, mode of operation, leadership, term of existence, and membership. Some members will be engaged through the span of the entire project; others may be brought in for shorter periods for specialized tasks. The team may overlap with the group of stakeholders discussed below.

In some cases, a need for expertise and shared decision-making in the step described above (*Understand the Problem*) will require that the core members of the project team come together before or during that initial step.

Identify and Engage Stakeholders

Stakeholders are those individuals, organizations, or agencies that have an actual or potential “stake” in the restoration project—the project in some way intersects with their economic, professional, political, or moral interests. Typical stakeholders include funders, permitting and other oversight agencies, landowners, site managers, easement holders, neighbors, those controlling site access, biologists, conservation groups, and researchers. As is apparent from this list, stakeholders are important for a variety of reasons. They may provide the financial resources backing the project, act as gatekeepers in the regulatory bureaucracy, offer much-needed expertise, be key to securing community support, and even determine whether or not a project many proceed. For these reasons, securing the support and buy-in of all possible stakeholders is crucial for the long-term success of the project.

Frequently, a project needs not only the passive support of stakeholders but also their active engagement with the project. Engaging them may involve face-to-face meetings, site tours, coordinated public-relations campaigns, public education and outreach efforts, strategic partnering, and so on. You must understand stakeholders' interests, acknowledge those interests at every available juncture, provide opportunities for participation in the planning process, and keep stakeholders well informed of project goals and timelines.

Photo P2.3 Repairing water control levy Photo: ESNERR

Assemble Experts

While some projects may not require the participation of experts, in others it is absolutely essential. In many cases a project simply has a better chance of success if experts are involved. The types of experts needed will vary depending on the type, scale, and complexity of the project. Expertise may be needed in any of the following areas: hydrology, geology, soil science, civil engineering, fish science, botany, restoration ecology, range management, forestry, biology, environmental compliance, stakeholder engagement, and project management. The individuals recruited to provide these forms of expertise may be involved in the project anywhere from a brief period to the entire span of the project. Those involved for longer periods may be considered part of the project team.

Each project described in this manual includes a list of areas for which special expertise may be needed.

Define Roles and Responsibilities

The larger the scale of a project and the greater its complexity, the greater the need for a variety of project roles to be clearly defined and assigned to specific individuals on the project team. While experts in science, engineering, and construction have their roles defined by the nature of their expertise, other more general roles usually require explicit description and assignment. These roles include leadership, project management, record keeping, environmental compliance, stakeholder engagement, budget oversight, and scheduling. For smaller-scale projects, many of these roles can be handled by a single individual; for larger projects and multiple-project efforts, they are best distributed among several individuals or assigned to experts.

Plan and Prepare

The topics discussed earlier in this chapter—*Understand the Problem* and *Form the Project Team*—are crucial elements of planning and preparing for a project, but they do not cover everything that needs to be considered before a project is implemented. This section outlines those additional steps.

Assess Resources and Capacity

Among the most important questions to ask at the beginning of a project is "can we pull this off?" Any project requires financial resources, organizational or labor capacity, and stakeholder buy-in. It is important to know if you can access or develop an adequate level of each of these key elements before commitments are made to proceed. A few practical make-or-break details such as site access are also important to consider. You may want to complete this assessment before assembling the project team; another approach is to make it the first thing the project team does.

Analyze the Site

It is important to know as much about the project site as possible before you begin to implement the project. Three types of formal analysis are often called for before doing restoration or water quality management work in or around a stream, riparian zone, or wetland:

Photo P2.4 Cattail Swale Photo: ESNERR

Hydrological analysis. The scope of the analysis required will depend upon the site and the objectives of the restoration project. For projects that involve changing stream flows or creating water storage capacity, you should hire a hydrologist to assess historic flows, river channel hydrology, and flood plain morphology.

Soils analysis. For many of the projects, it is a good idea for a soil scientist or geologist to determine the permeability of the soils at the site and their potential for erosion or impaction.

Biological assessments. There are several possible reasons for performing biological assessments. A survey may be needed to determine the presence and/or status of sensitive plant or animal species and/or non-native species (such as bullfrogs) known to prey on or compete with native species. If the project is intended to improve fish habitat, you will want an assessment of current habitat conditions and population sizes. As part of the biological assessment process, it may be wise to conduct a relatively thorough survey of the flora and fauna around the site to create a baseline dataset against which to compare data from post-implementation surveys (see Chapter 3). This is necessary if you want to be able to make rigorous conclusions about the ecological or water-quality impacts of the restoration project.

In addition to carrying out these formal assessments, you may want to carefully assess site access issues. Will an existing road allow the necessary equipment to get to the site? If a road must be built, what impacts will it have? Does site access involve movement through an adjacent property? Will it be necessary to secure permission to move through the property?

Assess the Potential for Impacting Cultural Resources

While a formal cultural resources survey is not necessary for most restoration projects, it is important to consider what historical and archaeological resources may be present in an area and to assess the potential for disturbing them. Identifying historical structures, middens, and similar cultural resources in advance will save both time and money in the long run. Keep in mind that any structure or artifact greater than 50 years old is considered a cultural resource and that many dams and bridges fall into this category because they were built in the 1930s. Be cognizant, too, of the fact that middens, habitation sites, and burials are often found adjacent to riparian corridors or wetlands and that the outward signs of their presence are difficult to detect. Digging in fence posts, excavating for ponds, and building embankments can disturb these areas. If archaeological or historical sites are uncovered during a project, the discovery will bring the project to halt and it could take many months to get back on track. It is recommended that restoration practitioners review historical maps, interview neighbors, and peruse county records as part of the process of analyzing the site. The upfront cost is minimal and the effort well worth the time investment.

Anticipate Potential Concerns

Although the manipulation of the environment that is performed during restoration work is intended to have positive impacts alone, it can have undesirable consequences under certain conditions or when subjected to unforeseen events. For example, a pond built to hold storm water (Project 4) could cause flooding if its outflow is blocked by debris. To minimize the possible harms of restoration infrastructure or installations, you need to anticipate everything that could possibly go wrong: unusually severe flooding, vandalism, drought, infrastructure failure, death of seedlings planted for revegetation, and so on. When they are anticipated, allowances for these events and circumstance can be built in to the project or in to the post-implementation maintenance schedule.

Draft an Implementation Plan

After a project has been chosen, the site analyzed, resources assessed, and potential concerns anticipated, it is time to draft an implementation plan. At a minimum, such a plan should consist of a materials list and step-by-step lists of site preparation tasks and construction/removal tasks. It can be put together only after careful consideration of site constraints, available resources, and project goals and objectives; this consideration may need to involve consultation with experts, particularly someone with expertise in engineering. Each task should identify the team member or contractor responsible for task completion.

Each project description provides information that may be helpful in drafting an implementation plan for that project. In particular, the *Implementation* section of each project discusses materials and methods. The *Potential Concerns* section often contains information applicable to the drafting of the implementation plan as well.

Estimate Costs and Create a Budget

Particularly when they are implemented at larger scales, the projects described in this manual can require considerable financial resources to plan, implement, and maintain. Obviously, you need to have a clear understanding of the total cost in order to insure that a project can be seen through to completion. Since you will eventually need an itemized budget—to report to funders, facilitate payments to contractors, and keep records for tax and oversight purposes—you might as well begin creating your budget early in the planning process, based on estimates of all the individual costs, from permits to materials and construction labor, and on estimates of funding sources. The numbers can be refined later when they are more precisely known.

Budgeting and accounting are crucial to the success of a project, but they are too complex—and individual circumstances too variable—to be discussed here in any detail. Many resources exist to guide you in making your projections and creating a realistic budget. In addition, each project description includes a *Costs* section that provides general information helpful for estimating costs.

Complete Environmental Review and Permitting

Because environmental review and permitting for restoration is complex and constantly changing, the best bet for success is to work with an expert who is experienced with such projects in the same geographical area where the project is being considered. Experienced project managers say that the total cost for environmental review and permitting can be as high as 50% of the total project cost. The timeline for securing all the needed permits ranges from 30 days to a year—so plan accordingly. A public trust agency such as CDFW or your local Resource Conservation District can help you understand how to best navigate the permitting process.

Chapter 3

After the Project is in Place

Ecological restoration is a long-term process with no particular endpoint. This is as true for individual projects as it is for restoration overall. After a project has been constructed, installed, or otherwise carried out, restoration practitioners should give their attention to several related tasks: maintenance, monitoring, reporting of data, and adaptive management. These tasks are critical to the long-term success of any restoration project.

Maintenance

Each project will have a certain level of maintenance associated with its management. Maintenance may be as simple as seasonal mowing of a buffer zone or clearing brush from a water-control structure after a storm event; it can be much more extensive as well, such as removing sediment from a stormwater retention pond or re-placing large woody material in a stream. It is important that the members of the restoration team discuss all levels of required maintenance in advance and include this in the overall design of the project. Together they should assign the proper person to be responsible for conducting the maintenance and creating the appropriate schedule for the work.

Maintenance can be integrated with the processes of monitoring and adaptive management discussed below. The regular visits to the project site required by conscientious maintenance can become excellent opportunities for assessment of overall conditions or collection of data. Further, because the need for maintenance can often depend on or be associated with the functioning of the project, a change in maintenance needs may indicate that a project is not working as it should and might need to be modified.

Monitoring

Photo P3.1 Seine netting in a pond. Photo: ESNERR

The purpose of any restoration or water quality management project is to realize a set of goals and objectives related to ecological health and improvement of environmental conditions. The only way to know if a project is working towards realizing those goals is to monitor the project and the environmental conditions it influences. Monitoring is the regular collection of observations and data that point to the status of habitats, vegetation and flora, physical and hydrological processes, ecological functioning, and water quality in the area impacted by a restoration project.

Regular monitoring of a site and tracking of the data collected will reveal whether or not, and at what rate, the project is changing the environmental conditions as originally envisioned. If the measured changes are not consistent with the project's goals, the project (or the context in which it exists) can be modified appropriately; this is the process referred to above as adaptive management.

There are many different monitoring techniques; the ones you may want to use will depend on your project objectives, the desired accuracy and precision, and your available resources. This chapter directs you to some of the more commonly used and most respected resources on this topic. Fortunately, there is a wealth of expertise in California, including private consultants, public entities, and government advisors. By learning from others, restoration practitioners can not only gain important knowledge, they can also help improve restoration efforts all over California.

Types of Monitoring

Readers will find that several types of monitoring are discussed in the literature related to riparian and wetland restoration. Most frequently mentioned are *implementation monitoring, effectiveness monitoring*, and *validation monitoring*.

Implementation Monitoring. This monitoring is conducted during and immediately after project implementation to determine if the work was completed successfully and according to plan and if meets permit requirements. Implementation monitoring (which is not really "monitoring" since it is typically conducted just once) is mainly an oversight function; if you are not required to perform a formal implementation assessment by a regulatory agency, you can focus your efforts on effectiveness monitoring.

Effectiveness Monitoring. This is the type of monitoring typically conducted after restoration work. It takes place over a relatively long period of time, perhaps 5 or more years, depending on the goals of the project. Effectiveness monitoring allows site changes to be assessed over time; it provides the data you can use to determine if a project's goals and objectives are being met.

Validation Monitoring. This third category of monitoring is similar to effectiveness monitoring except that it is more rigorous and may continue for an even longer time frame. Its goal is to confirm "the cause-and-effect relationship between the project and biotic or water quality response." As such, its use is generally restricted to scientific research projects. Although the care and rigor associated with validation monitoring are good standards to strive for in collecting monitoring data, most restoration practitioners will find that some level of effectiveness monitoring is adequate for their needs.

Levels of Monitoring

Two levels of monitoring are often distinguished. Basic monitoring involves qualitative information collection such as using photo points to track change over time and visual observations of vegetative cover and wildlife usage; it may also employ simple water quality testing. Basic monitoring is simple to do and can be cost effective when trained volunteers are involved. Extensive monitoring includes quantitative data collection using specialized tools and techniques and may require expertise in such areas as sedimentation rates, water chemistry, hydrology, and engineering. The level of monitoring to employ will depend on objectives, desired accuracy and precision, timing and available funding. In practice, basic and extensive monitoring exist along a continuum. A decision to conduct basic monitoring does not preclude using one or more data collection methods that might be considered part of an extensive monitoring effort.

Baseline Data

It was noted in Chapter 2 that restoration practitioners should assess and record the conditions at a site before beginning any restoration work. The data collected at this time can provide an important baseline against which to measure and evaluate the changes that occur after project implementation. Ideally, each of the parameters measured during post-implementation monitoring will have been measured prior to implementation; assuring that this is the case will obviously require a fair amount of foresight and good planning.

If baseline data were not collected prior to implementation of the project, it is still possible to at least estimate prior conditions. Nearby sites that are similar in important ways to the project site before implementation may represent prior conditions reasonably well. For certain parameters, it may be possible to obtain meaningful prior-state data from previous surveys, collection records, aerial photos, interviews of previous landowners or fishers, and other sources.

Developing a Monitoring Plan

A monitoring plan outlines all the facets of the monitoring effort: what kinds of data to collect, how they will be collected, who will do the collecting and data analysis and when, and how the data will be shared and used for adaptive management. The first two elements (the "what" and the "how" of data collection) are contained within a monitoring protocol, which is discussed separately below.

Three preparatory tasks should be accomplished before the plan is formally developed:

1. Establish a monitoring team. Bring together a team of advisors, partners, and/or colleagues to assist in developing the other elements of the monitoring plan and the monitoring protocol. It may be wise to utilize the expertise involved in the project planning process and to include such people as engineers, consultants, landowners, land managers, and staff members from permitting agencies. For small-scale projects, it may be possible for a single individual to carry out the monitoring, especially if he or she has access to expert advice.

2. Clarify the goals and objectives of the restoration project. Revisit the goals and objectives set down during the planning process (see Chapter 2) and refine them as needed or in response to what was learned during project implementation. These will play a central role in the development of the monitoring protocol (see below).

3. Assess available resources. Different data collection methods require different levels of training and skill, and their costs vary considerably depending on what equipment is needed and if analysis by a lab is required. Therefore, the monitoring team needs to know who is available for collecting monitoring data, what their time constraints are, and what level of expertise and knowledge they have, and it needs to know what level of funding is available to compensate monitors' time, to train monitors if necessary, to buy and maintain needed equipment, and to analyze samples. These parameters will determine the practical constraints on the monitoring protocol—the types and amounts of data that can be collected, the frequency of data collection, and the duration of the monitoring process.

Once these steps are completed, the monitoring team can focus on the design of the monitoring protocol, which, as the core of the monitoring plan, must exist in a least a draft form before the parts of the monitoring plan related to personnel, finance, and management can be developed.

Designing a Monitoring Protocol

The monitoring protocol, as noted above, sets out the specifics of data collection. It begins by specifying which parameters need to be monitored. These are determined largely by the original goals and objectives of the project. You may find it helpful to define each parameter in the form of a question that can be answered through the collection of monitoring data. For example, for a project intended to create upland habitat for the California red-legged frog (CRLF), you would want monitoring to answer two primary questions: "Are CRLF using this habitat?" and "Does the habitat reflect the known characteristics of viable CRLF upland habitat?"

For each parameter, the protocol then specifies how the data will be collected. The "how" of data collection has a number of components: method (e.g., photo point, pit trapping, water sampling and analysis); frequency of data collection; and duration of data collection. See the example in Figure 3.2.

Project: Trees planted on streambank
Selected goal: Decrease water temperature

Data to Collect	Method	Frequency of data collection	Duration of data collection	Expertise required	Cost
Number of trees planted	Field survey: count	once	n/a	low	low
% of trees surviving	Field survey: count and calculate	annually	medium term (several years)	low	low
% cover	Field survey: estimate area	annually	long term: at least 5 years	moderate	moderate
Water temperature	Measurement with probe thermometer at 6 established sites, 2 each above, within, and below project area	monthly	long term: at least 5 years	moderate	moderate

Figure P3.2 Example of a Monitoring Protocol Design Table

In developing the monitoring protocol, it is important to consider the cost of each method and the expertise required to conduct the data collection. If you have completed the resource-assessment step described above, then this is a matter of limiting the scope of data collection to that which can be accommodated by the available resources. Although the example in Figure 3.1 gives only relative cost levels for each form of data-collection, you will want to estimate costs in actual dollars per year.

