Restoration Field Guide

A USER-FRIENDLY GUIDE FOR RESTORATION TECHNIQUES IN RIPARIAN HABITATS.












A publication from
The Land Conservancy of San Luis Obispo County

Contents

Background

This field guide for riparian restoration techniques, published July 2010, is an outgrowth of habitat restoration projects funded by the Avila Beach Trustee Council, a partnership between the California Department of Fish and Game (CDFG) Office of Spill Prevention and Response (OSPR) and the U.S. Fish and Wildlife Service (USFWS). The Trustee Council oversaw multiple restoration projects associated with the settlement with Unocal over an oil spill in Avila Beach in 1992. The Trustee Council retained the Land Conservancy of San Luis Obispo County to assist in the planning and implementation of projects designed to restore or replace resources damaged by the spill. Between 1999 and 2008, projects were completed that addressed migration barriers for steelhead, streambank stabilization and revegetation, instream habitat for steelhead, and water quality enhancement.

Throughout the restoration projects, the Land Conservancy relied heavily on published guides to develop implementation strategies. These published resources provided extensive information regarding how projects should look when constructed. However, they contained very little information of a practical nature relating to "how" the projects should be built and what potential problems could arise during construction. Project delays caused by accidents, unforeseen problems, and insufficient materials on site make projects more costly and complicated than necessary. They may also cause damage to habitats and injury to people. It was only through the experience gained in the field, or communicated by other experienced restoration managers, that methods were developed to address common problems associated with common project types.

The purpose of this field guide is to share the experiences of the Land Conservancy staff and other restoration organizations gained during implementation of restoration projects so fellow project coordinators can better plan construction projects. It is not intended to be a comprehensive restoration manual, but rather a user-friendly guide to specific field restoration techniques and trouble-saving tips. The concepts presented here are field tested, and will help users prepare for and solve common problems that may arise during a project. This guide will be useful for complex riparian restoration projects, including damaged riparian habitat that may need restoration after emergency response procedures, such as oil spill cleanup in a stream.

The guide is intended to be used as a companion to other authoritative restoration guides, and is primarily geared toward agency personnel responding to emergency situations in riparian areas and the nonprofit partners that are often engaged in the follow-up restoration work. However, even professional restoration specialists may glean valuable tips as they navigate new and challenging projects. The guide assumes that the readers have some elementary knowledge of stream habitats and restoration techniques. The references listed in the literature review include more specific design information than what is discussed in this guide.

The projects upon which these suggestions are based have primarily been in the south central coast area of California (San Luis Obispo County), with some experience from the upper Sacramento River. The habitats on these sites have some bearing on the solutions chosen to share. Some lend themselves better than others to transferring to other parts of the state. Readers are encouraged to adapt some of these recommendations to their own areas rather than depend solely on these recommendations.

About the Authors

Brian Stark has worked throughout San Luis Obispo County on over 30 habitat restoration and watershed planning projects involving stakeholder outreach, watershed enhancement planning, streambank stabilization, fish passage barrier modifications, revegetation, and water quality monitoring. Many of these projects were completed on behalf of the Avila Beach Trustee Council, a partnership of the California Department of Fish and Game (CDFG) Office of Spill Prevention and Response (OSPR) and the U.S. Fish and Wildlife Service. He is the author of the *Final Plan for Restoration Actions Within the San Luis Obispo Creek Watershed; Unocal Oil Spill, Avila Beach, 1992*, and managed the implementation of the projects described in the plan. He has also managed multiple projects for other funding agencies over the last 15 years, including projects associated with another oil spill in Avila Beach. Brian is also the author of the *San Luis Obispo Creek Watershed Enhancement Plan* and the *San Luis Obispo Creek Invasive Species Management Plan for Riparian Areas*, and coordinated the San Luis Obispo County Fish Passage Barrier Priority Project for the California State Coastal Conservancy.

Kaila Dettman managed several projects that arose out of the restoration program that were not in the original restoration plan. She has 7 years of professional restoration experience in California and is a Certified Professional in Erosion and Sediment Control. Prior to joining the Land Conservancy's team she worked on projects along the Sacramento River with Salix Applied Earthcare and prior to that worked for the Vegetation Establishment and Maintenance Study at California Polytechnic State University, San Luis Obispo.

The projects upon which this guide is based were implemented primarily through the Land Conservancy of San Luis Obispo County, a nonprofit land trust serving San Luis Obispo County. The organization has been involved in habitat restoration for over 20 years. Throughout these projects, we have learned a great deal about the field of habitat restoration, including many pitfalls and common challenges associated with working in a riparian system. All of the knowledge we have gained has provided feed back into subsequent projects and greatly streamlined construction. To add to this field guide, we have enlisted the assistance of some of our local partners, as well as our restoration friends from throughout the state. Their tips are also included in this guide to broaden the applicability of this guide to include other parts of California. The tips we share will help readers avoid common mistakes, ensure they have materials onsite to deal with emergencies, and get more high quality work done for less money.

Acknowledgments

When we started this guide, we knew that our experiences were limited by the projects we have had the opportunity to work on. To expand the knowledge base of this guide, we sought the comments of some of our long term partners on restoration projects, as well as some of our fellow restoration professionals from other parts of the state to glean information that will be helpful statewide. We want to thank the many other restoration professionals that have contributed to this field guide by sharing their insights on common restoration challenges.

Dave Highland – Fish Habitat Specialist, California Department of Fish and Game

Meredith Hardy – Fish Habitat Specialist, California Conservation Corps

Phillip LaFollette – Restoration Project Manager, California Conservation Corps

Freddy Otte – Biologist, City of San Luis Obispo

Sydney Temple – Principle, Questa Engineering Corp.

Special thanks go out to the California Department of Fish and Game, Office of Spill Prevention and Response (OSPR). By funding the preparation of this guide they are contributing to the growth of the restoration field, which is relatively new and expanding. The staff from OSPR also placed a great deal of faith and trust in the Land Conservancy of San Luis Obispo County to complete these projects and were our most valuable partner in the restoration of San Luis Obispo Creek.

Literature Review

This section describes existing resources that are commonly used in project design and implementation of riparian habitat restoration projects for streams in California. Each contains valuable information that is necessary for project managers. They are presented in an annotated bibliography format beginning with the most relevant documents.

Gary Flosi, Scott Downie, James Hopelain, Michael Bird, Robert Coey, and Barry Collins. California Salmonid Stream Habitat Restoration Manual, Third Edition. California Department of Fish and Game.

This publication is the most often used restoration guide in California and is essentially a must-read for all who are undertaking fisheries habitat restoration in California. The California Salmonid Stream Habitat Restoration Manual presents a comprehensive set of guidelines that begin with a brief history of the development of restoration programs in California. The documents cited are descriptive of studies that document the losses of steelhead and other salmonids throughout the state and the various prescriptions for improving the state of salmonid fisheries in California.

The Manual continues with detailed information on overall watershed assessment and habitat inventory methods that are essential for project site identification and prioritization. Part II lists the recommended contents for a watershed assessment and some tools, such as maps, photography, and hydrographs for forming a watershed action plan. Natural processes such as erosion are briefly described.

Part III includes information on fisheries sampling methods and data analysis methods so populations can be accurately assessed. This work is usually done in advance of restoration projects as part of a goal-setting and prioritization process. The project planning chapter presents the elements of watershed and project planning, and the implementation chapter provides comprehensive descriptions of varying methods to stabilize streambanks, improve instream habitat, improve migration access for fish, and proper anchoring techniques for structures. The manual also contains a chapter on monitoring and assessment techniques used to evaluate project success.

Appendices in the manual provide more detailed information on various topics including Fish and Game Commission Policies, classifications of streams systems, determining the appropriateness of planting fish, and other legislative findings. Information on the role of hatcheries is also discussed.

The restoration methods described in the California Salmonid Stream Habitat Restoration Manual contain detailed drawings on how projects should be constructed. This discussion, however, does not include information on common problems that occur in the field.

Griggs, Dr. Thomas F. 2008 California Riparian Habitat Restoration Handbook, California Riparian Habitat Joint Venture.

The California Riparian Habitat Joint Venture began in 1994 and is focused on riparian habitats as they relate to California bird species. The goal of this handbook is to provide practitioners, regulators, land managers, planners, and funders with basic strategies and criteria to consider when planning and implementing riparian conservation projects. The information in this handbook is based on experience on river systems in California's Central Valley, but has information that is broadly applicable statewide.

This publication provides a general description of riverine ecology, restoration terms, salmonid life-cycle information, human impacts on riparian systems, and the restoration planning process. There are basic recommendations for the design process for restoration projects along with monitoring protocols and a review of the types of permits required for most projects. The technical methods section discusses project implementation and is formatted from both pro and con perspectives that look at varying practices related to field preparation, planting, irrigation, plant protectors, and labor resources.

USEPA, 2000. Principals for the Ecological Restoration of Aquatic Resources. EPA841-F-00-003. Office of Water (4501F), U.S. Environmental Protection Agency, Washington DC. 4pp. Found online at www.epa.gov/owow/wetlands/restore/principles.html.

This publication provides a list of guiding principles for riparian restoration projects extracted from the common experiences of the Watershed Ecology team, U.S. Environmental Protection Agency (EPA) Office of Wetlands, Oceans, and Watersheds. These principles are broad in nature and represent conceptual approaches to restoration. The publication does not offer specific guidance on individual restoration practices.

***Ecological Restoration, A Tool to Manage Stream Quality* is a manual developed by the U.S. EPA that focuses on stream restoration to improve water quality. The entire manual is online at http://www.epa.gov/owowwtr1/watershed/restdoc.html. Ch. 6 has specific case studies. http://www.epa.gov/OWOW/NPS/Ecology/**

The EPA manual is based more on practices used to protect and enhance water quality than fisheries habitat, but the practices that are promoted are consistent with improving habitat through restoration techniques. The manual defines restoration, discusses the regulatory framework of water quality legislation establishes the links between restoration projects and water quality impacts, provides a decision-making guide for practitioners, an outline for watershed assessment, and has a section on monitoring.

In their guide, the EPA states an important realization in the restoration field, that “restoration is not yet a perfected approach with accurate and precise predictive capabilities and, in fact, is still an exercise in approximation. Additionally, because ecological systems are complex and may take years to reach equilibrium or fully demonstrate the effects of restoration and other management activities, seeing or measuring results of restoration efforts may take a long time.” The EPA manual also recommends an ecological approach to restoration and acknowledges that often times the solutions to stream problems may be multifaceted.

Certain techniques are described in the appendices in a general form; there are no specific recommendations for aspects of construction.

Riley, Ann L. 1998. <u>Restoring Streams in Cities: A guide for Planners, Policymakers, and Citizens</u>. Island Press, Washington D.C.

Ann Riley presents a comprehensive view of the field of urban stream restoration, beginning with a review of ecological values of streams and identifying the types of professionals that are ultimately needed to undertake such restoration projects. There is a very interesting discussion of the history of urban stream restoration and the status of federal programs from agencies identified as responsible for urban drainages. The remainder of the book provides a guide for urban residents on how to begin a project from the perspective of citizen-based restoration organizations and some of the basics of restoration project design. This book is not intended to be a restoration manual, but provides important information for citizens to get involved in the care and restoration of urban streams.

<u>Field Guide for Construction Site Dewatering,</u> California Department of Transportation, Construction Division, CTSW-RT-01- 010. Sacramento, CA. 2002.