Although many aspects of the monitoring protocol must be adhered to throughout the duration of the monitoring effort in order for the data to be valid and useful for drawing conclusions, a certain degree of flexibility does exist. Certain monitoring tasks can be phased out over time, for example, if the data collected no longer serve your needs.

Conversely, new forms of data collection can be added if it is determined that it is helpful to have this additional information. Allowing flexibility in the monitoring protocol makes possible significant cost savings.

Reporting Monitoring Data

The primary purpose of monitoring is to provide useful feedback for the restoration effort on a particular piece of property or in a particular watershed or wetland. Fulfilling this purpose does not require that the monitoring data be shared with anyone outside the restoration team (unless this is required by funders or permitting agencies). But sharing monitoring data with others can have important benefits. When the larger community of restoration practitioners has access to monitoring data from all over the state, its members can better assess the effectiveness of particular practices and projects in meeting the goals of restoration, ultimately leading to improvements in those practices and cost saving to funders.

If you are going to report your monitoring data, you must ensure the data are of high quality. Data quality is a product of the monitoring protocol and its application, and is ultimately dependent on the training and expertise of those who collect the data and how strictly the rules and conventions of data collection are enforced.

Next, you must decide how to share your monitoring data. One method often used by local watershed groups is to publish annual monitoring reports and make the reports available on the Internet. Another method, potentially more valuable because of the breadth of access it offers, is to upload the data regularly to a database.

There are a number of excellent sites to which you can upload monitoring data:

- The California Habitat Restoration Project Database (CHRPD) captures, manages, and disseminates data about habitat restoration projects in California benefiting anadromous fish. The CHRPD currently contains data from the California Department of Fish and Wildlife's Fisheries Restoration Grants Program (FRGP), the CALFED Ecosystem Restoration Program (ERP), the National Fish and Wildlife Foundation, the State Coastal Conservancy, the NOAA Restoration Center, the U.S. Fish and Wildlife Service, the California Conservation Corps, and the Cantara Trustee Council. State Water Quality Database: http://www.calfish.org/ProgramsData/ConservationandManagement/RestorationProjects.aspx

- San Francisco Bay Joint Ventures: http://www.sfbayjv.org/resources.php
- California Environmental Data Exchange Network (CEDEN): http://www.ceden.org/
- Central Valley Joint Venture: http://centralvalleyjointventure.org/science/monitoring
- The California Avian Data Center: http://data.prbo.org/cadc2/

Using Monitoring Data: Adaptive Management

When monitoring data show that a restoration project is improving ecological conditions in a manner consistent with its original goals, you can claim success and congratulate yourself and other members of your team on a job well done. It is rare, however, for a restoration project to work exactly as planned and anticipated. A project can fall short of meeting its goals or objectives, work well for a time and then fail, or have mostly positive results but one or more negative ones that can't be overlooked. If you have collected monitoring data according to a well-designed plan, these data will not only indicate that the project's goals aren't being met, they will also help you figure out how to modify or redesign the project so as to better meet its goals. As noted at the beginning of this chapter, this use of data to inform management is referred to as adaptive management.

A recommended strategy is for the monitoring team to regularly review the monitoring data for signs that restoration goals are not being met. Depending on the nature of the gap between desired and actual results, the team can then recommend changes or adjustments in the project or in the way it is managed.

You may find it helpful to build in to the monitoring plan a pre-determined "decision point" for each parameter being monitored This is a point in time (often expressed as the number of months or years after project implementation) when the monitoring team reviews the data on that parameter and decides if any adaptive action is called for. For example, for the project described in Figure 3.1, the team could decide that the decision point for "% cover" is five years after planting—if the trees are not creating the desired amount of cover by that time, remediative action will be taken (this might involve planting additional trees of a different species).

When reviewing monitoring data to determine whether or not some adaptive change should be undertaken, it is important to keep in mind the likely accuracy of the data. This is determined in part by the monitoring protocol and by the other factors affecting data quality that were discussed above. If you have a relatively low level of confidence in the accuracy of the data, you may want to delay any management decisions until better or corroborating data are available.

The concept of adaptive management can also be applied at a scale larger than that of an individual restoration project. Monitoring data collected for a single project can help restoration practitioners design similar projects for other sites or implement additional projects that work in concert with an existing one to improve habitat or stream conditions. In the broadest sense, adaptive management becomes the necessary approach for dealing with the long-term shifts in climate and environmental conditions that can be expected to occur over the next several decades.

Practitioners who implement any of the projects outlined in this manual should be prepared to make adaptive management decisions during the first few years after installing the project, and possibly longer, based on monitoring data. Conditions should be expected to change after the implementation of a project, either positively or negatively, and possibly dramatically in light of climate change.

Photo P3.3 Large scale repair on existing water control structure Photo: ESNERR

Developing a Riparian Bird Index to Communicate Restoration Success in Marin County, California

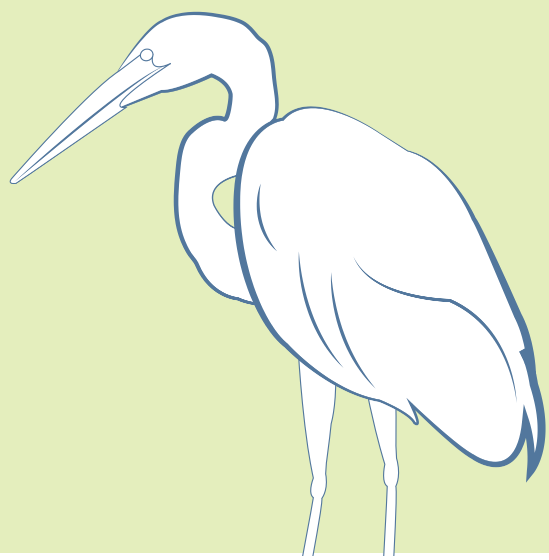
Point Blue Conservation Science has developed a Riparian Bird Index in an effort to create a simple means for clearly identifying restoration success and to provide pathways for improving ecosystem performance from investment in restoration.

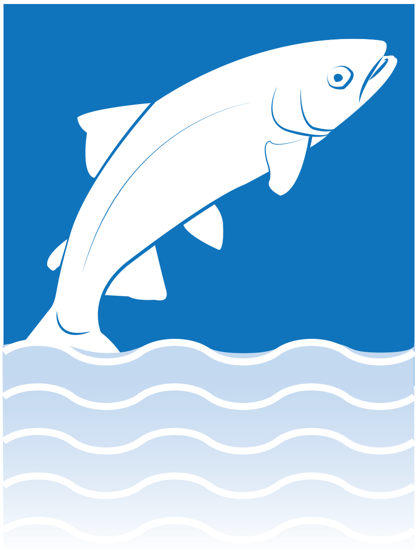
The Riparian Bird Index, based on historical bird survey data from reference and restoration sites in Marin County, is essentially a species richness score for a given area that is weighted by the degree to which each species detected is associated with target riparian vegetation. The score can be converted into a simple rating of "poor," "fair," "good," or "excellent" to communicate restoration success to a diverse audience.

The Riparian Bird Index is a biologically meaningful way to evaluate restoration performance and to communicate this to a wide range of stakeholders. It can be used to initiate discussions among agency staff, biologists, restoration practitioners, and individual landowners on how to improve restoration performance.

Riparian Bird Index PDF

Information source: N. E. Seavy, and T. Gardali. 2012. Developing a Riparian Bird Index to Communicate Restoration Success in Marin County, California. Ecological Restoration 30: 157–160. PRBO publication #1865.



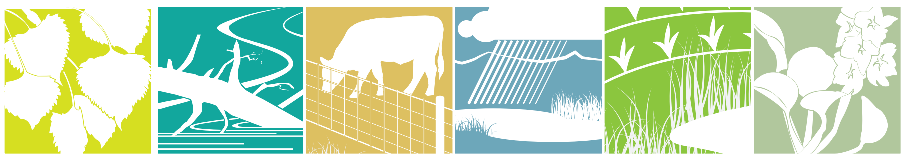


Chapter 4
Six Key Projects

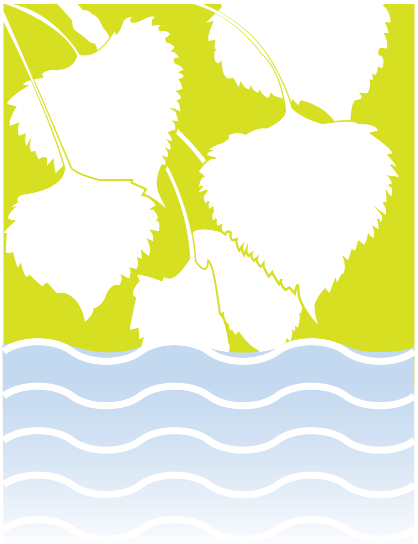
The restoration projects described in this chapter were carefully chosen to represent a broad range of methods of restoring habitats and managing water quality. They are applicable to most of California, proven to be effective, and critical to restoring habitat and water quality in the state. This is not meant to be an exhaustive list; there are many more projects and practices available to restoration practitioners. Additional projects may be added to this evolving manual as their effectiveness and importance are evaluated.

Each project write-up is meant to provide general guidelines for planning and implementing that particular project, either alone or as part of a larger restoration effort. The practitioner is advised to seek out additional resources and experts for help determining if a particular project is appropriate and for assistance in subsequent planning, preparation, and implementation.

Each project offers a wide range of benefits to wildlife, stream health, and water quality. The table below identifies some of the specific benefits associated with each one.



	Removing an In-stream Barrier	Emplacing Large Woody Material	Fencing a Riparian Area	Trapping Stormwater	Buffering a Wetland	Managing Wetland Water Level
Allow fish migration	💧					
Restore hydrologic processes	💧	💧				💧
Increase habitat complexity		💧			💧	💧
Control erosion & sedimentation		💧	💧	💧	💧	
Restore habitat	💧	💧	💧			
Improve water quality			💧	💧	💧	💧
Recharge groundwater				💧	💧	
Control non-native species			💧			💧
Support wildlife populations	💧	💧	💧		💧	💧



Project 1
Removing an In-stream Barrier

The removal of in-stream barriers has two primary objectives: improvement of passage for aquatic species and restoration of more natural hydrologic processes.

Background

Rivers and streams flowing into the Pacific Ocean along California's coast provide critical habitat for threatened aquatic species, most notably Coho salmon and steelhead. These anadromous fish depend on access to fresh water for breeding and rearing habitat to complete their life cycles. More than 13,000 barriers in California's coastal watersheds threaten the survival of these fish. Throughout California, in-stream barrier removal has the potential to restore 80% of the critical spawning and rearing habitat historically available to salmon and steelhead and other fish species.

Benefits

Improves passage for aquatic species. Many aquatic species, particularly anadromous fish, need to move between varying habitats along a stream course to support different life-history stages (Photo P1.1). Because in-stream barriers—even small culverts—limit or prevent this movement, their removal can allow these aquatic species to increase their numbers or even repopulate a stream from which they had been absent (Figure P1.2). In-stream barrier removal projects have resulted in the return of native fish within the first season of barriers being removed. There is a long-documented history of success improving habitat for aquatic species elsewhere in the U.S. through such barrier removal (i.e., Horowitz, Overbeck et al. 2001; O'Donnell 2001).

Photo P1.1 Barrier removal benefits include recovery of fish migration corridors Photo: ESNERR

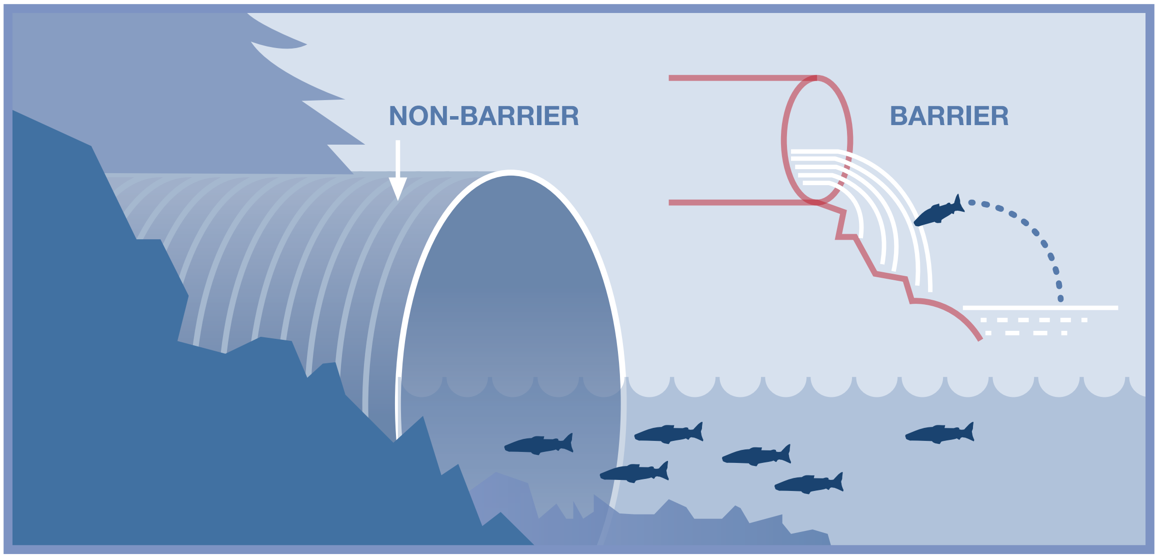


Figure P1.2 Even small barrier removal projects can have significant benefits for fish. Luis Prado/DNR

Restores natural stream processes. In-stream barrier removal restores natural hydrological processes both upstream and downstream of the site because it allows unimpeded stream flow and the transport of sediment and large woody material. After in-stream barriers are removed, sediment can more readily move downstream, restoring gravel and cobble habitat, which is crucial for the breeding success of anadromous fish. Allowing large woody material to be transported downstream also improves fish habitat. Beaches benefit from sediment flow after barriers are removed and the natural sinuosity of streams may be restored. In-stream barrier removal also restores riparian habitat by decreasing the unnatural water storage that typically occurs upstream of barriers and which inundates riparian habitats.

Planning

Barrier removal needs to be considered as part of broader, watershed-scale planning. If in-stream barrier removal is determined to be appropriate, specific, project-level assessment of barrier removal effects on stream channels is necessary (see *Site Assessment* below).

The California Department of Fish & Wildlife, National Marine Fisheries Service, and the California Coastal Commission have catalogued the rivers and creeks that should be prioritized for barrier removal and have done much of the needed hydraulic analysis and species surveys of these waterways. The U.S. Department of Agriculture, Forest Service has also developed a useful on-line document: National Inventory and Assessment Procedure – For Identifying Barriers to Aquatic Organism Passage at Road-Stream Crossings.

Advance Analysis

Site Assessment

The watershed-scale planning that usually precedes identifying an in-stream barrier as a candidate for removal normally includes watershed-scale hydrological and biotic assessments. If such assessments have been completed, the need for further site-specific environmental assessments may be limited to a water and sediment flow analysis. This analysis predicts how the sediment trapped behind the barrier will be transported downstream and how this sediment transport combined with increased stream flow will cause changes in channel form.

Because bridges and historic irrigation systems greater than 50 years old may be classified under federal law as protected cultural resources, it may also be necessary to conduct a preliminary assessment of the age and status of any structures that would be removed as part of implementing this project.

Seasonality

Work should take place between late spring and early fall in order to minimize impacts on water quality, stream habitat, and aquatic species. A hydrologist familiar with the region can identify appropriate seasonal dry periods and suggest the best times for construction. If the restoration project is taking place on a stream that does not dry down, it is necessary to consult with a fish biologist to plan to avoid negatively impacting any species of concern. In many streams where federally and/or state threatened, endangered, or sensitive aquatic species are present, specific regulations may dictate the range of dates in which work or disturbance to the stream channel and/or riparian corridor can be conducted. Project proponents should contact the California Department of Fish and Wildlife, the National Marine Fisheries Service (for projects in marine and anadromous waters) and the U.S. Fish and Wildlife Service (for projects in anadromous and fresh waters) for guidance. In addition, a California Department of Fish & Wildlife "Streambed Alteration Permit" must be obtained for any activity that will "substantially divert or obstruct the natural flow of any river, stream or lake; substantially change or use any material from the bed, channel, or bank of, any river, stream, or lake; or deposit or dispose of debris, waste, or other material containing crumbled, flaked, or ground pavement where it may pass into any river, stream, or lake."

Expertise Needed

In addition to involving the experts listed below, it will be necessary to identify an entity or person who will be responsible for developing an adaptive management plan for the project (see below).

Characteristics of a Fish-friendly Road Crossing Over a Stream

- The crossing width is at least as wide as the active channel.
- The culvert is able to pass a 100-year storm flow.
- The crossing bottom is buried below streambed level.
- Natural bed material is able to accumulate along the bottom of the crossing.

In general, a bridge is preferred over a culvert as it usually doesn't constrict a stream channel as much as a culvert

Hydrologist. A hydrologist must perform a baseline assessment and a hydrological analysis. Expertise in predictive modeling is important given that the project is designed to cause changes in stream hydrology. A hydrological analysis can be and is frequently done by an engineer with the appropriate expertise.

Fish Biologist. A biologist familiar with the affected aquatic biota should perform a baseline analysis of desired and undesired species and determine the best course of action given biotic targets. Expertise in aquatic ecosystems is important; in some cases expertise in the species being targeted for restoration or control is also important.

Water Quality Scientist. A water quality scientist can assist with understanding baseline conditions for water quality and designing the project in a way that will maintain or improve water quality. If a specific water quality impairment is targeted, the scientist should be familiar with management and monitoring measures for that target.

Engineer. An engineer is necessary for guiding the careful removal of barriers and potentially for engineering safe fish passages.

Implementation

Materials and methods for removing in-stream barriers vary from site to site and are dependent on the scale of the project, the type of barrier being removed, and the size of the riparian area.

Methods

Barrier removal may entail the rerouting of the river or stream during the construction period. Prior to commencing a project the stream should be netted above and below the construction site and any fish present removed from the site. The California Department of Fish & Wildlife and a fish biologist should oversee the fish removal and relocation process.

With fish safely removed, the stream may be diverted and dewatered in preparation for the barrier removal. Depending on the type of barrier to be removed the work may involve hand-held tools or heavy lifting equipment.

Removal of in-stream barriers may result in changes to channel morphology (NRCS 2007), and so some projects should include widening of the stream channel and the restoration of a natural stream bottom with boulders (for grade control).

If the barriers involve road crossings, the restoration work includes not only the removal of the barrier but also its replacement with a fish-friendly crossing and repair of the road affected by the project (see *Characteristics of a Fish-friendly Road Crossing Over a Stream*). If road removal and replacement is involved, permission for temporary closure should be obtained during the initial project planning stage.

Materials

Possible materials needed include netting and electro-shock equipment for removing fish, large lifting and hauling equipment for removing the barrier, and replacement culverts, bridges, or boulders.

Adaptive Management

Restoration practitioners who remove a barrier to improve fish passage should be prepared to make adaptive management decisions during the first few years after the project, and possibly longer. Of particular concern will be the new hydrological characteristics of the stream, sediment dispersal, debris movement, and possible erosion of streambanks.

Monitoring

Annual and seasonal monitoring of stream flow, sediment deposition, water temperature, and physical habitat may be required to detect and document the significant changes in the hydrology and ecology of the stream that are to be expected in the first few years following the removal of a barrier. If targeted fish species are present, their populations and breeding behaviors should be monitored on a regular basis.

Maintenance

If new structures have been put in, these passages must be checked periodically for debris and damage.

Potential Concerns

Water quality disturbance. Initially, barrier removal may adversely affect water quality through the transport of sediment-bound contaminants residing in the upstream impoundment. The initial site assessment should inform the project managers of potential sediment contaminants present in the impoundment. In some cases, historical analyses of the watershed can help identify potential pollutant issues.

Photo P1.3 Installing culverts to improve water quality. Photo: ESNERR

Increased sediment. Sediment transport increases after barrier removal and can cause immediate loss of fish habitat downstream due to accumulation and scouring (Catalano 2001). An understanding of the native fish and their life cycle assists in designing a project that avoids spawning seasons and allows time for natural river hydrology to evolve. Within one season new pools are created and sediment dislodged during construction clears. The likelihood of habitat-affecting sediment movement is one reason a qualified fish biologist should be involved in the planning stage and should monitor the project after completion.

Habitat loss. Barrier removal may lead to the loss of valuable upstream aquatic habitats. Restoration practitioners must make decisions that evaluate and weigh the importance of each kind of ecosystem.

Species shifts. Upon removing a barrier, both native and non-native species are free to move upstream into areas from which they were once restricted. This shift in species abundance can lead to species of concern being displaced. While many anadromous species benefit from the expanded migratory range offered by in-stream barrier removal (Gardner 2011), other aquatic species may face increased competition and predation from these as well as invasive species. An analysis of riparian habitats and assessment of the local species informs decisions for addressing this concern. A California Department of Fish & Wildlife biologist can assess the presence of sensitive species in up-river waterways as well as the presence of any potential invasive species downstream. If invasive wildlife species are identified, a plan for their removal may be warranted. If complete eradication is not possible, increasing habitat heterogeneity through such methods as emplacement of large woody material (see Project 2) and boulders may offer protection for some species of concern. Other design options for mitigating the movement of invasives can be developed during the planning stage. In most instances the benefits of barrier removal to sensitive fish species outweigh the threats of invasive movement (Hart, Johnson et al. 2002).

Costs

The costs associated with barrier removal vary depending on the scope and scale of the project. Costs are incurred in hiring experts and contractors, purchasing materials, traveling to and from the site, securing permits, and renting heavy equipment and/or hiring equipment operators.

A number of factors influence the final costs, including site accessibility, the type of materials needed, and whether or not it is necessary to replace the removed barrier with a functional equivalent.

Recent estimates of costs average around $110,000 per mile of habitat restored (Five Counties Salmonid Conservation Program 2012). See Table P1.4.

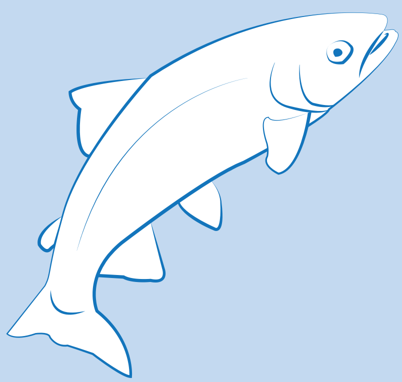
Table P1.4: Project costs of a barrier removal project in Northern California

County Engineering Staff	$3,984.81
County Road Staff	$5,930.18
Concreted-Rock Slope Protection Under Flatcar Bridge	$300.00
Flatcar Bridge	$24,595.00
Grade Control Boulders	$175.00
Planting Trees	$560.00
Rip Rap 1/2 Ton Rock	$12,161.63
River Run Material Used to Recreate the Stream Bed	$1,467.94
25% of Base Contract Price (labor and equipment)	$55,897.50
Concrete Footings for Flatcar Bridge	$2,100.00
TOTAL PROJECT COSTS	$107,172.06

Related Resources

- The California Department of Fish & Wildlife website offers numerous documents and resources regarding river and stream restoration, fish passage, and historical data available in reports on file. These resources include the *California Salmonid Stream Habitat Restoration Manual for Stream Passage* (Taylor and Love 2003). Part IX of this document is specifically focused on fish passage design (Flosi, Downie et al. 1998). The Passage Assessment Database is an on-going inventory of barriers to anadromous fish in California and is accessible from the Calfish website: https://nrm.dfg.ca.gov/PAD/Default.aspx

- The Five Counties Program (5C) includes Del Norte, Humboldt, Trinity, Siskiyou, and Mendocino Counties and was formed in 1997. The program has removed or modified 53 barriers, opening up 130 miles of stream and providing immediate benefits to salmon. 5C and American Rivers are two non-profits that support barrier removal with a grant program (Five Counties Salmonid Conservation Program 2012). Their websites and case studies offer excellent information and resources for riverine restorationists. http://5counties.org



Case Study

Yonkers Creek Migration Barrier Removal Project

Wonderstump Road, Del Norte County
Five Counties Salmonid Conservation Program

Located in Del Norte County, Yonkers Creek was identified by CDFW as a valuable tributary to Lake Earl and host to all native species of salmonid found in the region. A metal culvert at Wonderstump road was shown to be a migration barrier to local salmonids. The Yonkers Creek culvert was elevated approximately three feet above the surface on the outlet end, creating a jumping barrier for juveniles. Additionally, the culvert experienced high winter flow volumes that combined with the height to create a migration barrier to the upper reaches.

Implementation

The project site was bordered by riparian vegetation both upstream and downstream. Access permission was obtained from the property owner and a road in the project area was closed to allow for access to the site and equipment operation. The final project design included removing the existing culvert and replacing it with a 30-foot-long corrugated steel culvert with a cross-sectional diameter of 28.3 square feet. A grade control structure was placed at the outlet to allow for backwatering during low flow seasons. During construction fish were removed both upstream and downstream of the site and fish screens placed to insure that no fish entered the site. Silt fencing was also placed downstream to protect water quality. Disturbed streambanks were revegetated after construction and bioengineering techniques were also utilized to aid in erosion control.

Results

The removal of this barrier allows salmonids access to 9,000 feet of spawning and rearing habitat. The natural channel design also allows for year-round fish passage and increased fish habitat. Project design includes continued monitoring to evaluate the long-term impacts of this project.

The Five Counties Salmonid Conservation Program includes five northern California Counties that have agreed to collaborate on restoration projects in response to the federal listing of the Coho salmon as a threatened species. Their website offers valuable resources and case studies illustrating the work they are doing (http://www.5counties.org/).

Task Checklist

Design the project

- [ ] Contact landowner to discuss restoration work
- [ ] Create a team of experts
- [ ] Describe objectives and purpose of restoration work
- [ ] Define adaptive management strategy
- [ ] Design barrier removal plan based on assessments
- [ ] Contact engineer
- [ ] Identify access to sites
- [ ] Create work plan
- [ ] Contact regulatory agency to understand pertinent regulations
- [ ] Contract with sub-contractors

Analyze the site

- [ ] Conduct soil assessment
- [ ] Conduct biological survey
- [ ] Conduct hydrology study
- [ ] Assess potential for the barrier to be considered a protected cultural resource

Prepare site for barrier removal

- [ ] Re-route water
- [ ] Remove fish and/or offer alternative passage
- [ ] Stream channel widening
- [ ] Stream bottom restoration with rock addition
- [ ] Predict nature of sediment transport after removal

Maintenance the first year

- [ ] Inspect for stream blockage
- [ ] Remove excess debris

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Project 2
Emplacing Large Woody Material in a Stream

Placing large woody material (LWM)—logs, trees with branches, and root balls—in streams increases stream habitat complexity and stabilizes streambanks.

Background

Humans have long removed large woody material from streams and rivers to improve navigation, improve flow, and to control flooding. In addition, large channeling operations have often cleared instream woody material and removed the riparian forest that served to recruit more large woody material. Recently, it has been recognized that these activities degrade stream health and negatively affect stream channel stability (Bilby 1984).

Benefits

Many streams in California, along with their watersheds, have been subject to management or alteration that has tended to simplify and homogenize stream habitats. Because it helps to reverse or mitigate these effects, the placement of large woody material into streams provides some important benefits.

Increases habitat complexity. Large woody material placed in a stream modifies stream flow and changes sedimentation patterns. It can create riffles and cascades, banks of gravel, and pools, all of which can be critical habitat components for many aquatic species. The material itself also casts shade, forms refugia where organisms can hide from predators, provides basking sites for reptiles, and provides perching and feeding sites for birds. In these various ways, placement of LWM restores stream habitats, benefitting many species (Carlson, et al, 1990; Beechie and Sibley 1997). Because they require habitat complexity, many aquatic animals in California's streams—including salmon and trout—are dependent upon the presence of in-stream large woody debris (Beechie and Sibley 1997).

Controls erosion. The placement of LWM in streams reduces erosion by increasing the stability of streambanks.

LWM helps to reduce high-flow energy and to redirect flow that would otherwise erode streambanks (Bilby 1984; Reckendorf 2010). Another factor in reducing erosion is LWM's role in restoring more natural sediment storage (Angermeier and Karr 1984).

Planning

Ideally, large woody material placement occurs after a comprehensive riparian restoration plan is developed, but it may be done without the expense of a full plan. A comprehensive plan addresses not only the placement of large woody material but also the natural production and movement of large woody material, so that the function of LWM can be sustained in the long term without human intervention.

Oftentimes, large woody material placement is a first step in restoring habitat complexity to a stream.

Advance Analysis

Site Assessment

Typically, a LWM emplacement project begins with a historical analysis and site assessment. Hydrologists or engineers typically assess historic flows and flood plain morphology. Site surveys also assess site stability, access issues, and river-channel hydrology, and create a wood transport budget.

Site stability and site access are key factors in determining the suitability of a LWM placement project. The Department of Fish and Wildlife *California Salmonid Stream Habitat Restoration Manual* (Flosi et al. 1998) outlines the factors to be assessed in determining site stability. The list of factors is too lengthy for the scope of this document. Site access assessment focuses on the possibility of avoiding or minimizing damage to riparian habitat.

Photo P2.1 Large woody material placement using locally harvested trees.

Hydrological analysis during the planning stage insures that the project achieves desired outcomes while avoiding potential negative impacts. Each stream and project is different and responds differently to the addition of wood. Assessment of historic flow and the adjacent flood plain morphology helps to predict flooding potential as well as the possible extent of stream scour and sediment deposition processes (Reckendorf 2010).

A wood transport budget aids project managers in understanding the processes and rates of natural wood recruitment, including its storage, transport, and decay (Benda 2002; Lisle 2002; Wooster and Hilton 2004). Creating a wood transport budget begins with an assessment of the potential of the existing riparian forest to produce LWM of adequate size and quantity. In areas of the state where endangered-species recovery plans have been completed, studies may already exist to inform wood transport budgets without completing often-expensive new analyses.

Expertise Needed

Hydrologist. A hydrologist should perform a baseline assessment and hydrological analysis to determine if the project can meet its goals. Expertise in predictive modeling is important given the potential changes in hydrology that come from emplacement of LWM.

Biologist. A biologist familiar with the affected aquatic biota is necessary for performing a baseline analysis of desired and undesired species and to determine the best course of action given biotic targets. Expertise in aquatic ecosystems is important; when a particular species is being targeted for restoration or control as part of a larger restoration effort, expertise in this species is also important.

Water quality scientist. A water quality scientist can assist with understanding baseline conditions for water quality and designing the project in such a way that it maintains or improves water quality. If specific water quality impairment is targeted, the scientist should be familiar with management and monitoring measures for that issue.

Engineer. An engineer works closely with the project hydrologist to advise on wood placement and, if it is determined to be necessary, how to secure the wood in place. Experience with regional hydrological patterns is advisable.

Forester. This expert should work closely with the engineer and biologist to provide guidance on wood load, wood recruitment possibilities, and safe access to the site.

Implementation

A variety of site-specific characteristics including project objectives, funding, wood sources, and site access are some of the factors that guide project design and decisions about materials and installation.

Design

Determining what size wood to use is an important aspect of project design. Different sized LWM will differ in the amount of time it persists in the stream (Lisle 2002). A standard rule is that LWM length should be approximately two times the width of the channel. Small channels (<10 m width) can form pools around smaller pieces of wood (<20 cm), such as alder logs. Large to intermediate channels require greater diameter logs to form pools (>60 cm).

The California Department of Fish and Wildlife *Salmonid Manual*, along with numerous scientific studies, provide detailed information on appropriate wood size (Flosi et al. 1998; Lisle 2002; Leicester 2005).