The California Department of Transportation (Caltrans) Field Guide provides Caltrans Resident Engineers and field staff with the information necessary to manage dewatering operations on construction sites to maintain compliance with Federal and State water quality protection regulations. This manual establishes uniform policies and guidelines to support dewatering operations on construction sites managed by Caltrans. The manual contains information regarding the necessary permits for projects requiring dewatering, options available for dewatering, issues related to water pollution, assessing water quality and estimating discharge parameters. There is also information related to working with adjacent landowners that may be affected by the project. Appendices include options for dealing with turbid water and sedimentation, requirements from the Regional Water Quality Control Boards (RWQCB), discharge permits, and National Pollution Discharge Elimination System (NPDES) considerations.

Appendix A presents specific water quality requirements for each of the State's 9 RWQCB regions. Appendix B provides detailed comparisons of varying methods for containing and managing sediments from dewatered sites. Each method is described with parameters such as flow range, footprint, product availability, equipment required, and rental and maintenance costs. Appendix C contains water quality and discharge assessment methodologies and standardized forms. Appendix D contains permit text from the RWQCB and the NPDES.

As a guide, the Caltrans manual is most useful for evaluating options more than a guide on building or installing dewatering systems. For specific guidelines for construction, this manual references the Caltrans Storm Water Quality Handbook entitled "Construction Site Best Management Practices" published in March, 2003. See the review of this document below.

This is a technical manual, so there is sparse information specifically about potential fisheries impacts of project site dewatering. This is, however, one of the more complete sources for information about dewatering options and sediment control from a technical standpoint. Much of the information in this manual will be helpful for restoration project proponents.

<u>Construction Site Best Management Practices</u>. Caltrans Storm Water Quality Handbooks, Published by the State of California Department of Transportation. March 2003.

This manual was generated to guide Caltrans in implementation of the agency's NPDES permit that regulates discharges from Caltrans construction sites. The manual is extensive and includes sections describing Best Management Practices (BMPs) associated with construction projects. Many of these BMP's will be useful for restoration project managers. The manual describes the selection and implementation of construction site BMPs including Temporary Soil Stabilization, Temporary Sediment Control, Wind Erosion Control, Tracking Control, Non-Storm Water Management, and Waste Management and Materials Pollution Control. A valuable appendix provides guidance on the selection of temporary soil stabilization controls.

This document is the most comprehensive listing of project BMP's that has widespread applicability and use in California. Pros and cons for each alternative listed give a project manager a head start in planning many aspects of project implementation.

<u>Erosion and Sediment Control Field Manual</u>. Regional Water Quality Control Board, San Francisco Bay Region. Distributed by Friends of the San Francisco Estuary, Oakland, CA.

While not specific to steelhead restoration projects, many such projects include erosion control as a primary purpose or associated precaution. This manual was prepared for the purpose of educating construction project managers, and consists of a series of BMPs for erosion and sedimentation control. This publication differentiates erosion control from sediment control, where erosion control is protecting the soil surface to prevent soil from being dislodged, and sediment control is handling soil particles mobilized by erosion. The authors present a set of guiding principles to prevent erosion before it happens that include descriptions of grading methods and important timing factors. There is very brief description of the impacts of clearing vegetation and grading and the benefits of minimal disturbance.

Included in the manual is a set of BMPs that are described in some detail and will be quite useful for restoration practitioners. These include recommendations for project timing, grading with the contours, terracing, the proper use of netting, mats, and blankets, seeding and mulching, dust control, use of fiber rolls, stream crossings, culvert outlet protection / energy dissipation, check dams, silt fencing, straw bales, sand bags, drain inlets, and portable sediment tanks. The information contains sufficient detail to be very useful. Some of these recommendations will be touched on in this field guide.

McCullah, John and David Grey 2005. Environmentally Sensitive Channel and Bank Protection Measures. National Cooperative Highway research Program, Project 24-19, Transportation Research Board, Washington DC.

This report describes a useful list of biotechnical, or bioengineered, streambank stabilizing methods, and comes with an interactive CD with a wealth of information on streambank erosion control techniques. Also included on the CD is a decision-making model that will help project proponents choose the most appropriate method given the site properties. There are 44 techniques in the report and they were arranged into 4 categories (1) River Training, (2) Bank Armor and Protection, (3) Riparian and Stream Opportunities, (4) Slope Stabilization. Within these categories, there is a three-level rating system that accounts for the amount, quality, and reliability of available information used to determine the project approach.

The software included on the CD is called Greenbank. It is a rule-based selection software designed to help transportation engineers select methods for erosion control. An associated knowledge base is included that contains the detailed rationale and reasoning behind the recommendations made by the software. The very comprehensive set of references in this publication will be of great value for those seeking more information on erosion and sediment control using environmentally sensitive techniques.

McCullah, John 2006. Dirt Time: Season One – Disk 3 Blink Works and Salix Applied Earthcare.

This video presentation takes the viewer through the construction techniques necessary to build certain types of bioengineered bank stabilization projects. The video documentation of actual project instruction is very useful in understanding some of the complexities involved in project construction and project type selection. This is one of the more useful references for construction practices and some of the recommendations will be included in later sections of this field guide.

Project Planning

Much of the work related to riparian habitat restoration happens long before the shovel hits the soil. In this chapter the process of project selection is discussed, as well as some of the crucial elements necessary to successfully implement a project.

Watershed Analysis

Ideally, all restoration projects should be undertaken in the context of a plan that recognizes what is happening in the greater watershed within which the site is located. The purpose of the plan is to lay out how watershed resources will be protected and restored based on solid science-based approaches. In some emergency situations, projects may need to be built whether there is a watershed plan or not.

Organizations interested in doing restoration work can plan ahead for future projects by having the watershed plan prepared in advance of the restoration work. Many restoration projects are also proposed through grant programs, and a watershed plan is an essential prerequisite to be competitive in securing grants. Without knowledge of the processes occurring in the watershed, it is not possible to know if any one project will add substantially to efforts to restore vital ecological functions. A watershed plan will place project priorities based on costs and benefits so it is clear that available funding is granted to projects that show a positive cost to benefit ratio. If the watershed being analyzed does not have a plan, then the first step should be to study the watershed and write about it.

The watershed plan will describe the status of local streams and fisheries, identify the main threats and causes of degradation, and prescribe curative actions for specific areas of the stream. The plan should also *set priorities* for future actions. Normally these are general prescriptions for specific reaches of stream, but most recommend specific projects where permission of the landowner has been granted. The California Salmonid Stream Restoration Manual, published by CDFG, is an excellent source of information about how to scope your plan and what the essential elements of the plan should be. The U.S. EPA also publishes the "Handbook for Developing Watershed Plans to Restore and Protect Our Waters," published in March 2008. The reference number is EPA 841-B-08-002. The entire document can be found at http://www.epa.gov/owow/nps/watershed_handbook.

Researching and writing a watershed plan is often done in collaboration with stakeholders in the watershed. These will include landowners, government leaders, agencies and departments, citizens, business interests, potential service providers such as engineers and materials providers, contractors, and many other professionals. Each may come with different knowledge, experiences, concerns, and capabilities; working together makes the plan stronger and more useful. It is vital that all stakeholders are not just given the opportunity to participate in forming the plan, but actively encouraged. When all parties have some "ownership" of the process and results, the plan is more likely to be followed.

In San Luis Obispo, CA the early watershed planning efforts of the Land Conservancy established standard stream reaches to describe specific stream areas. These were used to assign priorities for certain project types. These reaches were later adopted by the City and County of San Luis Obispo for future studies so all new information could be seen in a common geographic context.

Project Plans & Designs

Planning for restoration projects is a team effort and should include an interdisciplinary approach. It is essential to engage biologists, hydrologists, contractors, engineers, permitting agencies, landowners, and others with specific skills and interests. Engaging other restoration organizations to share their experiences is also valuable. With input from all your partners you are able to think through the project goals and methods that will yield a high quality project.

The project design team should discuss each aspect of the plan in terms of alternatives. There are usually multiple approaches that would achieve similar results, so the design team should evaluate the merits of each alternative with respect to costs so project designs can address the relative value for the money. Designers should also consider alternatives to address potential areas of compromise. Most restoration specialists want to do the most biologically beneficial design for every project, but sometimes that project design conflicts with competing interests. For example, projects to improve fish passage through public infrastructure, such as culverts, will also need to address flow capacities and flooding issues. In many cases, the project design is a compromise that provides for the best possible fish passage while maintaining the effectiveness of public infrastructure.

Below are some additional tips on project designs.

1. It is helpful to start with a design philosophy that best conforms to the natural functions of the stream. The best alternative to achieve this is the most appropriate. Then as site challenges, and in some cases public requirements dictate, adjust projects systematically to address concerns. The goal should be to achieve the most natural project allowed that will still meet functional goals.

2. Some of the most important information for project designs will come from a hydraulic study of the watershed. These studies model predicted flow rates and stream power, and can be used to evaluate project alternatives. Most public works or flood control agencies have master drainage plans and design hydrology studies they use in evaluating projects. These should be consulted by project design engineers. Most jurisdictions also have specific analysis procedures which must always be met for project approval.

3. In the case of a project that involves publicly owned culverts, modeling flow for before and after conditions is a prerequisite to permit approval. If the watershed does not already have a master hydraulic study, work with stakeholders to propose it. This information generally has lasting value and can save substantial funds when compared to doing smaller local studies for many projects.

4. When proposing a project on publicly owned infrastructure, it is essential to include the agency responsible for the structure in discussions prior to the design process. Invariably, there are specific requirements and standards to meet, and even staff time from the agency will also need to be approved. Do not begin any design work before securing permission and a commitment from the responsible agency. When a commitment is made, be prepared to work closely with agency staff and a design engineer.

Project Permits

Securing permits for work in a stream is a field in and of itself, and presents its own challenges. In most cases, there will be federal, state, and local permits required. Some emergency case projects may be exempt from specific permits, or permits may be acquired “after-the-fact” when a public agency is responding to emergency situations.

Acquiring a permit for non-emergency work requires substantial forethought in the project design phase. A project must be planned with knowledge of specific requirements so accommodations are made for permit compliance. Below are some tips on securing permits for your project.

1. The most important tip regarding permitting a project is to start as early as possible. Permitting a restoration project takes substantial time and having to wait on a permit to begin work can complicate your construction planning and scheduling. On the south coast, our construction season generally ends on October 15th. If you have a project that will take several weeks or

months, the permits need to be in hand much earlier. It is not unusual to begin the permitting process one year or more before construction.

2. If possible, discuss your project with a representative from each regulatory agency prior to submitting the permit. This is a good way to build long term relationships with regulators so they can become more confident in the quality of your work. This is also the best way to learn what issues your regulator is most concerned about so you can be sure to adequately address these concerns in your project description in your permit application package. Often they will have specific recommendations that will enhance your project.

3. Once your permit application has been submitted, it will be necessary to shepherd it through the process via frequent contact with regulatory staff. First, it is critical to contact agencies to confirm receipt of the permit request and to learn which staff member will be processing your request. This should be done within two weeks. Then follow up every two weeks or so to make sure that certain processes have been initiated.

4. As organizations dedicated to recovery of important species, project proponents should be willing to do anything possible or feasible to protect listed and special status plants or animals during a project. For this reason, we have taken the approach that all of our projects have the potential to affect these species and we simply assume their presence on site. With this assumption, we develop avoidance measures to protect all of these species during construction. Even if there is some additional cost, we find this assumption to be good insurance. It has never served our projects to try to assert that these species are not present just to avoid practices that we should be doing anyway.

Project Financing

Before undertaking a project, it will be important to think through how you will pay for the work. If the project is funded by a grant, it is common for payment to come in arrears after an invoice has been submitted. This means that the organization usually has capital (or debt) invested in the project before they get paid. Most contracts with your contractors have payment terms of 30 days net, meaning you owe them funds in 30 days. It is unlikely that you will have similar terms in your contract with the grantor. It is more common that you will get paid in 60 to 90 days. Project managers will need to figure out how to pay contractors while waiting for grant funds.