Appropriate installation methods for large wood material placement will vary depending upon the project location, downstream considerations, watershed characteristics, and goals. Traditionally, many large wood material placement projects included fixed or cabled structures, sometimes in conjunction with boulders. At the Soquel Demonstration Forest in Santa Cruz County and all along the North Coast of California, unanchored large woody material is increasingly gaining favor as a way to effectively improve salmonid habitat along longer lengths of streams.

Unanchored wood placement, where appropriate, involves the reintroduction of unsecured or wedged large wood along stream channels. This practice begins by directionally falling streamside trees into the channel where riparian shade is sufficient, or by translocating large wood from outside of the riparian zone with heavy equipment. Once the wood has been placed into the stream, it may be left unsecured and allowed to move with the natural flow of the stream.

It may be determined during the planning phase that anchored wood placement is required; this is a more involved practice and requires additional materials and techniques. Natural boulders may be used as brace points, but most commonly steel cables, wire rope, rebar, and bolts are employed. The decision about whether to use secured or unsecured wood should be made in the planning phase, as it affects the materials used and the final cost of the project.

The Engineer Research Development Center, a branch of the U.S. Army Corps of Engineers has published a guide to emplacing large woody materials in streams for the purposes of restoration. This document is an excellent resource for learning what goes into the planning, engineering, and implementation of this project (Fischenich and Morrow 2000).

Materials

Large woody material may consist of logs, root balls, or felled trees. Each type of material can be used on its own or they can be used in combination. The most important consideration is longevity, and this varies with size and tree species. For example, conifer species such as redwood last longer than hardwood species such as willow or alder. Ideally, materials are available from the project site. However, if materials must be imported, site access and cost must be considered.

As noted above, if the LWM is be secured, materials such as steel cable, re-bar, and bolts will be required.

Adaptive Management

Preserving and encouraging the growth of recruitment trees in the riparian forest is part of the adaptive management strategy. Ideally a restored riparian/riverine system becomes self-supporting: LWM placement protects streambanks, allowing trees to grow, which ultimately supplies more LWM to the system. The possible management implications of preserving LWM input, transport, and presence within the stream channel is reviewed in the 1992 report of the California Board of Forestry and Fire Protection's Technical Advisory Committee (California Board of Forestry and Fire Protection Technical Advisory Committee 2007).

Further management practices are reviewed and outlined in K. J. Gregory and R. J. Davis's article in *River Research and Applications* (Gregory and Davis 1992).

Monitoring

Data on location of placement of LWM, anchoring or non-anchoring techniques, and size of wood should be collected when the LWM is put into place. Subsequently, it is recommended that a monitoring program collect data on movement of the LWM, the biological effects of its placement, and the creation of pools and bars of gravel and sand. The success of future LWM placement depends on the sharing of data to continually improve the use of this restoration practice throughout California.

Maintenance

Seasonal maintenance will include removing excess debris or possibly adding additional wood after storms.

Potential Concerns

Habitat damage from large equipment. Large equipment may be used for transporting and placing logs and root balls. The use of large equipment can potentially damage riparian habitats and weaken streambanks. Loss of riparian vegetation can lead to loss of shade and recruitment of woody material as well as the introduction of non-native invasive plant species. Consider site access and identify the least impactful routes during the planning stage.

Bank failure. Streambank erosion is a naturally occurring process in a healthy riverine system. If not done properly, however, LWM placement can lead to undesired bank failure. Understanding historic channel flow and the hydrology of the system helps engineers and planners to better predict the outcomes of LWM placement (Reckendorf 2010). These studies guide the engineer in assigning placement sites and determining the size and types of woody material to be used.

Mobilization of large woody material. With large woody material placement there is the risk that the woody material could mobilize from the restoration site and endanger critical public works infrastructure downstream. Using very large wood can limit potential movement and downstream impacts. Keeping the rootball intact also reduces the threat to downstream infrastructure. If the mobilization of LWM poses a large risk, the wood can be secured or anchored at the site. There are numerous techniques for anchoring wood material and each should be considered carefully and with a complete understanding of what it entails.

Flooding. Increased wood in the system could lead to impoundments and thus trigger a rise in flood levels. Adding LWM to a system already wood-rich could create not only flooding but also stream diversions and impact surrounding habitat and infrastructure. To address this potential outcome, conservationists and planners should assess the site before introduction of LWM and determine the proper size and amount of wood to be added. Research suggests that the smaller wood pieces tend to cause the most significant flooding problems. Models for determining the loading targets for certain types of streams have been developed (Lisle 2002).

The Army Corps of Engineers Ecosystem Management Restoration Research Program technical report (Fischenich and Morrow 2000) addresses these and other potential problems associated with large woody material placement and provides suggested environmental protection measures.

Costs

Costs associated with large woody material placement can vary from site to site and are influenced by several factors, including site access, the need for large transport equipment, the type of trees used, and whether or not anchoring equipment is required.

As noted above, site analysis is necessary to determine the needed load for the system based on the hydrology of the river. The cost of employing experts should be accounted for when planning to implement this project.

Long-term costs can be greatly reduced by managing the surrounding riparian forest in a way that results in natural recruitment of LWM.

As part of a study of the effects of large woody materials placement on juvenile Coho recruitment (Cederholm et al 1997), the Washington State Department of Natural Resources estimated the costs associated with two different techniques for emplacing LWM. These estimates are shown in Table P2.2. The findings suggest that directional felling of trees into a stream is the most cost-effective way to get wood into the stream.

Table P2.2 Expenses for two different methods of large woody material placement

	Engineered section	**Directional falling section**
Total cost	$82,250.00	$6,450.00
Cost/m of channel	$164.50	$12.90

Source: Density and Size of Juvenile Salmonids in Response to Placement of Large Woody Debris in Western Oregon and Washington Streams (Roni and Quinn 2001)

When trees must be brought in to a site, there is a considerable additional cost. Timber cost varies from year to year and species to species. For example, Washington Douglas Fir is $100 per 1000 board feet and California Redwood costs about $510 for the same amount.

The NRCS Cost Share Practice Standard estimates that the materials cost of a LWM project using anchored wood is about $1,900.00 per acre and about $924.00 per acre for one using unanchored wood (these materials costs represent 50% of the total cost).

Case Study

Effect of LWM Placement on Salmonid Populations

Thirty Streams in Western Oregon and Washington

Between August 1996 and April 1999 thirty streams in western Oregon and Washington were sampled to study the response of salmonid populations to large woody material placement. The study indicated that LWM placement can lead to higher densities of juvenile coho during summer and winter and cutthroat and steelhead during the winter.

Many studies suggest that LWM placement plays a critical role in the rehabilitation of fish habitat in streams (Roni, Hanson et al. 2008). LWM creates pools, provides shade, increases habitat complexity, reduces sediment, and traps gravel, leading to an overall improvement in the streams' health and its value as fish habitat. These benefits have led to LWM placement becoming one of the most common stream restoration practices. This study sought to correlate these benefits to increased salmonid abundance.

Implementation

Paired treatment and reference reaches 75–120m long were selected in each of the thirty streams. The streams were selected based on physical and biological stream characteristics. It was important for reference and treatment reaches to have similar characteristics such as stream size, bankful width, channel type, and fish species composition in order to control "background noise."

During summer and winter surveys, the amounts of LWM and fish numbers were recorded in each stream. All natural and artificially placed LWM was counted and measured and categorized based on length, with, and function. Electrofishing was used in summer to census fish, and in the winter divers counted fish.

Results

Treatment and reference reaches were identical in length and other physical characteristics; however, there were some physical differences between the two that correlated with the increased LWM in the treatment reaches. LWM reaches had greater pool area, wetted area, and number of habitats. The study also found significantly higher densities of juvenile coho in summer and winter in the treatment reaches. The results of this study support previous findings that restoration projects that increase LWM and thus increase pool area and stream complexity provide the largest increase in fish populations.

Source: Density and Size of Juvenile Salmonids in Response to Placement of Large Woody Debris in Western Oregon and Washington Streams (Roni and Quinn 2001)

Related Resources

- The Wood for Salmon Workgroup has researched various methods for large woody materials placement. This organization has publications that address permitting concerns and suggests partners that can assist in this work (Warmerdam 2012).

Task Checklist

Design the project

- [ ] Contact landowner to discuss work
- [ ] Create a team of experts
- [ ] Describe objectives and purpose of restoration
- [ ] Develop adaptive management strategy
- [ ] Design LWM placement plan based on assessments
- [ ] Determine if wood will be anchored or unanchored
- [ ] Identify LWM source
- [ ] Identify access to sites
- [ ] Create work plan
- [ ] Contact regulatory agency to understand pertinent regulations
- [ ] Contract with subcontractors

Analyze the site

- [ ] Conduct geomorphic assessment
- [ ] Conduct biological survey
- [ ] Conduct hydrology study
- [ ] Conduct forestry survey

Prepare site for LWM placement

- [ ] Erosion control

Maintenance the first year

- [ ] Inspect for stream blockage
- [ ] Remove excess debris
- [ ] Add additional wood if needed

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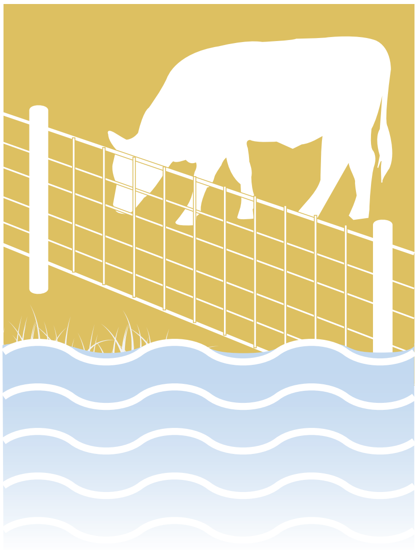

Project 3
Fencing a Riparian Area to Manage Livestock Impact

Fencing around a riparian area allows a manager to exclude livestock when such exclusion is seen as a way of reaching habitat or species goals within the riparian ecosystem.

Background

Improper livestock use of riparian areas, particularly in the arid western United States, has been broadly implicated in a variety of water quality, habitat, and species-related threats (e.g., Belsky et al. 1999; Freilich et al. 2003). The impacts of improper livestock management include altered plant community composition and structure, soil compaction, and reduced bird species diversity and abundance. Fencing can help managers more easily control livestock use of riparian areas. Completely excluding livestock from riparian areas may not be necessary or warranted, and may even have negative consequences (Nelson et al. 2010).

Benefits

Livestock can have both positive and negative impacts in riparian areas. When a riparian area is surrounded with fencing, the livestock manager or landowner can control the timing and frequency of grazing to minimize the negative impacts and maximize the positive, thereby furthering goals for habitat restoration, species conservation, and water quality improvement.

Improves water quality. Livestock can trample streambanks and remove vegetation, leading to erosion and sedimentation. During the summer, the tendency for livestock to congregate in cooler riparian areas can cause fecal contamination of the stream and increased nutrient loading. If downstream areas are used for recreation or drinking water, this can be a serious problem. Excluding livestock can help limit nutrient loading and fecal contamination (Belsky et al. 1999; Davies-Colley et al. 2004). Excluding livestock with fencing can also increase vegetation cover, reduce the area of bare soil, reduce soil compaction, and reduce streambank erosion, resulting in decreased sediment delivery into the stream or river (Platts and Waggstaff 1984; Kaufmann and Kreuger 1984).

Protects and restores riparian habitat. Riparian habitats can benefit from the management flexibility provided by installation of livestock fencing. Riparian fencing controls the potentially destructive movement of livestock into and around riparian habitats. Fencing riparian pastures can help some managers to manage more effectively for riparian vegetation-related goals (Kauffman and Krueger 1984)

Aids wildlife populations. If fencing is used successfully to recover riparian vegetation and stem erosion and sedimentation, there can be resulting benefits for terrestrial and aquatic wildlife species. Restored riparian forests provide habitat for bird species to forage, nest, feed, and elude predators, resulting in increased diversity and abundance. Additionally, aquatic species, including listed fish species, benefit from the shading and resulting decreased water temperature provided by restored riparian vegetation (Armour et al. 1991; Blann and Nerbonn 2002) and the reduced sedimentation benefits benthic invertebrate species and the eggs and larvae of fish (Bjornn and Reiser 1991).

Planning

When considering the installation of riparian-area fencing, is important to note that full livestock exclusion is not being recommended. Livestock use of riparian areas has proven beneficial consequences. For example, California tiger salamanders and California red-legged frogs are known to prefer habitats with trampled banks and to benefit from nutrient-rich water (Ford et al. 2013). Exclusion of livestock is appropriate when the goals of the project are explicitly habitat restoration and/or water quality improvement for sensitive aquatic species. Even then, managers may find it beneficial to allow livestock to graze within the fenced area for periods of time as long as there is particular attention paid to critical movement periods for certain amphibians.

Planning for this project should occur within the context of an existing livestock management plan, preferably one that includes clearly defined restoration objectives.

Advance Analysis

Site Assessment

A baseline understanding of the biological and soil resources present at the project site helps to determine many aspects of fencing design; it also provides a basis for determining how the new fencing will function within the grazing management program. It is important to know where sensitive resources or target habitats are located in relation to the riparian fencing, so that appropriate plans can be made for grazing inside the fenced area vs. outside.

Hydrological analysis may be important as well. Containing livestock grazing within the fenced riparian area in the wet season may be a concern if there is the possibility of flash flooding.

Seasonality

Installation of riparian fencing is normally seasonally constrained. In many parts of Northern California, fences are built from spring through fall, as digging may be a problem when the ground is frozen or wet. In other areas installation takes place after August 1 to avoid disturbance to native birds or migrating amphibians. Stream crossings and new livestock water access areas are built during the summer, when work is least likely to disturb fish (Bush 2006).

Expertise Needed

Livestock manager. A livestock manager provides important input on fencing design and directs long-term management of the fencing once it is installed.

Biologist. A biologist helps determine where the fence should be placed and what materials it should be constructed from to maximize benefit and avoid undue impact to biological resources. If fencing traverses a stream or river, a fish biologist needs to identify presence of native fish and other aquatic species. A biologist's expertise also assists in choosing the best timing for construction.

Soils expert. Potential soil erosion from cattle movement up and down slopes as well as along stream banks is addressed and mitigated by this expert. A soils expert may also help predict interactions between fence post material types and different soil types, so that materials that last the longest can be employed.

Implementation

Design

A key design issue is the scale of the fencing project. This will depend on basic project goals (protecting a relatively small area with a spring vs. a long reach of a stream), the size of the riparian zone, long-term management goals, and budget.

The design of the fencing should facilitate long-term management. Adding gates into the fenced riparian area, for example, allows a rancher to give livestock access to the area inside, to free trapped livestock, and to easily enter the area to perform regular maintenance activities such as weed control. An unplanted strip along fences allows vehicle access and prevents livestock from pushing against the fence and potentially weakening it (Prunuske 2006). If the fencing will cross a stream, special designs and materials are needed to ensure stability in high-flow situations and security during low flows.

Since excluding livestock from a riparian area may also mean cutting them off from a water supply, the project should be designed to account for alternative water sources. When linking to an alternative water source, consult the experts. Any piping crossing streams must be buried, and trenching associated with this must be a minimum of three feet deep to ensure that scour does not eventually reach the surface of the pipeline (NRCS 2007). In general, increasing the number of places livestock have access to water reduces overgrazing near one water source (Bush 2006).


Photo P3.1 Mowing fence lines allows for easy access for repairs and maintenance. Photo: ESNERR

Particularly when installing fencing is part of a larger riparian restoration project, fence installation may involve planting of native species (see Chapter 1). Generally, revegetation occurs after the fencing is installed to avoid damaging new plants with fence construction activities. Practitioners might consider waiting to replant for one to two years after installing fencing, because plants native to California's riparian areas often return naturally. If revegetation occurs immediately after fence installation, it is recommended that livestock be excluded for 3 to 5 years to allow for plant establishment.

Materials

There are numerous materials available for constructing riparian fencing for livestock. The choice of materials depends on the conservation objectives established during the planning stage. For instance, if improving water quality is a goal and the fencing crosses water or wetlands, then it may be best to use non-treated wood or metal posts. Wildlife-friendly fences are available for use where wildlife movement is a concern. Choosing between barbed or non-barbed wire and placing fence posts at a distance that insures wildlife movement are important installation considerations. As mentioned above, including gates in the construction allows access into and out of the fenced area for both livestock and manager. In public use areas, signage may be required to properly inform passers-by of the purpose of the fencing.

Adaptive Management

Livestock managers who utilize fencing to manage livestock movement in riparian areas should be prepared to monitor these areas during the life of the installation and make adaptive management decisions when necessary. Although livestock management itself is integral to any riparian fencing project, methods for managing livestock once the fence is in place are beyond the scope of this document (the Related Resources section below lists livestock management resources that pertain to riparian fencing).

Monitoring

Monitoring of water quality (and, if appropriate, of the populations of sensitive species and their habitats) should begin during the planning stage and inform the adaptive management plan for the life of the project. As the site is monitored over the years, land managers are able to make repairs to the fencing and adjustments to the grazing regime to insure that the project is achieving its goals and objectives.

The Marin RCD handbook for erosion control suggests photographing the site before, during, and after implementation as part of the monitoring efforts (Prunuske 2006). This information will prove valuable as the project ages. Photographic monitoring helps to inform grazing regimes and identifies when modifications must be made.

Maintenance

The success of livestock exclusion depends on fencing working properly. Periodic maintenance to insure that poles are stable and that cables and/or wire are still attached is required. In riparian areas the fencing should be inspected after all rains for potential bank destabilization. If alternative water sources have been provided as part of the project, the manager must maintain these water sources regularly to insure the safety of the livestock.

Management of invasive plants is often necessary, particularly when restoration of native vegetation or habitat for sensitive species is a project goal. Even if livestock are excluded for only part of the year, their absence in the exclusion area may lead to undesirable growth of non-native vegetation. Electric fence lines risk high grasses shorting out the current, so areas near such fences must be mowed seasonally.

Managers should be aware that fencing may need to be redesigned over time if use of the area by humans, livestock, or wildlife changes.

Potential Concerns

Disrupted grazing regime. Riparian fencing can change the grazing regime, either by design or as an unintended effect of the exclusion, and these changes may not work well for the rancher/landowner. Negative consequences can be avoided by emphasizing a collaborative approach to project design. Potential negative impacts to wildlife and livestock are addressed during the design phase as well as through vigilant monitoring.

Risk to wildlife and livestock. Placing fencing in a riparian zone and across a riverine system can place native wildlife and livestock at risk. Animal entanglement and habitat destruction can occur during installation. Livestock also risk entanglement and injury on fencing as they move to get closer to water sources and desirable vegetation. All of these issues should be anticipated during the planning and advance analysis phases, but ongoing monitoring of the fencing is also necessary to detect any damage to the fence that could lead to these negative outcomes. Wildlife-friendly fencing is available to protect wildlife movement patterns. These fences are designed with smooth bottom wires and are placed an adequate distance from the ground to allow small animals to move under the fence freely (Bush 2006). Fencing with wire strands closer together prevents cattle and larger animals from pushing their heads through to reach vegetation, avoiding potential entanglement.

Photo P3.2 Vehicle access along livestock fencing.
Photo: Nils Christoffersen

Debris accumulation. Regularly scheduled inspections and inspections after flood events can address debris accumulation in fencing, which can inhibit fish passage and result in fence damage.

Weed and fuel load management. Certain fencing designs may limit landowners' ability to use livestock to manage weeds and fire fuel loads (George et al 2004). A well-designed livestock management plan, developed in a collaborative manner, can usually mitigate this concern by allowing livestock access to the fenced area during certain times of the year.

Costs

The costs for installing riparian fencing vary from region to region and are influenced by the physical characteristics of the site as well as by the people and organizations involved in the project. Developing a plan that addresses site constraints and project objectives is a first step to controlling the cost of installation. Stakeholders should work together to create a detailed plan that allows contractors and laborers to understand the scope of the project in advance and allows all costs to be figured into the project estimate.

The type, design, and length of fencing ultimately affect the final cost of the project. Numerous styles of fencing exist; the choice depends on the goals of the project and the location and placement of the fencing. The type of fencing used (electric, woven wire, barbed, etc.) determines cost as well as the terrain. Rotational grazing and the installation of alternative water sources may decrease the number of miles of stream fencing required. Vegetative buffers can be used in conjunction with fencing to further minimize the length of fencing required. Once fencing is installed, maintenance costs are minimized with a carefully designed maintenance plan that involves scheduled inspections and post-flood-event inspections.

In a recent project, fencing two 100-foot corridors cost about $6,000 per stream mile (Platts and Wagstaff 2011). Federal cost-share programs can defray fencing costs from $1.60 to $5.00 per linear foot depending on the type of fencing, but the associated engineering and materials requirements may increase the base cost (Natural Resource Conservation Services 2012). The cost can increase considerably if a fence is to be constructed on certified organic ground (fence posts that meet certification standards do not have chemical additives or preservatives). Likewise, projects that must comply with American Made and prevailing wage requirements can increase costs.

Maintenance costs per stream mile per year can run between $60 and $200. Maintenance in flood zones is intensive because ranchers must clear fence lines of debris following storms.

Related Resources

- *The Grazing Handbook: A Guide for Resource Managers in Coastal California* is a handbook for public agency personnel and private landowners along California's Central and Northern Coasts. It develops guidance on utilizing livestock grazing as a management tool. The handbook includes excellent information on incorporating fencing into a management plan (Bush 2006).

- The New South Wales Government Fishing and Aquaculture website offers descriptions and diagrams for fence placement along streams and in riparian habitats. The site answers questions about where to put the fence, how to identify flood-prone areas, what type of fencing should be used, and what are the various fencing options (NSW 2012).

- The Marin RCD has published an erosion control handbook that addresses erosion control and livestock management issues related to riparian fencing (Prunuske 2006).

- *Fencing to Control Livestock Grazing on Riparian Habitats Along Streams: Is It a Viable Alternative?* (Platts and Wagstaff 2011)

Case Study

Riparian Fencing at Lynch Canyon

Lynch Canyon, Solano County CA
Solano Land Trust

Lynch Canyon is a 1040-acre working cattle ranch owned by Solano Land Trust (SLT) since mid-1990s. A 1998 Management Plan recommended excluding cattle from the riparian areas for vegetation improvement, ground and riparian nesting birds, and native grass improvement. Riparian fencing was installed to buffer the two forks and main channel of Lynch Creek, the main drainage on the property. Prior to fence installation, cattle had year-round free access to the creeks and large impacts to bed and bank, riparian trees and shrubs, and native grasses were evident. Tree recruitment (particularly with oaks) was negligible with the former grazing scheme.

Implementation

Five-strand barbed wire fences with periodic gates were placed in segments along the creek as funding was gathered for this project. As of 2013, both forks and the main section have continuous fencing that exclude cattle from the riparian area. The distance from the creek to the fence varies throughout the valley, from 30 to 300 feet from top of bank. Cattle grazing is now limited to a four- to six-week season in late summer to allow ground and other nesting birds to fledge and reduce cattle impacts during wet seasons. Along the valley, SLT-installed cattle troughs fed by springs and wells provide off-creek water for cattle. Vegetation planting was performed with volunteers and staff; it ranged from simple (placement of non-irrigated willow sticks and acorns) to more intensive (irrigation and use of Dri-Water and individual plant protections).

Results

Native vegetation along the creeks has increased dramatically, particularly where willows and other riparian plantings to add diversity were installed. Where shrubs were essentially absent in the past, mid-story vegetation made up of willows, elderberry, and coffee berry has done well. Oak and bay trees dominate the upper story vegetation at the site and these species have rebounded with less impact to their trunks and lower branches and more seedling recruitment. The native grass *Elymus triticoides* has rebounded such that after 4–5 years it dominates the upland grasslands within the exclosed areas. Noticeable increase in bird nesting has occurred with ground-nesting birds, raptors in tall trees, and mid-canopy nesters.

Task Checklist

Design the project

- [ ] Contact land owner to discuss restoration work
- [ ] Create a team of experts that include but are not limited to; land owner, livestock manager, environmental consultant, local RCD and/or NRCS staff, contractor……
- [ ] Describe objectives and purpose of restoration work
- [ ] Define grazing regime for restoration
- [ ] Define adaptive management strategy
- [ ] Design fencing to accommodate soil type and wildlife interaction
- [ ] Identify potential alternative water source
- [ ] Identify locations for stream crossings
- [ ] Identify locations for needed gates
- [ ] Account for machine access
- [ ] Create work plan
- [ ] Contact regulatory agency to understand regulations associated with practice
- [ ] Contract with sub-contractors

Analyze the site

- [ ] Conduct soil assessment
- [ ] Conduct biological survey
- [ ] Conduct hydrology study
- [ ]

Prepare site for the installation of fencing

- [ ] Clear site of brush
- [ ] Dig holes
- [ ] Install fencing and gates
- [ ] Install or connect to alternative water source
- [ ] Plant native plants in riparian areas
- [ ]

Maintenance the first year

- [ ] Remove debris
- [ ] Replant where necessary
- [ ] Mow around fence line if needed

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Project 4
Constructing a Storage Pond for Trapping Stormwater

The creation of stormwater storage ponds provides flow control for storm-related runoff and can reduce erosion, recharge groundwater, improve water quality, and provide wildlife habitat.

Background

Stormwater runoff is the rainwater that is not absorbed into the soil but instead runs across the soil surface and into streams and rivers. This runoff can transport pollutants, sediments, and debris into drainages and ultimately into larger bodies of water. It can also cause significant erosion. Stormwater runoff is part of a natural hydrologic process, but the impermeable surfaces and altered natural drainage patterns associated wtih human development can greatly increase the volume of stormwater runoff and thus the severity of its negative impacts.

Historically, stormwater management plans focused on managing rare events, such as the large-scale, infrequent storms that occur typically only once in 100 years ("100-year events"). More recently, the increasing frequency of

Benefits

By reducing the amount of pollutants and sediments reaching streams, stormwater storage ponds improve water quality and riparian habitat values. A variety of secondary benefits, noted below, increase their value as restoration projects.

Reduces erosion. By limiting the volume and flow of surface runoff, stormwater ponds reduce erosion downslope.

Recharges groundwater. Runoff held in storage ponds may infiltrate into the ground, replenishing aquifers.

Improves water quality. Stormwater storage ponds remove sediments, nutrients, bacteria, oil, pesticides, and other pollutants contained in runoff. When runoff is held in ponds for sufficient periods of time, sediment and associated particulate pollutants are allowed to settle and are not carried further downstream. Other pollutants are removed as the water percolates through the soil, and as plants growing in the ponds absorb nutrients.

Provides habitat. When they hold water for significant periods, stormwater storage ponds can serve these large-scale events, along with an increasing awareness that storms of medium intensity—and even the low-intensity storms that begin the wet season in California—can produce significant runoff carrying harmful pollutants and sediments, has changed our approach to managing stormwater. It is now recognized that managing the runoff from storms of all sizes is an important way of protecting streams from the negative effects of storm runoff, particularly where human development has altered drainage patterns.

as wetland habitats. Although little information exists from California, studies of stormwater storage ponds elsewhere suggest stormwater storage ponds provide at least low-quality habitat for a limited number of species (Bishop et al 2000a and Bishop et al 2000b).

Planning

The first step in addressing stormwater runoff or pollutant issues is to complete a stormwater management plan. This type of plan analyzes the watershed as a whole and determines the most feasible means of addressing stormwater-related issues. Increasingly, this planning is being done in conjunction with proposed development, so that stormwater solutions can be integrated into the planning and address the issue of how to maintain surface permeability and soil water retention in the built landscape. However, in some cases stormwater management planning or mitigation takes place *post hoc*, when means of addressing stormwater issues are more limited. In both situations, stormwater storage ponds can be a primary means of addressing runoff issues.

When a stormwater storage pond is called for in a plan, or otherwise deemed appropriate, pond location, soil permeability, pond size, inflow runoff volume, hydraulic residence time, and maintenance requirements are important planning considerations. Data related to some of these factors are gathered in the Advance Analysis phase discussed below.

A key choice to make during the planning phase is what type of storage pond to construct. Stormwater storage ponds can be designed for either detention or retention. Detention ponds hold water during a storm event and slowly release the water via infiltration or evaporation. Retention ponds are designed to hold water year-round. Both are beneficial in controlling stormwater runoff but offer different conservation benefits. The choice between the two is determined by the size of the site, the permeability of the soil, and the objectives of the project, as determined by the stormwater management plan. A detention pond is the better choice for groundwater recharge benefits; a retention pond carries the potential of creating its own wetland habitat.

Site constraints strongly influence stormwater storage pond design. It is best if the site is accessible and relatively flat; if the site is more than gently sloped, it should be geologically stable so that the pond does not pose a threat to downslope property and lives. Retention

Photo P4.1 Black wildlife exclusion fencing to exclude sensitive amphibians. Orange fencing to preserve native plants. Photo: ESNERR

ponds require more space than detention ponds, and are not recommended for small areas. With either type, a large pond is often necessary to make up for the loss of water-storage capacity in the soil that is associated with covering significant areas of soil with non-permeable surfaces such as roads and roofs.

Planning a stormwater storage pond often involves a landscaping plan. The terrestrial vegetation uplsope of the pond and downstream of its outlet may play an important role in reducing the sediment load of stormwater runoff, and may be nearly as important as the aquatic and semi-aquatic plant life in the pond in removing nutrients and other pollutants.

Advance Analysis

Site Assessment

Soil permeability determines the anticipated hydraulic residence time of the pond, which in turn has important implications for the type of pond to be constructed. Soil analysis, therefore, is the most important assessment informing pond design. Sandy soils offer greater permeability and so are more appropriate for detention ponds; clay soils are less permeable and more appropriate for retention ponds (Lemus, et al. 2003). If the soils are determined to be particularly porous, pond design may need to account for the possibility that soluble chemicals such as nitrate and chloride may leach through the soils into groundwater.

A hydrological assessment is also crucial because the potential rate and volume of runoff to be directed into the pond determine the pond's minimum size and volume and the amount of runoff that may need to be released from the pond.

The landscape contours of the immediate site determine how much engineering will be required to create a pond with the desired volume and function. A steeper site will require a taller impounding embankment; in a relatively flat site much of the pond volume can be created through excavation. The relative steepness of the slopes perpendicular to the main slope are an important factor as well because they affect the length of the impounding embankment. These basic characteristics of the site must be surveyed prior to creating a design for the pond.

Seasonality

As with most restoration projects in California, actual construction of the pond should be completed during the dry season from late spring to early autumn.

Expertise Needed

Hydrologist. As noted above, it is necessary for a hydrologist to assess the proposed pond's catchment area and its runoff potential. A hydrologist may also help determine how best to manage the water levels in a retention pond.

Biologist. If sensitive species may be impacted by pond construction or operation, or if growth of invasive species is anticipated to be a problem, a biologist may be needed to provide guidance on mitigating these concerns.

Botanist. A person with expertise in native plants can help to design more natural conditions and promote better water quality benefits.

Photo P4.2 Expertise is important for designing stormwater storage ponds.

Engineer. An engineer provides valuable input on pond design, particularly as it applies to the pond's impoundment barrier and outflow. An engineer may help direct pond excavation, construction of the impounding embankment, and installation of the drainage and outlet devices.

Implementation

Design

Pond size (surface area and volume) is a primary design issue. Storage pond volume must account for small but frequent annual storms and larger 10- to 20-year storm events, and do so in the specific context of the pond's catchment area. Storage ponds are often shallow (3–9 feet deep), in part to allow for more rooted wetland vegetation around the perimeter. The depth of the pond's pooled water is determined by the elevation of the outlet above the basin floor at the far end of the pool. The recommended length-to-width ratio is 3:1 to allow for level spreading of water over the entire basin (Lemus, Devinney et al. 2003). It should be noted that ponds designed to effectively contain and treat pollutants from first-flush scenarios may need to hold considerably higher volumes of water than previously thought (Sansalone and Christina 2004).

A stormwater storage pond is typically built with three distinct volume levels. The top level should have the storage capacity to manage large, infrequent storms (10-, 25-, or 100-year). The middle level or "water quality" level is designed to hold runoff from smaller storms for a period of time that allows pollutants to settle out and be removed. The third or bottom level can be designed to be either a permanent storage pond or to be seasonally dry.