Another financing issue is the common practice of granting organizations withholding 10% of each invoice until the grant is complete. This is ostensibly to make sure that the grantee actually finishes the project, but it can also complicate financing. With large projects, such as construction of a $1 Million bridge or culvert, the project proponent will be $100,000 short of the funds necessary to pay for the work until the entire project is complete. Even for smaller multiyear projects it is common to be carrying the debt on behalf of the grantor. Debt costs money too, so project costs actually increase due to short and long term delays in payment. Below are three strategies for handling project financing.

1. A line of credit from a bank can be a valuable tool in managing project costs. It provides available cash so contractors can be paid in a timely manner. In order to get a line of credit, the organization needs to have solid finances to show credit-worthiness. Since nonprofit

organizations generally cannot put up assets as security for the debt, these are usually unsecured business lines of credit. In considering the line of credit option, be prepared for strict management of debt as it relates to project costs. Like a credit card, balances can grow and this is real debt that must be paid off. Before going this route, the organization's Board or Trustees will need to decide if they are willing to take the risk of assuming debt and preparing policies associated with this form of financing.

2. A second option is a specific construction loan that is backed by the grant contract. Again, credit-worthiness is a prerequisite. Most community banks are required to do some local community-benefit lending. If you have a close relationship with a bank you may be able to negotiate credit.

3. Work with your contractor on payment terms and work to secure more time to pay. Any additional time means carrying debt for a shorter time period and can save on debt costs. With larger contracting firms, we have been able to negotiate terms of up to 60 days. This makes them the banker for the project. Usually only the largest companies can carry these costs as most smaller operators do not have the capacity to do this. When possible, negotiate so that you can include a "will pay when paid" clause in your contracts.

Landowner Coordination

When working on private property, coordinating the project with the landowner is very important. The landowner needs to be comfortable with the project details and both parties will want some written understanding of their respective responsibilities and liabilities. Below are some specific items that need to be articulated in an agreement with a landowner, and considered by the restoration organization.

1. The agreement with the landowner should contain a full project description that includes the specific description of project site access. This includes where equipment will enter the property, where equipment will be stored when not in operation, where staging operations will take place, and where turbid water can be discharged if not in a sediment catchment that returns water to the stream. It is also common to specify the conditions of access to the landowner's property. In most cases, specify that access is limited to the needs of the project.

2. A legal agreement called a nonexclusive license agreement may be used to lay out the responsibilities of both parties. In some cases, these will be exclusive licenses. The agreement must specify that the landowner is not to take any actions that are contrary to the project goals such as modifying the work before, during, or after construction. This agreement is also used to assign liabilities and determine a schedule for the project.

3. Liability coverage is probably one of the most important parts of any working agreement. It is common to provide some form of indemnity to the landowner for injuries or damages that occur as a result of the project. The level of indemnity you extend to any landowner should be determined in consultation with attorneys for both parties.

4. Any restoration organization that will be engaging in physical projects needs to evaluate their organization's insurance policies to be sure they are covered for potential damages caused by the project. Types of insurance may include liability coverage, auto/vehicle insurance, herbicide

application insurance, directors and officers insurance, and workman's compensation insurance. An umbrella policy is also advisable. The specific types of insurance and amount of coverage are best determined in consultation with your insurance agent(s).

Contracting

For all but the simplest hand built and/or planting projects, contractors will be hired to construct the project. They call builders "contractors" for a reason, <u>because a contract articulates all responsibilities.</u> The liabilities associated with work in and along creeks demand that work be completed using licensed contractors and have a firm contract. The contract articulates the conditions and responsibilities under which the project is constructed, such as the cost, schedule, billing procedures, and assignment of liabilities.

In many cases, the selection of a contractor is based on a bidding process. This process is designed to elicit competition among contractors in an attempt to get the best value or price. Through the bidding process, contractors state their understanding of the project goals and their qualifications to perform the work, list their rates for specific people and equipment, and state an estimated cost for the project. When a bid is accepted, it is usually for a lump sum that will be paid to the contractor for the work.

A word on bidding…
Most government agencies have specific procedures for requesting bids for public works projects. It is less common for non-profit groups to have these. Non-profit organizations are wise to borrow some of the bidding procedures from your local city or county government to ensure that the process yields a fair comparison.

It may be the case in some areas that local contractors will not bid on restoration projects. This may be that the projects are not large enough and contractors only want to put a lot of effort into preparing a bid if the reward of winning is large. Some contractors may also fear working in a creek due to the liabilities tied to possible environmental damage or violations. It may be necessary to be proactive in encouraging bids.

Below are some points to consider when working with contractors.

1. The best way to ensure quality construction is to work with a Class A licensed contractor, also called a General Engineering Contractor. A General Engineering Contractor is a contractor whose principal contracting business is in connection with fixed works requiring specialized engineering knowledge and skill. This class of contractor is required to have specific skills associated with work on and within waterways. A properly skilled contractor may cost a bit more, but will likely get work done faster, better, and more efficiently.

2. When bidding works, consider prequalifying contractors and only solicit bids from those that meet the qualifications, such as Class A contractors. This can prove important because it is fairly common to get low bids from under-qualified bidders. Low bids also tend to result in more change order requests that bump the prices after the contract is signed. When going with the low bidder, pay particular attention to their experience and always call references. The photo below shows a low bidder going after a steel reinforced dam with a hammer, yielding only cosmetic damage.

3. When reviewing a bid, look through the equipment list offered to ensure that the contractor has access to any specialized equipment that may be necessary, such as a thumb attachment for the excavator bucket.

4. When requesting project references, specifically ask for references associated with their last four to six projects. This provides the most current sense of their abilities, rather than cherry-picked references from their only two successful projects.

5. When a qualified contractor is found that does great work and understands project goals, consider hiring them again for other projects. When contractors gain more experience with stream restoration they can be important partners over the long haul. By doing this, contractors gain valuable experience that may serve future projects.

6. When reviewing bids, pay close attention to the contractor's understanding of the project. Be sure they are aware that this is a restoration project and it may be more challenging than the work they have done before. Installing restoration features often takes a lot of patience by equipment operators and they should understand that they will be working closely with the onsite project manager from your organization.

7. In some cases, a time and materials contract can save money. These are mostly for smaller jobs where costs can be controlled by rigid management of the work and contract. If using this type of contract, plan specifications must be very detailed and constant supervision onsite is critical. This is why it is most common for projects to use a bidding process.

The First Day Field Meeting & Safety Planning

The first day in the field on a restoration project is mostly a mobilization day when equipment and materials arrive and the project team goes over the details of how the project will go. Depending on permit requirements, there may also be prescribed training for the building crew on recognition and protection of special status species. This is when the project manager from the restoration group establishes lines of communication between themselves and the contracting crew. Below are recommendations for the first day.

1. If training will be provided for the project, such as training for protection of special status species, have the entire contracting crew that will be working on the project present for this training. It is important to let the contractor know this in advance so the trainer does not need to be called back later for new workers. Be sure to schedule this with the approved biologist or other trainer so everyone is on schedule.

2. Project monitors all need to be on site for the first day as well. These may be monitors for biological resources, cultural resources, and possibly Native American monitors. They will have a role to play in discussing important constraints on the site, and as the project manager it is

important to clearly articulate the role of the monitors to the contractors. Particularly, if monitors have authority to stop construction in the event of a threat to resources, this authority must be clear to everyone working on the site. Monitors are partners in the project and it is always better to work closely with them to avoid damage to special resources than to deal with a violation of a permit condition.

3. Make sure there are copies of all project permits onsite and let the crew know where they can be found in the event they are asked to present them to any regulatory inspectors.

Working with Heavy Equipment

Using heavy equipment is often the only way to construct large projects. It is important, however, to know that heavy equipment can also cause a great deal of site damage in a very short time. It is important to have a discussion with the equipment operators to let them know about some of the challenges of the project and what is expected of them during construction. For some restoration projects, the project manager should be present onsite regularly enough to ensure that certain specifications are being met. Consider it a responsibility to make sure the operators don't fail or end up violating a permit condition.

Boulders are usually delivered in an end-dump truck. These can hold upwards of 18-20 tons of rock and get top-heavy when dumping. They will need to do this dump on a flat surface. Therefore, a staging area needs to be delineated. Nobody should be near one of these trucks when it is dropping its load because the truck could tip or the falling rocks can send flying shards.

Below are some suggestions for working with contractors.

1. Prior to bringing equipment on site, meet with the contractor's project manager on the site and discuss any access constraints. Working along creeks can provide certain challenges for access and plans should be made in advance. Truck drivers that will be delivering materials, such as boulders or tree trunks, should also inspect the site because some trucks have access and delivery constraints.

2. Power lines are of particular concern in bringing equipment on to the site. Often in rural areas, the wires are relatively low compared to the height of an excavator on a lowboy trailer. In these cases, it may be necessary to either drive the excavator in with the bucket lowered, or the wires may be able to be temporarily lifted using a wooden brace. Power lines must always be marked with a sign viewable by the operator (usually on the ground). In most cases, they can't see the wires from the cab.

3. If the excavator or other tracked equipment is driving into a site, remember that metal tracks can do a lot of damage to pavement. Pavement should be protected to avoid liabilities associated with the damage. Plywood is sufficient to protect pavement and is low in cost. A thickness of at least 5/8 inch is recommended.

4. Shooting some video of the access to a site, and focusing on potential issues, is an easy way to prepare contractors to enter the site with heavy equipment. This can save a trip out to the site.

The video may also be helpful in showing the condition of the site access areas prior to construction so contractors can be required to maintain that baseline condition.

5. Establishing equipment traffic lanes on larger projects ensures that the equipment does not damage an unnecessary amount of land. Routes should avoid any rare plants or steep slopes. It is also best for a project site to set specific areas where a stream can be accessed for construction. This reduces the total area of collateral damage from the equipment accessing the stream.

6. When working within a stream channel, it is best not to have an excavator in the normally wetted part of the channel. This is because heavy equipment is, by definition, heavy and it vibrates. The combination of weight and vibration can create liquefaction of the stream bed. Beach-goers will know that when you pat wet sand, water rises. When this happens, the excavator may sink into the substrate and get stuck. It also creates a quicksand effect in the channel that can be a safety issue with people on the site.

"I'll never forget the day we had the excavator in the channel and noticed it was sinking. We got it out of the channel immediately and onto a graded platform on the stream bank. After moving the equipment we needed to get into the channel to make an adjustment to the diversion pipes. A CCC Corps member was the first into the channel and he sunk nearly waist deep in the quicksand. It took 15 minutes to free him due to the suction effect of the mud. This could have been a very serious safety problem had the mud been deeper." -Brian Stark

7. Heavy equipment is dangerous, and it is often difficult for the operator to see what is behind them. Field personnel must avoid the all parts of an excavator when the operator is in it. Most people look at the bucket as the dangerous end, but the back swings wide when the bucket is moving and can strike unsuspecting people behind it. It is wise to have a separate access to the site for machines and people, and to actively help the operator to know where people are working. When working closely with equipment wear safety vests and do not approach the machine until making eye contact with the operator and getting an acknowledgment.

8. Most heavy equipment such as backhoes, hoe rams, loaders, and excavators make use of hydraulic power to lift, grab, push, or hammer materials. The hydraulic fluid flows in rubber hoses that can break, causing a spill into the stream or stream channel. These spills need to be controlled rapidly to avoid impacts associated with the spill. Always have a portable oil boom and oil absorbing cloths on site and within reach if a spill occurs. It is common to include this requirement in the contract with the contractor.

9. Heavy equipment will need to be fueled and occasionally lubricated onsite during the project. Establish a specific fueling and maintenance area on the site for this activity. This area should be at least 100 feet away from any water source. Having only one location for this activity is helpful in the event there are any spills because the area to clean up is concentrated.