Pond shape, surrounding vegetation, and optional enhancements are additional design considerations. Long, narrow ponds or wedge-shaped ponds are the preferred shapes for extending settling time and improving water quality of streams downslope. The vegetation around the pond helps remove pollutants and provides habitat. Additionally, creating a forebay, an area of the pond that is more easily and regularly maintained, can reduce the build-up of pollutants in the rest of the pond, improving habitat function and extending the pond's useful lifetime.

The steepness of a storage pond's sides is another important design consideration. The selected slope must balance ease of access, available space, and erosion potential. The side slopes of storage ponds should be no steeper than 3 units in the horizontal to 1 unit in the vertical. Gently sloping sides encourage vegetation in the shallower areas of the pond and provide rearing habitat for aquatic larvae. Flatter slopes also allow for easy access for maintenance and protect the sides from erosion during large storm flow events. However,

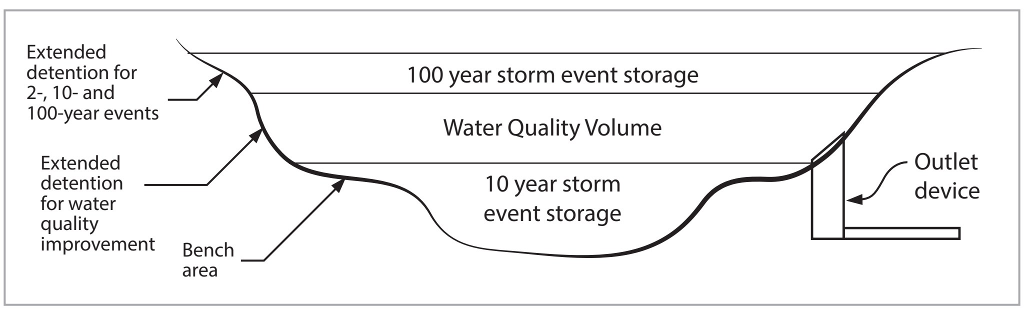

Figure P4.3 Cross sectional design of a typical stormwater storage pond (from Pitt 1996).

in cases where space is limited, side slopes may need to be relatively steep to create a larger storage volume. In urban settings, vertical concrete retaining walls may be used, although this does not allow for rooted vegetation. If rooted vegetation is not possible, non-rooted vegetation may be retained around the perimeter.

It is important that the downslope embankment or dam impounding the stormwater be properly designed. It must, first of all, be capable of holding the pond's maximum volume without any risk of failure. This is a minor concern for ponds on relatively flat slopes constructed primarily through excavation, but the steeper the slope and the more that fill from the excavation is used to create a dam that increases pond volume, the more attention must be given to the integrity and strength of the impounding embankment. A related issue is the design of the pond outflow and emergency spillway; they must together be capable of handling the maximum anticipated volume of overflow without causing downslope/downstream erosion. The level of water in the pond must not be capable of rising high enough to overtop the impounding embankment, because this could cause it to quickly erode and fail.

Materials

The materials needed to create a typical stormwater storage pond are piping and other materials for the outflow, riprap for reinforcing embankments, and concrete or riprap for the spillway. Many ponds will also incorporate aquatic plants, terrestrial plants for landscaping around the pond, and imported earth/rock material for construction or reinforcement of the impounding embankment. Some ponds (e.g., retention ponds in sites with sandy soil) will need lining materials.

Adaptive Management

Monitoring

Whether monitoring is part of a stormwater storage pond project or not depends on the goals and objectives of the stormwater management plan and the role of the pond within that plan or another restoration or management plan. Since a stormwater storage pond is usually intended to protect the water quality of a stream or wetland not in the immediate vicinity of the pond, the most relevant environmental monitoring would occur in that stream or wetland. Data from this monitoring might then inform adaptive management of the pond. If a goal of the pond is to create new wetland habitat, then the pond itself might require monitoring in order to assess how it is meeting that habitat goal.

Maintenance

Because they are designed to trap sediment, stormwater storage ponds will gradually fill with sediment. Sediment build-up greatly reduces the efficacy of a retention pond. Monitoring sedimentation and minimizing sediment inflow are therefore two primary maintenance activities. Regular maintenance and sediment removal ensures better performance and extends the useful life of a pond. Studies suggest a need for inspections at least as frequently as every two years (U. of Minnesota 2015).

A maintenance plan should include inspection for and removal of rotting plants, debris, and invasive or nuisance pests. Regular repairs to the sides and bottoms prolong the life of a pond. In addition there should be an established schedule for mowing, plant and sediment removal, and regular cleaning to insure unobstructed flow. Mosquito abatement may be necessary.

Ponds designed as retention ponds may require supplemental water to counter evaporation during dry periods. In the case of detention ponds, is important to mimic natural hydroperiods to provide habitat that favors native aquatic and semi-aquatic wildlife.

Table P4.4 Typical maintenance activities for dry ponds

Activity	Schedule
Assess erosion of pond banks	Semiannual
• Inspect for damage to the impounding embankment • Monitor sediment accumulation in the facility and forebay • Examine to ensure that inlet and outlet devices are free of debris and operational	Annual
Repair undercut or eroded areas Mow side slopes Manage input of pesticides and nutrients Remove litter and debris	Standard maintenance
Seed or sod to restore dead or damaged ground cover	Annual, as needed
Remove sediment from the forebay	Every 5 to 7 years
Remove sediment when the pond volume has been reduced by 25 percent	After 25 to 50 years

Table modified from Livingston, E., et al. 1997.

Potential Concerns

Negative impacts to wildlife. Stormwater storage ponds may benefit or harm sensitive species, depending on their design and management. To avoid detrimental impacts, ponds should be designed so that construction and management measures avoid negative impacts to species. Stormwater storage ponds offer the greatest benefits if operated like ponds found in the vicinity. The further the pond moves away from these local natural conditions, the greater the potential for doing harm. A survey of ponds in the vicinity identifies species that are likely to be attracted to the newly created pond. Management plans that involve seasonal draining or infrequent dredging must consider the life history of species that are predicted to use the pond.

Attraction of pest species. Stormwater storage ponds that hold water for longer periods of time risk attracting pest species such as mosquitoes. Mosquito control can be addressed through proper design and maintenance of these ponds. During the planning stage, local vector control agencies should be consulted as they understand the highly variable regional issues associated with mosquito control. In general, mosquito breeding potential depends on the depth and location of standing water. Design and maintenance manuals contain recommendations for minimum pool depths and suggest how to create habitat for mosquito predators such as dragonflies (Lemus, et al. 2003).

Anoxic conditions. In retention ponds where water sits for extended periods and nutrient levels are sufficient, conditions can promote the growth of algae. While algae may benefit some species, if left unmanaged it can bloom, creating anoxic conditions and nuisance odors. The potential for algal blooms may be reduced by limiting the pond's nutrient input and managing the pond's aquatic ecosystem to ensure the presence of algae-consuming organisms. If these strategies are inadequate, it may be necessary to introduce air to the bottom of the pond to oxygenate the water and encourage mixing.

Flooding. During heavy flow periods, stormwater storage ponds may fill too rapidly to contain the volume. Flooding can occur if the pond overflows in an uncontrolled manner or the impounding embankment fails. This risk is minimized by employing experts in hydrological analysis and engineering during the planning and design phases. A properly designed impounding embankment includes an emergency spillway that can handle unusually large volumes of water (such as those generated by 100-year flooding event) and prevent overtopping of the embankment.

Habitat damage. During pond construction, heavy ground moving equipment may be used; the resulting disturbance can present risks to the surrounding area and species. Careful advance planning that accounts for the specifics of site access can minimize this damage. If sensitive species may be present, it is important to survey for them and undertake appropriate mitigation steps.

Photo P4.5 Stormwater pond Photo: ESNERR

Contaminant accumulation. As stormwater flows over the landscape, it can accumulate various pollutants and nutrients. As it passes through urban areas, stormwater can capture oil, chemicals, and trash. Stormwater flowing from agricultural fields often contains nutrients from fertilizers as well as pesticides. Stormwater storage ponds are designed to allow these materials to settle out of the water or be absorbed by plants. Over time, these materials will accumulate in pond sediment. At the very least, this means that when sediments are removed from the pond for maintenance purposes, the potential load of toxics must be accounted for. Some contaminants, such as mercury, do not remain inert but are instead incorporated into the aquatic food chain and bio-accumulate in living tissue; this presents a different set of management issues.

Human safety risks. Finally, there is the potential risk to human life associated with open water. Drowning, while rare, may occur in ponds, especially when they are located near urban areas. It is recommended that exclusionary fencing and informative signage be placed near and around all ponds. A gradual slope around a pond eases maintenance access and limits the risk of people accidentally falling into the pond.

Costs

The costs associated with the creation of stormwater storage ponds vary greatly between sites and projects. Detention ponds tend to be less expensive than retention ponds because they are often smaller. Cost estimates should consider all phases: planning, design, implementation, and adaptive management. Annual maintenance costs typically equal 3–5% of construction cost.

One study (Brown and Schueler 1997) evaluated the costs associated with creating stormwater storage ponds. Their findings, which should be adjusted for inflation, are presented in Table P4.6.

Table P4.6 Estimated costs for construction of detention and retention ponds of varying volume

	Detention Pond	Retention Pond
1 acre-foot	$41,600	$45,700
10 acre-feet	$239,000	$232,000
100 acre-feet	$1,380,000	$1,170,000
Formula for cost calculation*	C = 12.4V0.760	C = 24.5V0.705

*Where C = construction, design, and permitting cost and V = volume needed to control the 10-year storm (ft^3). Data from Brown and Schueler 1997.

Related Resources

- The Stormwater Mitigation paper (Lemus, et al. 2003) is an excellent resource for suppliers and designs for storage ponds.
- *The Minnesota Urban Small Sites BMP Manual* (Metropolitan Council 2001) provides guidance on design and maintenance of stormwater storage ponds.
- The Society of Wetland Scientists' paper on mosquito control in wetland management (Megonigal, 2009) provides an overview of the biological context for mosquito control and reviews tools and techniques available to wetland managers to control mosquitoes.

Case Study

Pajaro Valley High School Stormwater Detention Basin

Pajaro Valley Unified School District, City of Watsonville
Watsonville Wetlands Watch

Pajaro Valley High School is a high school located within the Watsonville Slough System watershed, a large and significant predominately freshwater slough system on the California coast. The school opened in 2005 and due to its location within the Coastal Zone and adjacent to sensitive wetland and associated upland habitat, several conditions were placed on the school. One condition was the creation of a series of stormwater detention basins (ponds) along the drainage corridor within which all of the stormwater runoff from the school passes prior to draining into sensitive habitat areas. The project serves as a model for school site stormwater management.

Implementation

All of the drainage from the school is directed to an underground network of drainage pipes that lead to the series of five stormwater detention basins. This includes a series of French drains located within grassed median strips in the school's parking area. Stormwater collects in each basin and then overflows into the next until it reaches the final basin, where it must pass through a carbon filter. Native plants have been planted around the detention basins in order to add natural habitat to the school site and provide an aesthetically pleasing demonstration of low water use landscaping within the school campus. Once the storm water leaves the campus it flows into West Struve Slough, which is part of a wildlife preserve owned by the California Department of Fish and Wildlife. Students have worked with the non-profit involved in this project, Watsonville Wetlands Watch, to install a 1-acre grassed waterway with over 5,000 native plants that provides additional filtration and soil stabilization downstream of the final detention basin.

Results

Water-quality testing conducted by the school district has shown that the water leaving the school is of good quality. Additional water quality testing at the top of the "post-treatment" grassed waterway and bottom of the waterway show additional nutrient and bacteria remediation benefits, with over 90% of total coliform and approximately 50% of nitrates removed. Native habitat has grown in at the entrance to the school, providing an aesthetically pleasing demonstration and learning site for students and the community to better understand stormwater treatment options and the importance of proper handling of stormwater.

For more information, visit http://www.watsonvillewetlandswatch.org/

Task Checklist

Design the project

- [ ] Contact land owner to discuss restoration work
- [ ] Create a team of experts that include but are not limited to; land owner, environmental consultant, local RCD and/or NRCS staff, contractor……
- [ ] Describe objectives and purpose of restoration work
- [ ] Define adaptive management strategy
- [ ] Account for machine access
- [ ] Create work plan
- [ ] Contact regulatory agency to understand regulations associated with practice
- [ ] Contract with sub-contractors

Analyze the site

- [ ] Conduct soil assessment
- [ ] Conduct biological survey
- [ ] Conduct hydrology study

Prepare site for the creation of a storage pond

- [ ] Clear site of brush
- [ ] Excavate site
- [ ] Grade sides to create optimum slope
- [ ] Line bottom if determined necessary in soil analysis
- [ ] Plant aquatic rooted vegetation
- [ ] Install outflow and emergency spillway
- [ ] Place rock and other reinforcement material
- [ ] Plant banks and spillways with vegetation

Maintenance the first year

- [ ] Remove debris
- [ ] Replant where necessary
- [ ] Mow if needed

Project 5
Creating a Buffer between a Wetland or Riparian Area and Adjacent Agricultural Land

Buffers are vegetated areas separating rivers, streams, creeks, and wetlands from adjacent land subject to intensive human use, usually farming or grazing. The buffer helps protect the natural area from various potential impacts (pollutant run-off, sedimentation, etc.) and may also yield benefits to the agricultural land.

Background

Restoring and protecting sensitive wetland and riparian areas is a top priority amongst restoration practitioners. These environments provide important ecological services such as wildlife habitat, water purification, flood control, and carbon sequestration. When they are adjacent to land used intensively by humans, their ability to provide these services is often compromised. Vegetated buffers can be effective in mitigating these effects.

Benefits

Wetland and riparian buffers can improve water quality by reducing the input of sediments and pollutants. They can reduce erosion, restore and improve wildlife habitat, and increase plant species diversity in the target areas.

Reduces sedimentation. Vegetation in wetland and riparian buffers helps to slow water flow, capturing sediment in runoff from adjoining land uses. In many cases, coarse sediments are removed efficiently in the first 16 to 66 feet of a buffer (Rein 1999; Sheldon, et al. 2005; Reid 2007). Vegetated buffers 80 feet in width reduce suspended sediment by as much as 92% from such high-impact land uses as feedlots (Young et al. 1980).

Reduces phosphorus pollution. Phosphorus is mostly attached to sediment particles, and so it is captured along with sediment (Wenger 1999). Even when a buffer becomes saturated with phosphorus, it can help to regulate the flow of phosphorus and prevent large pulses of the nutrient from reaching wetlands and riparian areas (Wenger 1999).

Reduces nitrogen pollution. Nitrogen contained in runoff is removed as denitrifying bacteria in the soil convert nitrate to nitrogen gas and plants growing in the buffer take up nitrates through their roots. Nitrogen removal efficiencies of 50, 75, and 90 percent have been reported for buffers approximately 10, 92, and 367 feet wide, respectively (Mayer et al. 2005).

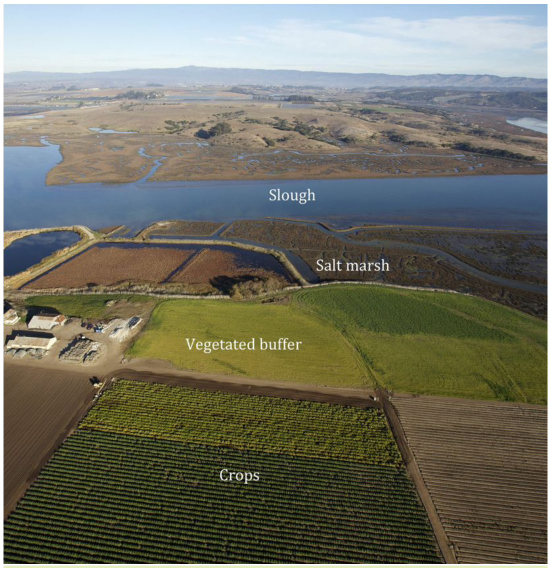

Photo P5.1 Riparian buffer adjacent to agricultural area. Photo Keith Ellenbogen

Controls erosion. Buffers can help to control erosion in wetland and riparian areas by minimizing disturbances by humans and livestock. Trampling by livestock can reduce vegetation cover in riparian areas, leading to bank erosion. Varied vegetation structure (i.e., dense thickets, trees, briars) in a buffer physically blocks livestock access to wetlands and riparian areas, controlling erosion (Chase, Deming et al. 1995).