Water Diversions & Work Site Isolation

When work will proceed in or adjacent to a stream channel and the work poses a threat to water quality or fisheries, it is often necessary to isolate the stream or completely dewater the work site. This will usually be the first activity undertaken and is one of the most important. Isolation and dewatering come with substantial risks for the aquatic life in the stream, thus adding a much greater level of responsibility for project managers. This section will describe some basic methods of dewatering and isolating streams and list some important considerations to reduce the possibility of harming fish or downstream habitats.

Water diversions come in several different forms including project site isolation and full dewatering. If work is occurring on just one bank of the stream, it can often be done by simply isolating the clean stream water from any turbid water in the work zone. Isolation is much less invasive for aquatic life and should always be considered before completely dewatering a stream.

When the project will be done in the active channel and requires equipment access to both banks or a substantial part of the stream bed, it will be necessary to dewater the work site. Dewatering is the part of a project where there are the greatest risks to fish. During this process, water is removed from the stream and all fish must be removed from the work area and placed in safe habitat. This is a very complex process that requires substantial pre-project planning and will often require adjustments in the field. This activity also requires specific permits that describe the acceptable methods to use and what types of monitoring and reporting are required.

This section introduces a few options and discusses their pros and cons. We will also list some complicating issues associated with diversion installations. For the most comprehensive guide to methods and practices associated with water diversion or site isolation, see “Field Guide to Construction Site Dewatering” and “Construction Site Best Management Practices”, both published by Caltrans.

Work Site Isolation

For project sites where work is occurring outside of the main channel or an adjacent bank, it is usually preferable to simply isolate the clean stream water from the construction area rather than dewatering the stream. Isolation is preferred over dewatering because it also does not involve significant fish relocation or the more extensive construction of diversions. This can be done a number of different ways, and in some cases the project permitting requirements will have some say in how this is done. The main objective is to ensure that sediment does not enter the clean stream during construction and that fish and other aquatic resources are not harmed or damaged. All isolation structures must be planned in advance and be described in any permit applications.

Isolation Using Straw Bales

Isolations may be fabricated using straw bales if the isolation is out of the water. Straw bales are effective for stopping sediment from coming off a graded slope toward the stream. If the isolation will actually rest in water it is better to use gravel bags because the straw bales will degrade rapidly and be hard to move when saturated.

Isolation Using Coffer Dams

Coffer dams are often used to isolate project sites. They are a good method because they are generally low in cost and can be built by hand. A coffer dam is usually built with sandbags that are filled with washed gravel or coarse washed sand, and may also incorporate plastic sheeting to improve the effective seal of the structure. Using washed river gravel (smooth stones) inside the bags is a good choice when the bag is primarily used for structural rigidity in combination with plastic sheeting for the seal. Bags filled with smooth washed gravel will not secrete sediment into the stream, they drain quickly when wet making them easier to handle, and the smooth gravel prevents tearing of the bags. When the project is completed, the smooth gravel can simply be deposited into the stream channel to form habitat and temporarily bind construction sediments in the work zone.

In some cases, there will be turbid water in the work zone and a downstream isolation barrier must prevent this water from escaping into the stream. Water can come up in an isolation zone through stream bed upwelling, but it also comes up due to the disturbance of soils in the work zone and pressure caused by equipment in the channel. Controlling this water can be difficult when water in the work zone builds up and the water pressure forces turbid water through the isolation barrier. This leakage of turbid water can be controlled by managing the water pressure gradient in the work zone with submersible pumps. Pumps pull turbid water from the work zone and deposit it outside the stream channel, usually into a sediment basin or onto adjacent land where it won't run back into the stream.

In the situation pictured to the left, an isolation weir was built because the pool was too big to dewater. The weir is made of gravel bags sealed with plastic sheeting. In this application, t-stakes were used to add structural support to the coffer dam due to the height of the structure. It is common for all isolations to have some leakage, and the challenge is to keep the turbid water out of the stream. This can be accomplished by running a single electric submersible pump and pumping the turbid water into holding ponds outside of the channel. It was not necessary to pump out all the water, rather just enough to keep the pressure gradient lower in the work zone than outside the work zone. This causes the clean water to "leak" into the work area instead of turbid water leaking out of it. When managing water pressure on two sides of a weir, it is important in many cases not to pump too much water out of the work zone. If water pressure gets too low in the work zone, the weir will implode due to water pressure outside of the work zone. If pressure gets too high in the isolation area the weir will collapse outwardly.

When using this method, it is best to schedule the completion of work each day at least one hour before turning off the pumps. This gives the sediment time to settle out of the work zone water before allowing pressure to equalize.

Case Study #1 – Being mindful of subsurface flows

On Stenner Creek we were pouring a concrete wall along one side of a set of fish passage weirs to keep the adjacent road from being undercut by the stream. The pool pictured here was sustaining approximately 15 steelhead despite the lack of surface flow. The pool was being fed cool oxygenated water via subsurface flow. Our permits on this project did not include dewatering, so we isolated 2/3 of the pool to protect steelhead. The remaining part of the pool was in the construction area separated by a coffer dam. While pouring the concrete, we set up a pump to remove the slurry and contaminated pool water. We found that if we pumped the slurry out too fast, we would pull the groundwater away from the pool, and the fish began gulping for air on the surface. We shut down the pump and the fish were fine. We adapted to running an electric pump for short periods and then turning it off. This was sufficient to manipulate water pressure and keep slurry water from entering the pools, and it kept the fish oxygenated and the water clean.

Case Study #2 – Isolating work on a dam

This modification of the Marre Weir in Avila Beach presented a very challenging isolation project. The project involved manufacturing a fish migration notch in a sheet pile weir. The notch was cut out and a welded a cap was fitted over it to bolster the strength of the weir and make the flow less turbulent through the notch. Isolation of the work area was necessary to get the water low enough to perform the welding on the upstream side.

This was a complicated diversion because work was necessary at the upstream side of the dam and it needed to hold back the water being impounded by the dam. It is easy to underestimate the power of all that water when it is standing still most of the time. The diversion was originally constructed of plywood and lumber and sealed with plastic. Problems arose when the contractors pumped the water out of the inside. The lumber was not strong enough to hold the external water pressure. It was then reinforced with aluminum piping, but that failed as well. Ultimately, it took a welded steel structure to hold back the water.

For sites where substantial volumes of water need to be isolated and water pressure differences are high, the best solution is to involve the project design engineer in the design of the isolation structure. While it costs more up front, it will ultimately be safer, save time and money, and allow the project to move through construction in a more efficient manner.

In hindsight, it may have been wiser to have used an underwater welder for this work. While more costly per hour, it would have saved a lot of time spent on the isolation structure. An underwater welder was hired to do a minor repair the next season with great ease.

More Tips on Isolations

1. Always be mindful of water pressure on both sides of the isolation weir so it does not collapse.
2. A seine net can be used prior to construction of the isolation structures to make sure no fish are present in the work zone.
3. Disturbance of the stream can be reduced if isolation structures are built from the work zone side. That way the turbidity caused by the crew can be held inside the isolation.

Stream Dewatering

When dewatering is necessary, there are several options to consider. In most cases, the diversions are built using coffer dams and pipe, or a pump is used to pump water around the site. In both cases, there is a complete separation between the water and the channel.

The part of the project that holds the biggest threat to fish is the installation of the diversion. Exercising care in this process can avoid unnecessary harm to fish. In the first step, ensure that the process of removing fish from the work area is as complete as possible. It is often the case, however, that the first pass of the fish relocation does not catch all the fish. It’s best to assume that there is still a risk for fish throughout the dewatering and construction process.

Fish Relocation

Prior to dewatering a site for instream work, fish need to be removed from the work area that will be dry and isolated during construction. Special permits are required for this work. Dewatering and fish relocation are the project elements that pose the greatest dangers to fish. Below are a few construction practices that can substantially reduce fish mortality.

1. Fish relocation may have two phases. A first phase usually consists of using seine nets to try to get fish out of the project reach and making sure that no more fish get into the work zone during the construction of the isolation or dewatering systems. A second round of fish movement may happen after the dewatering systems are installed, and usually involves

reducing water flow to encourage fish to concentrate in pools where they can be captured with dip nets.

2. The day prior to the dewatering and fish moving activity, manually remove vegetation growing in the wetted area. This includes the herbaceous plants growing along the wetted perimeter as well as dead material in the active channel, such as sycamore leaves. Also remove large cobble and downed wood if possible. The removal is done gently and slowly by hand so fish are not harmed. When removing these temporary habitat features, fish tend to move out of these areas and the total number of fish to be moved is decreased. It also helps during the fish relocation because fish cannot hide among the vegetation where it is hard to remove them safely. Ultimately this results in less stress on the fish and a faster relocation process. Removed vegetation usually consists of herbaceous plants that will be disturbed during construction anyway and re-grow quickly following construction.

3. With larger habitat elements removed from the wetted channel, seine nets can be used to exclude most fish from the construction area. Two seine nets are used in this procedure where one is placed at the downstream extent of the exclusion area. The second is placed in the channel immediately upstream of the lower net and kicked upstream by the netters. Generally, it is best to move fish in an upstream direction because these habitats will not be disturbed during construction and any accidents during construction that may cause habitat disturbance downstream do not affect the moved fish. In some cases, habitat availability may impact the direction of seining. If there is no or poor quality habitat upstream, fish may be moved downstream.

4. Stream channel beds are usually uneven, so gaps below the netting provide fish spaces to avoid the netting, so it is likely that the seining will not exclude all the fish in the project reach. In most cases it will be necessary to continue fish movement during the construction of the diversion. Once the diversion is partially intact, slowly reduce water flow to the project reach. When flow drops, fish will concentrate in pools and can be captured with dip nets or d-nets quite easily. It is important to have a number of different sized nets onsite so the proper net size can be used. Using nets that are too large or too small can increase the risks to fish as nets are jostled into position. Once fish are isolated in the pools pumps can be used to pump down the water levels if necessary and easily capture fish. It is critical that your pumps are properly screened so they do not entrain any fish. It is important during the construction of the dewatering coffer dam to not initially divert all the water. Rapid water loss will result in stranded fish that didn't make it to a pool. Rather, dewater sites slowly and leave some live flow until you are confident that all the fish have

been moved. Be sure to remove the seine nets after the diversion is in place to allow for fish passage through the pipes during construction activities.

A method for fish capture that is generally considered more effective and safer for fish is electro-fishing, or e-fishing. In this method, a trained specialist uses a battery pack to electrically charge the water. This has the effect of stunning fish. Stunned fish float easily into nets without a struggle and regain consciousness in the bucket. An advantage with this method is that it doesn't require chasing fish, so it can be done more slowly and methodically without jabbing nets out and potentially crushing fish. It is advisable to request e-fishing in the permit application for all projects that require fish relocation. Make sure you have an incidental take provision in your NOAA Fisheries Biological Opinion (B.O.) before moving any fish anywhere.

When applying for a permit through the U.S Army Corps of Engineers, project managers should specifically request having the ability to electro-fish to assist with moving fish, <u>if the site requires it</u>. The Army Corps then seeks a Biological Opinion from NOAA Fisheries regarding the request. NOAA Fisheries will not assume that project proponents need to be able to electro-fish.

5. When netting fish, place them in buckets of fresh cool stream water and place some vegetation in the bucket to block sunlight. It is customary, and often required to count the fish and determine age class prior to releasing the fish. These data are later reported to permitting agencies. These buckets need to be emptied fairly often as the water can heat up and the dissolved oxygen can be depleted. Experienced fish movers highly recommend using battery-powered electric air pumps to oxygenate the water in the buckets.

6. It is critical that federally-approved biologists assist with moving fish and they should be consulted as to how to best proceed under site conditions to minimize harm. Also, be sure to consult the conditions listed in the Biological Opinion and other permits. Have at least 3 to 5 people present under the supervision of the biologist to assist. Precise, quick movements can make the difference in whether or not fish survive the move.

<u>Special Considerations</u>

1. When moving fish in a high gradient stream reach, it is doubly important to make sure the dewatering coffer dam does not divert all the water. High gradient reaches go dry very quickly as water flows down through the reach and can strand fish in dry sections.

2. An important thing to remember when using pumps in an area containing fish is that pumps can suck up (entrain) small fish. It is important to screen pump uptakes to prevent this. The screening of the pump intake must take into account the size of the fish, but also the intake capacity of the pump and the amount of debris in the water. Fine screening reduces the effectiveness of the pump and intakes are prone to debris accumulation. The best way to prevent problems with the intake is to design a concentric layering of screens, with the outer layer trapping debris, the middle layer excluding fish, and the pump intake in the center. By

expanding the screen area for the fish screen, more water can pass though to the pump. A bucket full of holes makes a good debris filter and a large net can be used in the bucket for fish screening. Buckets full of small holes and screened on the outside with regular window screening are also useful. Screening on the outside of the bucket prevents the screen from imploding toward the pump intake.

Beyond the issue of entrainment of fish, the pumps used for dewatering and managing turbid water in the work zone will get clogged intake screens. It is often necessary to monitor the intakes constantly and clean them repeatedly. It may be necessary to have someone sit by the intake and constantly remove debris from the intake. A plastic scrub brush makes an effective intake cleaner.

Stream Dewatering Techniques

Water diversions are most often based on gravity flow through pipes, but in some special cases, pumps are used. These are constructed using coffer dams and some form of pipe. Gravity systems are efficient because they don't require moving parts, they can be left un-monitored overnight, and they are relatively less expensive than pump systems. Pump-based systems need to be running constantly, so they need to be monitored 24 hours a day. They also consume a lot of fuel, which increases the cost, as well as the carbon footprint of the project. Pumps can also break down, requiring fast action to get a replacement pump in service. Before considering the construction of a diversion for a project, consider whether it might be better to have a contractor build the diversion based on some specific performance stipulations placed in the contract. It may be that the contractor has more experience in this area, and it also places the responsibility of permit compliance on the contractor rather than the restoration organization. If the contractor does not have the ability to do this step, it can also be contracted to experienced consultants.

Building a coffer dam with a pipe diversion

For a standard coffer dam and pipe diversion, you will need sandbags filled with washed sand or gravel. Gravel is preferred because, as mentioned above, the bags are just a structural support for the visqueen®, or sheet plastic, that will actually form the seal. The gravel does not contain fine sediments that could leach out of the bags and into the stream. When using gravel, select rounded gravel so it can be left in the stream after use. You will also need the plastic sheeting for the seal and some form of pipe. A corrugated plastic pipe is a preferred type because they are the easiest to repair if damaged. Finally, you will need baling wire to affix the plastic to the pipe.

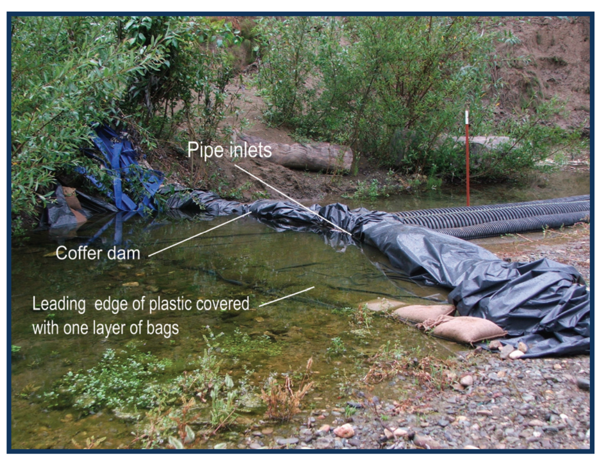
The sizing of the pipes can vary depending on the flow you are trying to divert. In some cases projects have required a rigid plastic corrugated pipe with a larger diameter. The upside is that this pipe can carry a lot of water. It is also very strong and can survive some beating. The downsides are that it is rigid, doesn't do curves well, and it is very heavy. These pipes are also harder to repair if damaged. It takes either heavy equipment or more people to move around. In general, this diversion remains in place during the project and cannot easily be moved.

On smaller streams, using smaller flexible corrugated pipe in 6" and 8" diameters may be easier. While each pipe holds less water, multiple pipes can be used to achieve the necessary flow capacity. Smaller flexible pipes can conform to curves in the channel and are light enough to be moved during construction without dismantling the diversion (see photo at right). The grooves make them easy to repair and seal. Generally, if more than four small pipes are needed to convey the water it is better to use the larger rigid pipe.

The placement of the coffer dam is also an important concern. These diversion structures should be built on a straight section of the stream rather than a bend. Also look for places where the channel form has well-defined banks that rise from the stream bed quickly. These channels contain water better because the potential channel volume is higher. If the diversion is placed in a place where the channel bed is wide and flat, the water spreads over a larger area requiring more gravel bags to prevent flanking of the diversion. The area to seal also becomes much larger and there is more potential for leakage. Narrower and deeper diversions also seem to drain better as they develop more pressure head. Sometimes there isn't a perfect location and it is better to build it where you can than make the diversion longer in search of a better channel form.

For standard specifications for construction of stream diversions see the Caltrans specifications cited in the literature review. Below are some tips on diversions that will make the construction and maintenance of the structure easier.

1. The project engineer can help determine the best pipe sizes for your diversion. This will involve calculating the flow rate of the stream and translating it to the capacity of the pipe to carry water. This can get tricky when comparing flow in the channel with flow in the pipes because the flow dynamics are substantially different in the channel and pipe. Generally, pipes can transport more water per minute at a given cross-sectional area than a natural channel.



2. Make sure to have plenty of materials on site when the diversion is to be built. It is best to order more materials than might be anticipated. Diversions require a lot of materials because as the dam impounds water, the volume and elevation of water upstream builds up and can flow around a coffer dam that is too small.

3. Stockpile gravel bags next to where the coffer dam will be constructed. Placement of the bags has to happen quickly, so you need your materials close by.

4. When attaching plastic sheeting to corrugated pipe, be sure to have the wire lying in the same groove of the corrugated pipe all the way around the pipe. This will form a good seal on the inlet. Once the plastic is mounted to the pipes, cut out an "X" pattern in the plastic on the pipe openings and fold the plastic flaps inside the pipe. The pipes are now ready to pass water.

5. It is a good idea to have a crew of 5 to 6 people onsite during construction. Depending on the width of the stream more people may be needed.

6. When the water begins to flow onto the plastic, it will compress the plastic onto the channel bed and form the main seal of the structure across the channel bed. It is at this vital junction, when flow is first being captured and kept from the channel, when fish may swim up and under the plastic while it is being compressed on the channel bed. This is likely a response to the rapid loss of water in the channel. Any fish that may not have been moved prior to the installation may race upstream in response. The smaller fish can easily get crushed in here. Lowering the plastic slowly while watching for fish, and using a seine behind the plastic to make sure fish cannot swim under the plastic are recommended.

7. While the water begins to be captured by the diversion, be sure to let the diversion leak, and fairly substantially at first. It is important to have some water flowing in the stream channel to sustain any fish in the project reach until they can be isolated in pools and relocated. As fish are isolated into the pools, begin to divert more of the water. Once finished moving fish, the coffer dam can be quickly sealed.

8. In most cases when water is diverted, a second coffer dam is constructed at the downstream extent of the project site. This dam is intended to keep turbid water in the work site from flowing into the live stream downstream. Even when a stream reach has been dewatered, it is often the case that there will still be water collecting at the downstream end of the work zone. This is usually a result of leaking diversions, water upwelling from the channel bed (very common in higher gradient reaches), and water brought to the surface by construction activities. Downstream dams also prevent fish from re-entering the work zone and can hold back clean water that may backflow into the construction zone. Backflow is common in low gradient reaches.

In most cases, these dams are constructed with sandbags filled with washed sand, rather than gravel, and without plastic sheeting. Straw bales may also work to block flow and filter sediment. In most cases, these weirs are not sealed because pumps will move the turbid water out of the channel for filtering. The dams are mainly a last line of defense in the case of a diversion failure and are a barrier to fish. The photo at right shows a downstream coffer dam holding back turbid water.

9. Once the diversion is up and running, it needs to be maintained and monitored. This is because coffer dams rarely form a dry seal. Some leakage is predictable. One strategy for managing leaks from a diversion is to dig a shallow (1 to 3 foot) hole in the channel about 15 feet downstream of the diversion. This hole, or sump, will capture the leakage both from the surface flow and shallow groundwater flow. Plan the location of the diversion so a sump can be installed upstream of construction activities. The sump can actually capture the leaked water while it is clean, so water can simply be pumped back upstream of the diversion. This can substantially reduce the volume of turbid water that needs handling downstream. The photo at right shows a sump capturing leakage to be pumped upstream.

10. Sometimes during construction, the water diversion may be accidentally damaged. When this happens, the diversion needs to be sealed quickly before the water from the pipes overwhelms the pump at the downstream end. With some advanced planning, this can be done quickly.

    First, being prepared in advance with materials easily at hand is critical. Prepare by having pre-cut pieces of plastic sheeting measuring approximately 3 feet wide by 4 feet long, staged next to the diversion. Also have baling wire, wire cutters, and pliers. In the event of a rupture, wrap the plastic sheeting around the pipe several times at the point of leakage. Then, wrap the wire over the plastic making sure the wire is in the same groove of the corrugated pipe. Pull the wire tight and twist. Do this both upstream and downstream of the rupture in the pipe. This can seal the leak and can be done very quickly.

    A good time to try practicing this technique is during construction of the diversion. Wherever two lengths of pipe are joined, usually with a junction sleeve, you can do the plastic wrap technique to get a better seal. It is good to do this anyway and by planning ahead there will be people onsite that have done this before and can work quickly.

11. During construction, it is common to pump turbid water out of the work area to keep it from flowing downstream. There are numerous methods for managing sediment-laden water, and the option you choose will be based on the volume of water and sediment to be moved, the types and sizes of sediments, site constraints, the length of time the pumps will be running, and the relative impacts the removal of water has on surface flow.

    On smaller streams during the summer, flow is generally low and it is fairly easy to pump the water to an upland area. Choose a location where water is distributed over a wide area to either percolate into the soil, or flow through sufficient vegetation to filter out the sediment before it flows back into the stream. For projects lasting many days it is common to move the discharge points periodically because soil gets saturated easily and the percolation rates decrease over time. Silt fencing can also be effective on gentle slopes to ensure that turbid water does not flow back into the stream.

Because there are so many considerations and methods for controlling sediment laden water, project managers should refer to the publication "Field Guide to Construction Site Dewatering; Appendix B" published by Caltrans.

12. Just as care was applied in setting up the diversion, care must also be taken when taking the diversion down and letting the creek flow. The biggest potential impact here lies with the channel bed substrate conditions created by the project. Channel disruption often leaves fine sediment on the top of the channel bed. Releasing water into this material can cause this sediment to flow downstream in a turbid plume.

    There are several ways that this impact can be reduced. One method involves actually applying a layer of smooth cobble and gravel to the channel bed prior to taking the diversion down. This gravel encapsulates the fine sediments underneath and prevents plumes of turbid water. Another method is to clean the channel in one of two ways. One is to use a pump with clean water to power a hose and nozzle that is used to wash fine sediments to the downstream of the diversion where it can be pumped out of the channel. A less technical way is to allow pulses of clean water to flow from the upstream coffer dam. The pulses of flow collect sediment where it is pumped out of the channel from the downstream coffer dam.