Improves habitats for multiple species. Wetland and riparian buffers protect and expand vegetation, protecting plants within and alongside these habitats, leading to expanded habitat area for many species. Vegetation in a buffer can add structural elements that provide refuge and nesting habitats (Castelle, Conolly et al. 1992) for both birds and terrestrial mammals. Many semi-aquatic species depend on the mesic ecotones surrounding wetlands and riparian areas for resting and basking as well as nesting and refugia. Riparian buffers improve aquatic habitat for fish and invertebrates by shading, which helps to cool water (Castelle, Conolly et al. 1992).

Planning

The decision to create a wetland or riparian buffer is normally the result of a comprehensive watershed management planning process intended to reduce point and non-point sources of pollutants (Mayer et al. 2005). Whether or not such a watershed plan exists, initial planning for the creation of a buffer should be a collaborative process involving the managers of the site as well as the landowners and focusing on developing a set of goals and objectives based on the available science.

Advance Analysis

Site Assessment

Buffer creation begins with assessment of the soil-related, hydrological, and biological conditions of the site. An inventory of existing conditions is essential for informing the objectives-setting phase of project planning. Overall goals and perhaps even objectives may have been determined by the earlier watershed planning phase (when a buffer was determined to be appropriate) but objectives are often refined as assessment of the site conditions reveals more information.

A biotic inventory identifies specific conservation concerns at the site; these in turn help to determine the optimal width of the buffer and other design considerations. An assessment of existing ecosystem functions also helps to determine the potential for the site to support various species that could be considered in a buffer planting. In addition, assessment of potential erosion and human/livestock disturbances is important. Soil inventories inform vegetation restoration potential as well as the potential for runoff filtration and infiltration.

Expertise Needed

Botanist. Appropriate plant choice is critical to the successful creation of riparian buffers. A trained botanist selects plants appropriate for the site and for meeting restoration objectives and water quality goals. He or she also considers how plant choices affect maintenance costs over the long run.

Photo P5.2 Volunteers planting native grasses Photo: ESNERR

Wildlife biologist. Wildlife biologists are critical in determining the species present and defining their needs in relationship to the buffer. Breeding, foraging, and migrating needs are important considerations when protecting and creating habitat with a riparian/wetland buffer.

Soils expert. A soils expert assesses the potential for sediment erosion along streambanks, the potential for pollutant runoff from stormwater and irrigation, and the permeability and stability of the soils. These factors have an important bearing on buffer width.

Engineer. The use of filter strips requires an engineer's assistance to calculate hydrologic factors associated with nutrient uptake.

Seasonality

Planting of new vegetation in the buffer should be done at a time of year when the survival rates and growth of the plants will be maximized (NRCS 2007).

Implementation

Design

The key design factor for a buffer is its width. Because buffers can become saturated with sediments and nutrients, gradually reducing their effectiveness, wider buffers are more effective over the long run. Locations with high sediment loads and steep slopes may also require wider buffers, all other things being equal, as the sediment removal efficiency of buffers decreases as slope increases (Wenger 1999; Sheldon, et al. 2005). The most effective buffers are at least 30 meters (98 feet) wide (Wenger 2000).

Depending on site conditions, much of the sediment and nutrient removal may occur within the first 15–30 feet of the buffer, but buffers 30–100 feet or more in width can remove pollutants more consistently (Dillaha, et al. 1988; Dillaha 1989; Magette, et al. 1989; Schoonover 2006). A minimum of 50 feet is recommended for effective nitrogen removal, depending on the soils (Wenger 1999). Phosphorous can be removed within the first 15 to 30 feet of a buffer, but it is more consistently removed by buffers of 30 to 100 feet (Dillaha, et al. 1988; Dillaha 1989; Kuusemets 2001; Lowrence 2005; Syverson 2005).

When wildlife conservation is the primary goal, wider is always better. However, different types of animals have been shown to have different requirements (see Table P5.3). Effective buffer sizes for wildlife protection may range from 33 to 5,000 feet, depending on the species (Environmental Law Institute 2003).

Table P5.3. Ideal buffer widths for different taxonomic groups

	Buffer Width
Birds	49 to 5,000+ feet (Fischer 2000)
Mammals	98 to 600 feet (McElfish 2003)
Reptiles	417 to 948 feet (Semlitsch 2003)
Amphibians	521 to 951 feet (Semlitsch 2003)

Source: Environmental Law Institute 2003

A second key design consideration is the vegetation of the buffer. The type of vegetation to be planted is generally considered in terms of zonation. Riparian buffers are usually defined as having three zones: Zone 1 begins at the water's edge; Zone 3 is immediately adjacent to the surrounding land use; and Zone 2 is the area in between the two. Each zone is typically planted with different types of plants, and the width of each is determined by the desired functions of the buffer and other site-specific factors. Figure P5.4 illustrates a typical zonation scheme. To the extent possible, each zone should be composed of native vegetation.

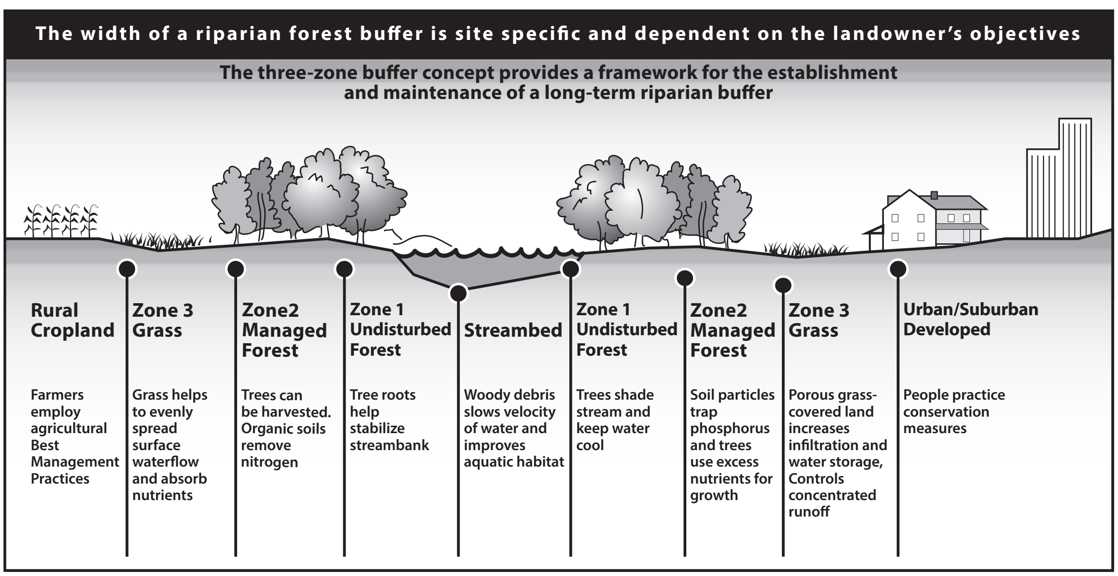

Figure P5.4 Buffer zones. (Source: Tjaden, R.L. and Weber, G.M. 1998)

Not all components of a buffer's vegetation need to be planted. Many plants will establish naturally, dispersed from upstream sources of seeds or other propagules. If the plan calls for relying on natural regeneration to establish a buffer, it is necessary to first assess the regeneration potential of the site.

Many buffer designs involve only planting of seedlings, sowing of seeds, and/or natural revegetation. However, some sites and designs will require engineering work (possibly with heavy equipment), soil manipulation, installation of fencing, or removal of invasive species.

Materials

The primary materials used in creating a buffer are the trees, shrubs, grasses, and forbs planted in the area of the buffer. As noted above, a qualified botanist should assist in the selection of the appropriate native plants for the site. Appropriateness is a function of site characteristics, restoration goals, and the type of vegetation that was present in the area before human disturbance. It is recommended that practitioners refer to the *Revegetation with Native Plants* discussion in Chapter 1.

Adaptive Management

Monitoring

Post-implementation monitoring will vary depending on the goals and objectives of the project. Since improvement of water quality is a typical goal of a buffer project, water-quality monitoring is a common focus. When a riparian area or wetland is being buffered from agricultural or grazing land, monitoring of water quality should include regular testing of nitrate and phosphorus levels. As noted in the *Monitoring* section of Chapter 3, the monitoring plan should be based on the goals and objectives of the project, and it should establish a regular schedule of monitoring activities. As with any restoration project, a pre-implementation assessment of baseline conditions provides an important reference point for evaluating monitoring data and project success.

Maintenance

The maintenance required for a buffer project can be extensive. It may be necessary to replace trees or shrubs that die, irrigate plantings until they are well established, remove storm debris, and control invasive plants. Watering new plantings and removing invasive weeds are the primary maintenance requirements for restored riparian buffers. Ongoing maintenance for buffers may also include selective cutting and/or pruning and mowing. Riparian buffer areas should not be mowed frequently—only about once per year for newly created buffer areas. Existing, mature riparian areas require no mowing at all. If a fence is installed to prohibit tractors and other farm equipment from entering the buffer, it will need to be maintained. Provision should be made for unscheduled inspections after storm events. If saturation with phosphorus becomes an issue, harvesting vegetation from buffer areas can help to permanently remove some phosphorus from the system (Wenger 1999).

Potential Concerns

Introduction of invasive and exotic species. Buffer creation requires planting large areas of grasses and other vegetation along sensitive riparian habitat; this activity carries the risk of introducing invasive and or exotic species into the system. To reduce this risk, use only reputable sources of seed and seedlings, and always plant natives.

Predators gaining access to nesting and foraging habitat. Generalist predators, like cowbirds, ravens, and raccoons, may inhabit buffer areas and move from them into sensitive riparian and wetland habitats, preying on nestlings, amphibians, and other animals. To mitigate this concern, restoration practitioners can provide appropriate refuge habitat within the buffer that offers cover and forage areas for sensitive species.

Accumulation of fuel. If left unmanaged, buffers can become overgrown and dense with accumulated fuel, both living and dead. Fire safety demands that restoration practitioners collaborate with landowners to develop a fire management plan during the planning phase. A fire safety plan consists of scheduled manual thinning and seasonal removal of dead vegetation. It may also incorporate a livestock management plan to assist with fire fuel control. There may be additional recommendations and requirements available through regional fire management agencies and these should be sought out.

Flooding hazards. Trees growing adjacent to a stream may be felled by erosion, wind, or ice, potentially blocking the stream and causing flooding. This potential flood hazard can be avoided with proper choice of trees planted during the implementation phase. Restoration practitioners should avoid selecting trees that grow too large and lack proper root growth to support their size. As part of a thorough management plan, buffer zones should be periodically monitored for weakened and fallen trees after large storm events (Griggs 2009).

Costs

Costs associated with creating a riparian buffer vary depending on the size of the buffer, the type of planting, and the scope of the long-term maintenance and monitoring plan. Costs are incurred for site preparation, plants, other materials, labor, and maintenance (Lynch 2000).

The land area to be converted to a buffer affects the quantity of plants required and the labor needed. Defining buffer goals in advance allows the restoration practitioner to determine the buffer size that meets those goals while remaining within a budget.

Maintenance and planting costs increase with the size of the buffer but are greatly affected by the type of buffer. Forested buffers cost more than simple grass buffers to maintain; they also require more site preparation, involve higher costs for the plants themselves, and are more labor intensive to implement. Additionally, forested buffers require some degree of replanting to account for tree loss in the first year (Lynch 2000).

Table P5.5. Estimated costs per acre of two buffer types.

Tree-dominated buffer, 400-600 trees			Grass-dominated buffer	
	Cost per acre			Cost per acre
Planting by machine	$75–130		Planting	$10–50
Planting by hand	$60–174		Seeds	$100–225
Plant material	$60–275		Site preparation	$18–40
Herbicides for site preparation	$110–170		Fertilizer/lime	$30–50
Replanting	$30-50		Maintenance	$10–60
Herbicides for maintenance	$30–60			
Mowing	$12–60			
TOTAL	$218–729		TOTAL	$168–400

Photo P5.6 Agricultural Buffer Photo: Ken Collins

Related Resources

The California Landowners Incentive Program (LIP) is a voluntary, incentive-based program that provides funding to cover some of the costs associated with restoring riparian buffers. The program is managed by the California Department of Fish & Wildlife. Technical assistance is also available through this program (State of California 2007).

- NRCS Field Office Technical Guide (eFOTG), Section IV, Conservation Practice Standard—Riparian Forest Buffer, 391.
- NRCS National Forestry Handbook (NFH), Part 636.4.
- NRCS National Environmental Compliance Handbook.
- NRCS Cultural Resources Handbook.
- The River Partners, California Riparian Restoration Handbook, additional budget planning guidelines associated with riparian restoration work (Griggs 2009).
- The Wetlands-At-Risk Protection Tool (WARPT), developed by the Center for Watershed Protection under cooperative agreement with the U.S. EPA, Office of Wetlands, Oceans and Watersheds. Visit online to access these tools, each of which includes case studies: http://wetlandprotection.org/protect-wetlands.html

Case Study

An Economic Analysis of Vegetative Buffer Strip Implementation

Elkhorn Slough, Monterey Bay, California

The Elkhorn Slough Estuarine Reserve, located on the Monterey Bay in California, protects a highly impacted estuary surrounded by strawberry growers and a dairy. Approximately 10,000 of the 44,900 acres of the estuary's watershed are in agricultural production; strawberries are grown on 3,600 of these acres, and the farming methods typically result in significant soil erosion. In 1999, The Nature Conservancy (TNC), in coordination with the Agricultural Land Trust and the Elkhorn Slough Foundation, implemented buffer strips on the reserve at a ratio of 1 acre of buffer to every 35 acres of strawberry field. The goal of the research project was to evaluate the environmental costs and benefits of implementing these buffers, considered from the perspective of the grower and of the society as a whole.

Implementation

The study (Rein 1999) was conducted in two parts. The first analyzed the quantifiable costs and benefits to the farmer, and the second assessed the benefits to the watershed and to society.

Results

Buffers result in several costs to the grower: agricultural revenue is lost from the acreage converted to buffer and costs are incurred in installing and maintaining the buffer. These costs, however, were found to be minimal in comparison to the money saved in minimizing erosion of farmland. The first year of the study saw a total cost to the grower of $1,850 per acre and a soil-saving benefit estimated to be $3,338 per acre. This result represents a net benefit of $1,488 per acre. By the 5th year of the study, the net benefit to the grower was $6,171 per acre.

Data from the second part of the study showed a significant reduction in sediment runoff due to buffer implementation. The reduction in sediment runoff translated to cost savings to society in the form of reduced road repair, reduced culvert repair, reduced harbor dredging, improved water quality, flood control, and mosquito abatement.

The overall environmental benefits of buffers—improved water quality, erosion control, and habitat improvement—coupled with the reduction of costs to growers and society suggest that creating buffers between agricultural land and wetlands is worthwhile and advantageous to all parties.