13. Once water is no longer being diverted into the pipes, the pipes should be emptied immediately. This is because fish are often in the pipes and the remaining water in the pipes can get heated or depleted of oxygen in a short time. To empty the pipes, start at the upstream end of each pipe and lift it above your head. Then, walk your hands down the pipe so the water is all forced out toward the downstream end (see photo at left).

14. For handling turbid water, pump options include electric pumps and gas-powered pumps. Both come in different sizes to meet the needs of any project. If using a gas pump, it should be set inside a containment vessel to prevent fuel spills from entering the water. Electric pumps are usually run by a generator, which can be located outside of the channel area, reducing the possibility of a fuel discharge into the channel. Since they are generally one speed pumps, the pumping rate cannot be manipulated like a gas pump with a throttle lever. In cases where the pumping needs to be moderated to avoid running out of water, a float valve can be used to turn

the pump on and off. Most electric pumps have their intakes on the bottom. This helps them work in shallower water than a gas pump. However, they don't work well when placed upright directly on the channel bed. They will need to be set at an angle in a deeper pool set on a stand to leave space enough above the channel bed to achieve good intake volume.

If the diversion and turbid water management system depends on pumps, it is worth the extra cost to have a backup pump onsite and ready. Pumps can break down and when they do it is important to have another ready to set up on short notice. It can be very expensive to stop work to get another pump as you are still paying for the equipment onsite to sit idle. Pumps also have maintenance needs, so these need to be considered. If the diversion is being managed by the contractor, talk with your contractor about having backup equipment ready.

15. Surface diversions are usually built during the day when riparian vegetation is drawing in water for growth. At night, when photosynthesis stops, the plants are not taking in water. The result is that water levels in most streams will rise overnight. Be sure the diversion has sufficient capacity to accommodate this extra water.

16. Always make sure there is an adequate budget for water management.

Case Study: Dewatering using a temporary well.

While working on a fish passage project on Stenner Creek, the surface diversion alone was not sufficient to dewater the work site. The issue on this site was that it was in an upwelling zone where groundwater was pushed to the surface. While it is normal to have subsurface flows below the channel bed, it is quite another issue if the subsurface flow is triple the volume of surface flow. To keep the site free of flow, another method was needed.

The solution was to use a submerged slotted well pipe to pump the subsurface flow out of the work site. An excavator was used to dig a hole approximately 7 feet deep. In the hole was placed an 8 inch PVC pipe with slots cut in it to let water flow into the pipe. The channel bed was re-filled with the pipe embedded in the channel bed. A submersible pump was placed into the pipe to pump the water down.

One of the benefits of using this technique is that the water being pumped was clean. Therefore, we could discharge it directly into the channel downstream of the project reach. When discharging water back into the stream bed, set up some way of dissipating the energy of the discharge so it doesn't create turbidity by disturbing the channel bed. Placing the hose in a basin made of larger cobble works well.

Building Habitat Structures

Rock Structures

Many riparian habitat restoration projects involve building rock structures. These projects can be challenging and a test of your patience, as well as your excavator operator's patience. Getting these structures constructed properly the first time saves a lot of time and money. Below are a few tips to help make your rock structures easier to build and longer lasting in the stream.

1. The most important part of a rock structure is, of course, the rock. Not all rocks are created equally however, and you want to use the strongest rocks available. In California, this is usually granite because it is very hard and heavy. It is capable of holding steel cables permanently and its angular shape makes them well suited to instream structures. Softer rocks, such as serpentine, are brittle and fracture easily, making them inferior for in-stream work (see photo at right, cabled rock failure). Caltrans has standard specifications for rock durability and density.

2. When building rock structures, the best rocks are those with angular shapes and large flat faces. Rock structures get much of their strength from adjacent rocks that have a lot of rock face to rock face contact. Boulders with rounder shapes tend to roll and not have good contact with adjacent rocks.

3. Nothing is more frustrating than finishing a rock weir and noticing after the first flow that it leaks like a sieve and does not perform its ideal function. Sealing weirs has traditionally been done by backfilling the weirs with graded gravel mixed with fine sediments. Sometimes this just doesn't work and you find yourself trying to wedge rocks in the gaps. Questa Engineering recommends an even better approach. On a recent project they used the stuffing from a Coir log to jam into the gaps between the rocks. The material is well known for its ability to trap fine sediments, and it also swells when it gets wet. It worked well on that project, sealing the weir right away. From their experiment, it appears that this method was quite successful.

4. When ordering rock from a quarry, it is very common to get some material (cheap filler) that just won't work structurally. It is either too small, too round, or has fissures in it. If possible, go to the quarry to pick the rocks out yourself. That way you can get what you need and don't pay for material you can't use (see tip #6 below, as sometimes there are good uses for the filler). Some quarries do not allow customers in the pits, however. In this situation, it is probably better to order an extra truckload of rock so you have the volume of usable rocks that you need. Another advantage of ordering some extra rock is that you have choices of several rocks to use in each situation. Building rock structures can be like building a puzzle. Sometimes a piece of a certain

size and shape is needed to finish it. Having several rocks to choose from makes building easier and faster. Before ordering extra rock, determine what will happen with surplus material, because removing is can add to project costs.

5. For most rock structures, the goal is to get the rocks to sit at certain elevations. For example, when building a crossvane, the elevation of the keyway into the bank will sit at the bankfull elevation and the spillway will be at channel grade. A fast way to make sure the elevations are correct is to set elevations using a laser level. With this system, a base station is set up on the site in a location that will not be disturbed. Baselines elevations are set for the bankfull and channel elevations. A receiver on the rod is set to the desired elevation, allowing quick readings. In this way, one person can direct the rock placement and check the grades at the same time.

6. It is also important to understand the gradation and level of sorting of the rock being used. Some structures require that specific large rocks are used and cabled together or set in place with the intention that they will not move, as discussed above. In some streams and projects, however, poorly sorted and well graded rock is best as this type of rock allows for structures to adjust and repair themselves when a failure occurs. In other words, a load of rock with many different sizes (poorly sorted) and each size being well represented (well graded) has the ability to re-settle and lock into place following some kind of disturbance to the structure. This is especially important to use with structures such as rock toes, rock vanes, and even riprap.

Case Study: Building adjacent to "fixed" structures and the path of least resistance.

This project on Stenner Creek involved construction of a series of step pools to help fish access a road culvert. The culvert had two barrels, one was at a lower elevation and contained an existing offset baffle for fish passage. The second barrel was about 1.5 feet higher and had an extended concrete apron that was used as a road to move farming equipment through the culvert. Both of the culvert barrels were perched above the channel bed, and the project plan was to use step-pools to raise the water elevation to provide better access to the fishway and allow all age classes to pass through the structure.

Rock weirs were constructed in the natural channel downstream from the culvert and adjacent to the longer concrete apron. The boulders were anchored into the natural bank on one side, but we were not able to key rocks into the concrete. Instead, the boulders were placed up against the concrete and attached by cables. Each weir dropped and had a narrow spillway for fish passage. By all appearances, the structures should have worked fine.

The structures worked for the first few flow events, but after a larger flow event the stream flanked the upstream weir by undercutting the concrete road/apron. Now with the stream flowing under the access road, fish passage benefits were lost and the road was destabilized. Placing additional rock at the upstream end did not solve the diversion of the water under the road.

In this case, the path of least resistance on the surface was not necessarily the path of least resistance below the surface. Under the rock weirs, footer rocks were installed, and these made for strong resistance once flows had mobilized enough bedload to expose them. Under these conditions, the main channel resisted flow better than the substrate under the road. So, flanking doesn't just happen on the surface.

In the photo above, the road has been undercut and the stream flowed underneath. Fortunately, this road is on the campus of a great engineering university. This thing was built with a lot of reinforcement, so only minor damage to the road was evident from the undercut.

When it came time to repair the project, the method chosen to seal the pathway under the road was a reinforced concrete wall. The wall extended approximately 4 feet below the channel grade.

Now sealed, the weirs have effectively provided fish passage on Stenner creek. In addition to the added wall, a whole truckload of concrete was poured into holes in the concrete road to backfill the undercut area. This made the road strong enough to use again.

The moral of the story is that in situations where there is fixed infrastructure, your options for improving fish passage are often limited and more aggressive design needs to be considered.

Case Study: Notching a Grade Control Dam for Fish Passage

On Prefumo Creek, three grade control structures were to be notched to better pass migrating steelhead. These were installed in this section of the stream when it was re-routed from its original path to fill a nearby lake. The first two were simple concrete walls and sawing out the notches was quite simple. Rock weirs were then installed downstream to help raise the pool elevation. The third, however, was a much larger structure made of mortared riprap. The structure itself was approximately 7 feet thick, so creating the notch was really more like creating a channel through the structure. The plan was to make the channel lower with the notch and raise downstream water elevation with a boulder weir. The project was laid out with the notch emptying into the existing plunge pool and the boulder weir at the existing pool tail. Smoothed cobbles were embedded into the mortar in the channel and it made for a great simulated channel.

Through the first few rains the flow created excellent passage conditions for steelhead. The problem came with the first big storm when water velocity in the notch channel was very high. Prior to the notching, high velocity flow dropped quickly off the weir and dissipated energy into the plunge pool in a downward direction. With the notch carved in the weir, the energy was more concentrated and directed downstream. This higher energy flow pushed the pool tail downstream and led to the water undercutting the boulder weir. Ultimately, the weir, though cabled together, flipped over. The flipped weir was no longer functional.

After one unsuccessful attempt to repair the weir, it was determined that it was not worth the effort. The cables were removed from the rocks to let them redistribute in the channel bed. Whether it was luck or nature, the “naturally” relocated rocks made the pool deep enough to facilitate adult steelhead passage.

The moral of the story is that when a project alters the concentration and the direction of water flow, plans need to be made to accommodate the shifting of existing channel bed features.

Looking back, the issues encountered in these case studies could have been anticipated. Today they serve as reminders that despite all the advances in the field of designing instream structures that it isn’t always possible to think of everything. With each lesson learned, however, our field continues to grow more each year.

Root Wads

Root wads are large sections of tree trunk with the roots still attached, and make an effective and natural material for habitat improvement projects in rivers and streams. They are anchored into the stream bank with the roots exposed to the stream flow to create a scouring effect that creates and maintains pools. CDFG’s California Salmonid Stream Habitat Restoration Manual provides a number of ways to use root wads and logs, including design drawings. Here are a few hints for ensuring that these structures work as designed.

1. It is important that the root wad has a good length of log attached to it. At least 20 feet of log is needed for anchoring. Better yet, get them as long as possible and cut them to size onsite. Length is important because the root wad will extend into the active channel and there still

needs to be sufficient length to key into the bank. If the log is too short, there will either be too little support for the structure in the bank, or it will not extend far enough into the channel.

2. Root wads are often hard to find because most tree removal is done by saws. Prior to deciding on a structure type, consider the availability of the material. It may be more efficient to use a structure that uses just logs since they are more available. If a good source of material is found, consider stockpiling it for future projects.

3. In the location where the pool will be created, it is best to use the machinery on site to actually dig the pool rather than waiting for high flow to do this. This is particularly valuable in areas where rainfall and flow are more fleeting. Periodic drought years may not generate the channel-mobilizing flow necessary to create the pool and it may take years to create pools if they are not dug during construction. On some projects, the bedload size in the vicinity of the scour structure is reduced by adding small material. This facilitates better initial scour and the formation of tailwater riffles. It's always more satisfying to see the project work immediately and for all the effort of construction it should begin benefitting fish as soon as possible.

4. When anchoring the log into the bank, the rock protection on the log should not extend too far into the channel. These can reduce the scour caused by the root wad and may even result in sediment accumulation. Most of the rock support can be buried with the log in the bank.

5. It is critical to key-in root wads deep into the banks because the exposed roots will be exposed to high flow energy and will be pulled out if not secured. There are several dimensions to think about in anchoring a log into a stream bank. First, a layer if rock should be placed in the key trench under the log as ballast. Cabling the log to these rocks will help it stay secure in the ground. Boulders are also placed over the log and ideally the logs and boulders are cabled together for added strength.

6. There is another way to key a log into a bank other than disturbing an intact stream bank to dig a large key trench. On some projects large root wads have been driven into the bank by sharpening the trunk end with a chainsaw and pushing the root ball into the bank with an excavator. The success of this technique varies depending on the soil type and the size of the equipment available on site.

Root wads should be placed well below the ordinary high water elevation in anticipation of some channel degradation immediately after construction. Ultimately, root wads make the most habitat when they have a high profile in the channel and stream gradients are high enough to provide a reliable source of scour energy. The tradeoff is that anchoring is more challenging in these cases. On lower gradient streams, the root wads tend to act more like deflectors and usually collect sediment, which can improve bank stability and offer some channel complexity. Occasionally higher flows may create a pool that is shorter lived before it fills once again.

Gradient Control

When working in an active stream channel, pay particular attention to the stream gradient. If the channel gradient in your project reach is steeper, adding to or subtracting anything from the channel will likely alter the hydraulics of the channel. These alterations can cause channel bed degradation (incision) or sediment aggradation (accumulation). Both can impact the habitats in the stream and need to be considered in the design phase of an instream project.

It is helpful to begin with the knowledge that channel bed elevations are not static from year to year, or even day to day in the winter. During storm events, channel material is mobilized and the channel depth may temporarily increase substantially. When placing material into the channel as part of a habitat project, you can expect some adjustment in the ways sediment is distributed during and after storm flows.

On many central coast steams, the channels are incised and may be disconnected from floodplains. The result is unusually high channel velocity and force on the channel bed. This energy causes substantial scour on the channel bed. For this reason, it may be necessary to include some form of gradient control in the project design, both to protect your investment in the habitat project and to help the project function properly over time. Below are some points to ponder when considering grade control.

1. When working in a higher gradient stream or incised channel, it is important to identify the existing gradient control for your site. These may be bedrock, boulders, logs, or any other structure that prevents channel bed degradation. These might even be manmade structures. In some cases, the gradient control might not be overtly visible because it is under the channel bed. The existing grade control should be assessed for stability to evaluate any risk of the grade failing and resulting in a headcut that can travel upstream and damage the project or other infrastructure.

2. Keep in mind that gradient control can create fish migration barriers in the future in actively incising stream systems. Be sure that the project design takes this into consideration. One way to address this is to place an additional grade control structure sub-grade downstream of the at-grade control structure. This can act as a step-weir in the event that the stream degrades. This can cost a few extra dollars, but on those more challenging or high-gradient sites it can save money in the long run.

Case Study: Gradient Control on a Small Dam Removal

This fish passage barrier project involved a flashboard dam in Stenner Creek. During low and moderate flows, the structure was usually passable by steelhead. As the flow increased, however, the force of the water increased behind the dam and caused a velocity barrier for migrating fish. The project plan was to remove the two walls that impinged on the channel, and leave the wing-walls to protect the banks and leave the concrete base and apron to act as gradient control. See photos below of the dam before and after construction.

However, in all the years that the flashboard dam was in place, the restriction of the high water flows caused bed-load to settle upstream and it formed a stable gradient of the stream. When the inner walls were removed, it allowed the water to flow much faster, and the stored sediment upstream was washed through the structure. The channel bed head cut traveled upstream approximately 200 feet and perched a culvert that was installed at the prior bed elevation.

The moral of this story is to specifically consider gradient issues with instream projects, and that gradient is not just a function of channel bed elevation, but a reflection of flow volume and velocity.

Streambank Stabilization

Unstable stream banks are among the largest sources of sediment in streams. In stream where sedimentation is a threat to fish and other aquatic life, repairing these banks offers a way to reduce sedimentation of streams and improve water quality and riparian habitats. Stable banks also support more vegetation to enhance instream habitats. A look through any urbanized watershed will show a hundred different ways to stabilize a stream bank. Unfortunately, most of these methods also contribute to excessive channelization of the stream and may cause as many or more problems than they treat.

Whenever and wherever possible, project managers should use bioengineering methods to repair banks that contribute not just to channel stability, but channel ecology. Not all of these methods are appropriate for all sites; however, choosing a stabilization method is probably the most important first step. Many methods are available to choose from and the sources cited in the literature review chapter of this manual are a great place to start.

Before stabilizing a streambank, it is useful to consider that it may not always be necessary or advisable to physically repair an eroded stream bank. Bank erosion provides the majority of bedload sediment in the stream system. Stabilizing the banks reduces the sediment input and may lead to channel incision. It is also through some bank erosion that streams naturally adjust to the dynamics of hydrology and sediment movement in a watershed. Stream movement is natural and it is not always proper to prevent that movement.

In most cases where banks are actively stabilized, it is done to address specific problems associated with the streambank, such as threats to farming operations or municipal infrastructure, or where sedimentation is anthropogenic or so persistent that natural habitats are damaged. Ideally, eroded streambanks should be evaluated and prioritized on a watershed-wide scale that considers natural functions and areas where nature is less likely to repair the stream as a result of human impacts on the stream.

When stabilizing streambanks, there are many methods to choose from. Some are based principally on restoring the most natural stream function and others are chosen for their strength and durability. Choosing the method is often a balancing act where each step taken to increase its strength compromises natural functions, such as the ability of the stream to migrate or its ability to support vegetation. In more urbanized areas where water velocity and force are very high, and where urban infrastructure may be at risk from the eroded bank, methods will trend toward the more robust engineered solutions. Outside the urban areas where streams have more room to move, have more space to work on the top of the bank, and where streams may have good floodplain connectivity, more natural methods can be used. On these sites there are usually fewer threats to critical infrastructure.

A last general word on streambank stabilization, and a very important one, is that an eroded stream bank can only be effectively stabilized if the upstream and downstream extents of the project terminate at existing stable banks. Trying to patch an eroded bank in the middle, with unstable banks on the upstream or downstream extent, simply will not work. Hydraulic forces will work against these projects and in all likelihood, the stream will flank the project reach. Below are some tips on installation techniques and materials associated with bank stabilization projects.

Tips for Bank Stabilization Projects

1. Choose a project design carefully using existing restoration guides. Project proponents can work with engineers to develop bank stabilization decision trees that address infrastructure needs and habitat quality.

2. It is recommended that project planners consult local engineers that have experience working on stream banks to discuss project methods with respect to the forces they will need to withstand. This doesn’t always mean having an engineered project, but their advice will help you make the most informed decisions. Obviously, if the project is critical to protecting infrastructure, a home, or other valuable asset the project should be engineered to ensure appropriate function. For lower risk areas it may not be necessary to go through a costly design process.

3. In general, project designers should first consider whether or not a streambank can be laid back to immediately stabilize the soil and reduce bank sloughing. Also, if there is room, floodplain benches can go a long way towards reducing velocities and alleviating stream bank erosion in incised systems. When re-sloping a streambank, a slope at 3:1 or close is effective in reducing erosion and supporting native vegetation. Some soils will maintain stability at steeper angles, so knowing the soil characteristics is important for your design. An engineer familiar with soil strength can be helpful in deciding what angle of repose is appropriate. If space constraints require a steeper slope, it is advisable to use a more robust stabilization method such as soil wraps, brush mattress, cribbing or brushlayering.

4. When working in areas where risks of infrastructure damage are absent or very low, consider using natural materials for toe protection. Both Coir® bio logs and willow fascine bundles can be very effective. These materials will either biodegrade or grow and leave the bank in a more natural condition. They are also flexible and can be formed around any desirable channel elements that you leave in place. When natural methods are used, the capacity for the stream to naturally migrate in the future is retained. Rock can be used as a bank toe stabilizer and still work very naturally depending on the size of the rock, the volume used, and the height of the rock on the bank.

5. When a stream bank is graded, the surface will need to be protected from erosion, both from rain and streamflow. There are many products on the market for covering streambanks, and some combinations of materials can greatly improve success. One effective method is to apply a four inch layer of shredded redwood bark mulch on the bank prior to installing a coir (coconut fiber) fabric. This mulch layer adheres well to the soil and the netting so there are few open spaces between the netting and soil. This prevents substantial flow over the soil under the netting and can keep erosion to a minimum. The mulch also has the added advantage of maintaining soil moisture, which is good for installed plants and suppressing most weed growth. Ultimately, this method reduces repair and maintenance costs and has helped projects be successful.

6. For banks where hydroseeding or broadcast seeding is to be used to help establish quick cover on newly graded banks, a 2 to 3 inch layer of coarse compost or other wood mulch can be applied under the coir fabric in lieu of the shredded redwood bark mulch. This will also fill the voids between the soil, insulate the seeds, and provide slow-release nutrients to newly planted stock. Be sure to check with local authorities on the use of compost near streams and never use hot or fine compost as the nutrients can be harmful to aquatic organisms. This technique works especially well on upper banks and to stabilize floodplains where revegetation is desired.

7. For streams that are deeply incised, including even a modest instream floodplain bench at the bankfull elevation can provide an ideal location for planting riparian trees where they can quickly access water. They also serve to reduce velocity at the bank toe.

8. In incised channels common in southern California, as plants spread up the bank, they are getting further from water and riparian plants may not get established in this “arid” location. For this reason, consider including some more drought resistant species on the upper banks. While this may alter the ecology somewhat, these species may help in providing functional habitat. Sometimes this means that shade is provided by an oak tree instead of a sycamore. These adjustments to plant palettes may also be appropriate on other streams in recognition that climate change is likely to alter rainfall patterns. In our southern part of the state we need to be prepared for a drier climate and make sure our plant palettes have sufficient diversity to adapt to changing conditions.

9. Stabilization of the toe of the bank is critical for all projects as the toe provides the base for all other techniques. For the purposes of this book, the toe extends approximately to bankfull

elevation. This is where the stream does the most "work", actively adjusting as it erodes soil particles and deposits sediment.

Slope & Bank Toe Stabilization

Rock Riprap

There is a wealth of information regarding specifications and installation of rock riprap. Engineers have developed sound formulas for specifying the rock size and structural dimensions needed according to the characteristics of a stream. Although riprap is commonly used and can be very successful in stabilizing streambanks, especially to protect infrastructure, it has lower habitat value than vegetation-based stabilization, and if installed incorrectly can easily fail.

The following design components and installation techniques can dramatically improve long term stability of riprap and decrease potential negative impacts to habitat.

1. Rock selection lies at the root of a riprap design. As discussed earlier in this discussion, rock rip rap should be composed of well graded, poorly sorted, angular rock to enable "self repair". The idea is that if one rock is dislodged by streamflow, the other rocks that inevitably slip will lock in together to fill the void. On the other hand, poorly graded, well sorted rock will likely fail since the odds are that the moving rocks in the structure will not fit well into the void that is left from the original moving rock. Essentially these rocks are more likely to bounce off of each other and continue to move. As an added benefit, the smaller rocks found in well graded, poorly sorted rock initially help lock in and stabilize the larger rocks, and provide an additional barrier between streamflow and the soil underneath.

2. One way to improve riprap is to vegetate it. This must occur during construction to be successful. The most common way to vegetate riprap is to install long willows cuttings in the toe trench and underneath the rock as it is placed to achieve good soil contact. The tips can then be bent up so that they stick out of the riprap. This technique is good for providing shade over the stream where otherwise the canopy would be nonexistent. Vegetation also provides additional roughness to reduce flow velocities and roots provide additional soil strength.