Task Checklist

Design the project

- ☐ Contact landowner to discuss work
- ☐ Create a team of experts
- ☐ Describe objectives and purpose of restoration work
- ☐ Design buffer to accommodate anticipated slope and soil type
- ☐ Determine the appropriate width for the buffer based on objectives of the project
- ☐ Create work plan
- ☐ Contact regulatory agency to understand pertinent regulations
- ☐ Contract with sub-contractors

Analyze the site

- ☐ Conduct soil assessment
- ☐ Conduct biological survey
- ☐ Conduct hydrology study
- ☐ Conduct cultural assessment

Prepare site for planting

- ☐ Till, smooth, and amend soil as necessary
- ☐ Remove invasive plants
- ☐ Make provision for irrigation
- ☐ Consider wildlife corridors
- ☐ Choose appropriate plants
- ☐ Identify planting supervisor
- ☐ Organize planting either with hired crew or volunteers

Plant

- ☐ Sow seed via broadcast or drill
- ☐ Plant seedlings
- ☐ Mulch
- ☐ Irrigate

Maintenance the first year

- ☐ Mow several times
- ☐ Maintain original width and depth of planted area
- ☐ Control weeds
- ☐ Exclude livestock and vehicles
- ☐ Replant where necessary

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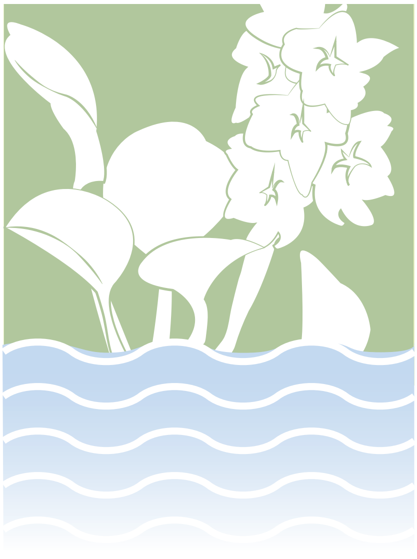
Project 6
Installing Structures for Managing the Water Level of a Wetland

Wetland water-level management structures are used to restore natural hydrological processes, ensuring that water flows with the desired volume and periodicity and that water levels support management goals.



Background

Human development in the watershed associated with a wetland, as well as disturbance of the wetland itself, may alter its natural hydrology, thereby degrading its habitat values and reducing its ability to improve water quality and provide other ecosystem services. Gaining the ability to manage the water level of wetlands affected in this way allows managers to mitigate or compensate for changes in wetland hydrology.

Benefits

Depending on which of its ecological functions have been compromised, a wetland can benefit in a variety of ways from the installation of water-level management structures.

Improves water quality. Water-level control has been shown to be a crucial factor in the reduction of pollutants in wetlands managed for water quality improvement (Garcia et al. 2005). Water-level control structures allow the land manager or restoration practitioner to regulate the rate of flow into and out of a wetland, potentially extending the hydrological period of an area and allowing for greater pollutant and nutrient removal by wetland vegetation.

Aids in flood control. Proper use of water-level control structures allows for seasonal flood control in sensitive wetland habitat.

Recharges ground water. Water control structures may be used to slow and reroute the runoff during rainy seasons to areas in need of recharge. In the coming years, the need for managed ground water recharge will increase due to climatic changes and increased groundwater use.

Aids in the recovery of wildlife and plant populations. Water-level management structures allow managers to create or maintain the conditions that promote particular plant communities or wildlife populations (Hammer 1997). Maintaining shallow water depth, for example, promotes upland game and waterfowl (Maul 1997; Elphick 2003), while deeper water allows some species (e.g., the California red-legged frog) to escape predation. Controlled flooding allows for fish movement into wetlands for spawning and provides rich nursery habitat for fry.

Controls undesired species. Wetland water-level management structures can provide various means for controlling undesired species. They can be used as physical barriers to prevent nuisance species from entering the system from downstream. By allowing draw-down of wetlands, they can enable managers to reduce the hydroperiod, favoring species (typically natives) that can survive a shorter period of inundation. Reducing the hydroperiod can be an important means of eliminating bullfrogs and non-native fish, for example (Adams and Pearl 2007). Draw-down can also provide managers access for more active elimination of species.

Planning

Successful installation and use of wetland water-level management structures requires restoration planning, informed design and installation, and oversight by an appropriate team of experts.

Because their effects may be far-reaching, wetland water-level management structures should be installed only after the preparation of a comprehensive restoration plan that considers all aspects of the proposed project. A wetland restoration plan typically includes an assessment of the site's hydrology, soils, and biotic features; this assessment then informs restoration goals and the specific water-level management strategies that will be used to pursue the goals.

Different wetland restoration goals require different hydrological management strategies. It may not be possible to pursue all goals at the same time, and not all goals require water-level management structures. To recover wildlife and plant populations, it is often necessary to emulate the natural hydrology of wetlands, accounting for California's historically Mediterranean climate as well as the seasonal rain patterns specific to the region (Pacific Estuarine Research Laboratory 1990). To improve water quality, adequate water flow and depth are important considerations (Garcia et al. 2005). It is important, therefore, to have a clear idea of your restoration and conservation goals before implementing the project.

Table P6.1 provides an example of how different management strategies can have widely varying effects on a wetland's value as habitat.

Table P6.1 Wetland habitat values associated with various summer water levels

	Summer water level		
	Moist soil (mudflat)	15 cm	> 30 cm
Plant species diversity	fair	excellent	fair
Wildlife use and diversity	fair	excellent	good
Fish abundance	none	good	excellent
Migratory bird use	excellent	good	fair
Invasion by nuisance species	high	low	low

Table adapted from Mitsch and Gosselink 1993.

Advance Analysis

Site Assessment

If the initial restoration planning process determines the need for wetland water-level management structures, a detailed site analysis is needed to inform structure design. In all cases, engineering calculations are necessary, and biotic concerns such as fish passage are often also a concern (Mitsch 1993). A soils assessment is also important as only hydric soils have the capacity to hold water on or near the ground surface for at least a portion of the year (Zelek 1999). Hydric soils form over a long period of time and are very difficult to create. For this reason, wetland water-level management structures are generally successful in restoring wetlands only where these special soils are present (Sargent 1999). However, when hydric soils are absent, clay or synthetic liners can be installed to increase the hydroperiod.

Revegetation

Revegetation often accompanies the installation of water-level management structures in a wetland. Refer to the *Revegetation with Native Plants* section in Chapter 1.

Expertise Needed

Hydrologist. A hydrologist should perform a baseline assessment and a hydrological analysis. Expertise in predictive modeling is important given that this project is designed to create changes in hydrology.

Biologist. A biologist familiar with the affected aquatic biota should perform a baseline analysis of desired and undesired species and determine the best course of action given biotic targets. Expertise in aquatic ecosystems is important; in some cases expertise in the species being targeted for restoration or control is also important.

Water Quality Scientist. If improvement of water quality is a primary goal, a water quality scientist can assist with understanding baseline conditions and factors to consider in designing the project to improve water quality. If a specific water quality impairment is targeted, the scientist should be familiar with the appropriate management and monitoring measures.

Engineer. An engineer works closely with the project hydrologist to design the structure and advise on its installation. Experience with wetland water-level control structures and regional hydrological patterns is advisable.

Implementation

Management goals and the characteristics of the specific site determine the type of structure to be installed; they also determine to some extent the structure's design and the materials that may be used.

Design

Water-level management structures are as varied as the wetlands in which they are installed. Core aspects of their design, however, are fairly consistent. A water-level control structure generally consists of some kind of barrier (a berm or levee) in which there is embedded a gate-like means for allowing water to penetrate the barrier. They are often employed in pairs, with one controlling the input of water into the wetland and another the output.

Traditional floodgates. These are simple systems that can be hinged at the ends of culverts or headwalls to allow flow of water in a single direction. The opening and closing of floodgates is dependent on changes of the water level caused by rainfall, floods, or tidal fluctuations. Floodgates are effective in managing the impacts of minor floods and may be used to drain low-lying wetlands, but they also can have serious environmental impacts if not managed properly.

Manually operated floodgate modifications. Winching systems, penstocks, and sluice gates can be added to the ends of culverts to allow for manual regulation of water flow. These modified floodgates provide for excellent water-level control and flood protection. They are reliable, adjustable, and require low maintenance. Depending on the design and materials they can be expensive.

Photo P6.2 Tide gate Photo: ESNERR

Weirs. Weirs are retention structures that require no adjustment after installation. Weir retention structures can guarantee a minimum water level in the system behind the structure to satisfy management objectives such as rehabilitating wetlands. Water control gates can be installed to allow fish passage. Sheet pilling weirs are an excellent design for use in sensitive environments where minimal disturbance to the system is required.

Adjustable water retention structures. Flashboard riser water-level control structures, with their increase-decrease style of incremental movable boards, have been used for centuries to control water levels in ponds, wetlands, and marshes. The movable board or log systems are ideal for adjusting the water level of small ponds or water containment basins. Pre-fab concrete structures offer excellent water control and are easy to adjust, easy to install, and inexpensive. Maintenance is important and structures should be regularly monitored to insure against tampering and vandalism.

Subsurface drainage. Subsurface drainage can be used to bring water from surrounding areas into a wetland. It is appropriate where the soil is permeable enough to allow economical spacing of the drains. A subsurface drain will provide trouble-free service for many years as long as it is carefully planned, properly installed, and constructed of high-quality materials. When planning a subsurface drainage system, make sure that a suitable surface or subsurface outlet is available or can be constructed. Where a surface outlet channel is used, all subsurface drains emptying into the outlet should be protected against erosion, against damage that occurs during periods of submergence, against damage caused by floating debris, and against entry of rodents or other animals.

Additionally, emergency spillways are often installed in existing or created berms or levees for water drainage during flood events. Spillway design and size will depend on the surrounding watershed and the total acreage of impounded wetland.

Essential to water level management is choosing the correct placement of a water control structure. Control structures should be positioned at the lowest elevation in a wetland to allow for complete drainage or drawdown if needed. Every wetland restoration is unique in its own way; consequently, landowners must identify the water control system that best suits their project needs and budget. The appropriate size and number of control structures required will often depend on topography, overall size of the wetland, and size of the surrounding watershed.

The Wetlands Engineering Handbook by the Army Corps of Engineers (Hayes 2000) discusses wetland engineering procedures, including design of wetland water-level management structures. Section four of the publication covers geotechnical aspects, describing soil handling and earthwork techniques including excavation and containment of dredged material.

Materials

Cost and durability are factors to consider in choosing materials, but types of materials are determined primarily by the type of control structure being installed.

Spillways. Spillways can consist of pipes; they can also be constructed from concrete or rock and turf-reinforcement netting. At a small scale, they can be installed by hand; larger projects may need heavy equipment (see Figure P6.4).


Photo P6.3 Spillway in use during flood

Culverts/Flashboard risers/weirs. Construction involves the installation of a concrete, plastic, or corrugated metal structure that creates a partial blockage to water flow. The center has a gap and each side has railings into which the dropboards are placed. Pre-fabricated concrete sides require heavy lifting equipment to install. The dropboards are of a size that can be managed manually and allow the passage of an appropriate volume of water.

Adaptive Management

Adaptive management planning is best addressed collaboratively; landowners, project managers, and project consultants should be among those involved. The design should take into account long-term site-specific management constraints and the need for long-term monitoring (Natural Resource Conservation Service 2007).

Monitoring

Monitoring targets will be defined by the objectives of the restoration project; they will likely include the status of fish and wildlife populations, the progress of the re-vegetation process, and measures of water quality. Water levels will need to be monitored to inform flashboard heights.

Maintenance

Routine maintenance is required for all water-control structures to maintain proper functioning. Control of inappropriate vegetation growth (especially on spillways), as well as erosion inspection and repair, should be part of a routine maintenance plan. Removing obstructing debris is necessary to avoid flooding and potential damage to structures. A maintenance plan typically includes an established inspection schedule and a protocol for inspection during and immediately following a large storm. Inspections during and after storm events can allow for removal of debris before problems become worse; installing structures to prevent debris impacts can also help (Bradley et al. 2005).

Potential Concerns

Blocked fish passage. Fish passage may be blocked by water control structures that are not placed or managed properly. A hydrological analysis of the wetland and a biological survey that assesses the presence of fish can identify potential issues and allow the project managers and land managers to address these in advance. A hydrologic analysis can determine where to place the structure to insure that fish movement is not impeded (Rampano 2009).

Flooding. Hydrologic analysis of the wetland and adjacent area should be completed during the planning stage to predetermine the potential for flooding. A strategic plan for mitigating this potential should be addressed with those individuals who will be maintaining the structure (Rampano 2009).

Sediment accumulation. As water flows across a wetland, sediment naturally moves and settles out. There is a risk, however, of sediment accumulating in front of water control structures, effectively blocking and compromising them. Filter strips and buffers with proper vegetation can limit the amount of sediment entering a newly created wetland and thus eliminate the potential for excess sediment accumulation at water control structures. These filter strips and vegetated buffers can also provide additional habitat for wildlife.

Costs

Costs associated with the installation of water-level control structures are highly variable and depend upon specific site requirements and desired conservation objectives. The cost of structural design and installation is influenced by many factors, including the need for engineering and scientific analysis, the type of structure, choice of construction materials, size and number of structures, nature of supporting infrastructure, cost of transport, need for erosion control, and on-going maintenance requirements

Installation costs are also be influenced by site accessibility and site conditions. Engineering and scientific advice is required with this project and cannot be overlooked.

Related Resources

- The American Society of Professional Wetland Engineers (American Society of Professional Wetland Engineers 2010) offers information on flashboard risers at: http://wetlandengineering.rcharney.com/index.php/Flashboard_riser_sources

- Wetland water level management structures are reviewed in: Water Control Structures: Design Suitability for Natural Resource Management on Coastal Floodplains (Rampano 2009)

Case Study

Structure for Water Control to Manage Prospect Pond

Ellicott National Wildlife Refuge, Watsonville, California

United States Fish and Wildlife and the Resource Conservation District of Santa Cruz County

Summary

Ellicott Slough National Wildlife Refuge, a 315-acre complex managed by United States Fish and Wildlife Service (USFWS), was acquired to provide vital wetland and upland habitat for a number of migratory birds and terrestrial and amphibian species, including the endangered and state-designated fully protected Santa Cruz Long-toed Salamander (SCLTS), the threatened California Red-legged Frog (CRLF), and the threatened California Tiger Salamander (CTS). In an effort to improve habitat and increase salamander populations on the refuge, Prospect Pond was constructed in 1997. However, the pond failed to retain adequate water throughout the time period needed to ensure salamander metamorphosis from aquatic larvae to terrestrial juveniles.

Implementation

A new pond was constructed in 2012 to improve wetland habitat and fulfill an objective in the 1999 Revised Recovery Plan for the Santa Cruz Long-Toed Salamander: to establish two functional breeding ponds as a measure to recover the species. To ensure adequate water, a 10-foot deep subsurface drain was constructed upslope of the pond to direct subsurface flow. Three water control valves were installed to regulate the amount and timing of this water entering the pond. In addition, a 24-inch high-density polyethylene riser pipe was installed within the pond. The riser pipe ensures that during large rain events, water does not overtop the pond embankment, which could result in structural failure; it also functions in conjunction with a 6-inch PVC pipe running through the berm and a control valve system that regulates water levels within the pond. The latter system allows water to be drained slowly from the pond to promote amphibian metamorphosis or to drain the pond if colonized by non-native fish or bullfrogs.

Results

Amphibian breeding occurred immediately after pond construction in the 2012/2013 winter season. Thirty-five CTS metamorphs were found in April 2013 during aquatic surveys, and nighttime surveys in November 2013 and February 2014 found juvenile CTS moving out of the pond. Given the ongoing drought, wetland management has focused on ensuring that water is retained. The system has not needed to be drained to encourage metamorphosis or to control non-native species.

Task Checklist

Design the project

- [ ] Contact landowner to discuss work
- [ ] Create a team of experts
- [ ] Describe objectives and purpose of restoration work
- [ ] Choose water control structure that allows access for manipulation
- [ ] Choose water control structure based on anticipated management
- [ ] Define adaptive management strategy
- [ ] Contact regulatory agency to understand pertinent regulations
- [ ] Account for machine access
- [ ] Create work plan
- [ ] Contract with sub-contractors

Analyze the site

- [ ] Conduct soil assessment
- [ ] Conduct biological survey
- [ ] Conduct hydrology study
- [ ] Conduct cultural assessment

Revegetate

- [ ] Choose appropriate plants
- [ ] Identify planting supervisor
- [ ] Organize planting either with hired crew or volunteers
- [ ] Sow seeds and plant seedlings as appropriate
- [ ] Mulch
- [ ] Irrigate

Maintenance the first year

- [ ] Regulate water level
- [ ] Remove debris
- [ ] Control invasives
- [ ] Replant where necessary

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