Rock riprap alone, along with techniques such as concrete lined channels, is among the least environmentally friendly techniques for bank stabilization. That being said, where critical infrastructure protection is needed, well designed riprap is very effective.

Rock Toe Protection

On sites where bioengineering is not enough and some additional armor is needed, rock toe protection is an ideal solution. This technique provides stability to the toe and can be used in combination with other methods as it forms a stable "foundation" for the installation of bioengineered techniques on the upper banks. Here are a few tips regarding the use and installation of rock toe protection:

1. Rock toe protection can be used in conjunction with redirective techniques such as rock vanes, and weirs, and other bank stabilization techniques such as brushlayering, soil wraps, erosion control blankets/turf reinforcement mats, and revegetation.

2. In most cases it is critical to use well graded poorly sorted rock for this type of structure.

3. The rock toe can be buried during construction to serve as a backup in case bioengineering techniques fail and the stream migrates more than expected. Trenching the rock below the anticipated scour depth ensures that the rocks are not undercut.

4. Rock toe protection can be used to form an instream floodplain bench.

Biolog Toe Protection

Coir biologs can stabilize a bank toe and make a good addition to a bioengineered bank solution (See photo on Page 48). They are often combined with willow pole plantings to encourage a natural bank toe. The logs are made of shredded coconut husks and are very dense. Properly anchored, these logs can sustain substantial hydraulic force. They act to protect the planted willows and the soil at the bank toe from direct scour. Other advantages are that they are flexible and can be curved around existing vegetation, and they also hold a lot of moisture, nurturing new plantings. These can be keyed into the channel bed, but in some cases can be installed at channel grade. One great advantage is that they can be installed by hand, so they are a good choice in areas where heavy equipment access is limited.

The most important part of using the biologs is to have them properly anchored. Many of the instruction sheets show these being anchored with wood stakes. This method has proven difficult on many sites with rocky soil. The wood stakes often break and cannot be driven deep enough for good stable support. In some of these cases it has been easier to anchor them with larger willow poles. These tend to hold up to hammering better than wood stakes and pilot holes can be driven in advance of inserting the poles. The willow poles on each side of the biolog are wired together before the final driving on the stakes. Biodegradable rope can also serve the same function. This pulls the log in good contact with the soil surface. Steel form pegs can be used to drive the pilot holes for the willows. These are the steel pegs often used in concrete and masonry work to support wooden forms. The stakes are rigid and they are pointed on one end. In some challenging situations steel pegs may be used along with baling wire to hold down the logs. While these materials are a bit less natural, they provide superior performance. In most cases these can be removed once the vegetation on the bank has become stable.

Willow Fascine Toe Protection

Willow fascine bundles are made by bundling live willow cuttings in a linear fashion, forming a continuous “wattle” of willow. Some of the references in the literature review have easy instructions for this simple technique. Used as toe protection they are among the most natural ways to treat a bank toe. In most cases, the material can be collected locally and constructed onsite. This is a good method for sites where equipment access is limited and where materials are abundant. The most important part of installing these is making sure they are very wet and that the soil used to bury them has good contact with the willow stems. Because water is so critical to achieving a successful outcome with this technique, it will be important to monitor and possibly irrigate.

Things to Avoid

In general there are techniques that are either known to fail more frequently or provide no habitat benefit and should be avoided. The following list identifies these techniques and provides brief justifications for why they should be avoided.

- Gabions (wire baskets filled with rock material), are a poor choice for most stream systems. They are often too rigid, and are prone to flanking and ultimately complete failure. The wire used to hold them together is prone to corrosion and can also be hazardous to fish, other wildlife and people once it breaks. Gabions, like riprap, can be vegetated. So, if project designers insist on using them, vegetation should be incorporated into the design and they should only be used to protect the toe. A more natural alternative to gabions are Bio-blocks ™ made by Rolanka, which are essentially a coir gabion.

- Grout is inflexible and also prone to failure over time. As dynamic systems, streams need to be able to adjust, and grout fills the voids in rocks that would otherwise be used by fish for cover.

- Very large rock is also inflexible and usually unnatural in most systems. When large rocks do shift they can deflect flow into banks, thus potentially causing new problems in the channel.

- Spurs can cause more harm than good when designed above bankfull elevation. Spurs, also known as groins, do not provide relief when streams are at flood stage and the eddies that form around these structures can cause erosion.

Case Study - Bank Re-Sloping Without Buried Toe Protection

The simplest way to repair a streambank is through re-sloping the bank and replanting it with native vegetation. In most cases, some bank toe protection such as coir biologs, willow fascine bundles, or rock toe protection is included. Toe protection is usually buried sub-grade to protect the new bank from undercutting. In some cases, however, using natural toe protection beginning at channel grade is acceptable. This allows some undercutting of the bank and was tested as a means of stabilization that did not preclude the formation of undercut banks.

On this project on San Luis Obispo Creek, the biolog toe protection was installed at channel grade in order to test a strategy of encouraging some bank undercutting. At this site, there were very low risks of property or infrastructure damage, so it made a good test site. The goal of the project was to stabilize the stream bank by re-sloping the upper banks and providing some strength for the lower bank where bankfull flows will have the most effect.

The nearly vertical stream banks did not support native vegetation well, so the bank continued to erode. Therefore, the bank was re-sloped. For most sites, a 3:1 slope is ideal. This slope will support vegetation and the increased channel volume will have the effect of reducing scour velocity. Typically, sloping the channel begins at the top of the toe protection since the toe protection can usually be at a steeper angle.

By avoiding the trenching associated with the toe protection, it was possible to complete the project without any water diversion, saving the associated costs of a sediment containment system. The biologs were planted with live willow cuttings between each log.

When finished with the grading, the bare bank was stabilized by applying a layer of shredded redwood mulch to a depth of four inches and covering the mulch with coir netting. The mulch has the effect of maintaining high soil moisture and suppressing most grasses and weeds. It also prevents raindrops or irrigation water from hitting the soil below and helps prevent washout of soil under the netting. Together, the netting and mulch help the native plants thrive while substantially reducing maintenance effort and cost.

The last step is the installation of native plants. The project was very successful, and years later this section of bank is not discernable from the natural adjacent banks.

<u>Case Study – Bank Re-Sloping with Buried Toe Protection</u>

This bank of Santa Rosa Creek in Cambria, California is a good example of using a combination of re-sloping and revegetation along with an armored bank toe. In this case the site had a nearly vertical eroded bank about 12 feet high. This project is in the lower portion of the watershed, so this reach of the stream receives high flow velocities. These flows can cause substantial scouring. It was fortunate that the eroded area was just about 150 feet in length and both the upstream and downstream banks were naturally stable.

This reach of the stream is located on the Fiscalini Ranch Preserve, a publicly owned open space area. Since the land is protected partly to enhance habitat values for fish and wildlife, it was important that the project was as natural as possible and ultimately fit in with the management goals for the property. At the same time, the eroding bank was progressively moving toward a main sewer line for the town of Cambria. In fact, the sewer line had already been moved once before due to encroachment by the stream.

The project plan was to stabilize the toe of the bank and slope the upper banks so they would support vegetation as the primary stabilizing measure. Rock toe protection was chosen to ensure that the bank did not undercut further and threaten the sewer line.

The rocks were placed in a toe trench on top of live willow stakes. For most projects rock only needs to extend up the bank to the height of the bankfull discharge elevation. This allows planting to be as close to the stream as possible while still providing stability. Since the toe was armored, it was stable enough to include two root wad pool structures. These make nice deep pools for the local steelhead.

The upper banks were then covered with shredded redwood mulch and coir netting and planted with a diverse palette of native plants. The plants were planted on approximately 4 foot so centers they would be able to grow together in the first few years.

The photos below show the bank just after construction, and then three years later where the site was stable and native vegetation was thriving.

Upper Bank Stabilization

Treatments to upper banks can generally be bioengineered and offer the most promise for incorporating environmentally-friendly techniques into bank stabilization projects. Below are some tips related to several types of techniques applicable to upper banks. Again, detailed specifications on how to design and install these techniques can be found in the references cited at the beginning of this handbook.

Brushlayering & Brush Mattress

Brushlayering makes use of alternating layers of live willow material and soil. In this technique, willow cuttings are placed horizontally, extending from the bank toward the stream. Between each layer of "brush", one or more foot of soil is added and lightly compacted forming the "lift". A brush mattress is a similar method, but involves placing a layer of willow cuttings vertically, extending from the bank toe up the bank slope. These are anchored onto the bank slope and buried. In both methods, the rooting willows stabilize the bank.

1. In Central Coast streams, willow is always the best material to use for brushlayering or mattressing. Cottonwood can also work well in Northern California and has also been known to do better than willow in places like Canada.

2. Willow should always be soaked immediately following cutting and prior to planting. Ideally willow cuttings would be soaked partially submerged in a bucket or a pool in the stream for one to two weeks prior to installation. The soaking triggers a rooting response in the willows and will help more of the cuttings survive.

3. When laying willow for brushlayering, always place it with the tips pointing out and slightly up. In other words, when forming each soil lift be sure that it is sloped down towards the bank. For a brush mattress, remember to place the willows with the bottom end on the bottom.

4. No matter how much total length of each willow cutting is covered by soil in each layer, be sure to cut most of the exposed tip off to equal roughly 80% in the soil and 20% above ground. That being said, it may be desirable to leave longer portions exposed on some of the cuttings to provide immediate roughness along the streambank.

5. Always water in willow cuttings. Once each lift is built, soak the willows with water hoses immediately after they are placed and continue to spray them with water as the next lift is started, until they are covered with soil. This is important because the structure will be very dense when finished and it will be hard to get enough water to percolate deep and evenly into the structure to initiate and sustain the rooting of the willows.

6. When building any live willow structure, it is important to have a long term irrigation plan, as a dry year or poorly timed rain can cause these structures to fail to root. Your water source should be identified in advance and plans made to ensure that they do not become dry. In situations when a private landowner or other party is taking responsibility for watering it is important to check in with them to be sure the project is being watered. Because water is so critical, it should always be a central part of your project budget.

Soil Wraps

Soil wraps are similar to brushlayering; however the soil lifts are reinforced with coir blankets or other types of erosion control fabric. The wraps provide immediate stabilization and last for up to 3 to 5 years while the willow and other vegetation are given a chance to establish. A soil wrap can be described as a soil filled taco with the opening buried in the bank. They are useful for steeper banks because they can be terraced to create a slope. In-between each wrap, or lift, live willow branches are placed to permanently stabilize the soil.

1. Soil wraps depend on a stable foundation. Rock Toe protection or softer techniques such as biologs must be installed at the toe to provide solid support for the lifts of soil.

2. Soil wraps are usually installed starting at bankfull elevation and extending up to the high water mark.

3. The size of each lift and the type of fabric used for this technique depends on the soil type and channel dimensions. Generally, a coir fabric with a weight of at least 900 g/m^2, should be used. There are also blankets made specifically for soil wraps with a finer fabric on one side to help keep fine soil particles from moving through the fabric. If you are unsure about what material to use, consult your project engineer or erosion control specialist.

4. Other geotextiles can be used for soil wraps but have drawbacks. Plastic netting can last longer than natural fabric, however the plastic will persist in the environment once it breaks apart, and the netting can kill wildlife, especially amphibians and reptiles. Avoid using this material if possible.

5. One of the challenges of installing soil wraps is getting a smooth face that allows the blankets to stretch tight when wrapped. It is very important to get good soil contact and snug fabric. Loose fabric is easily agitated by high stream velocities and it creates its own localized turbulence which can cause premature breakdown of the fibers and mobilization of the soil particles underneath. Ideally, the bucket of the excavator can be used to shape the face and the horizontal plane of each lift. If you are having trouble keeping the soil at the correct slope/angle, or you are doing small soil lifts by hand, plywood sections can be used to shape the face.

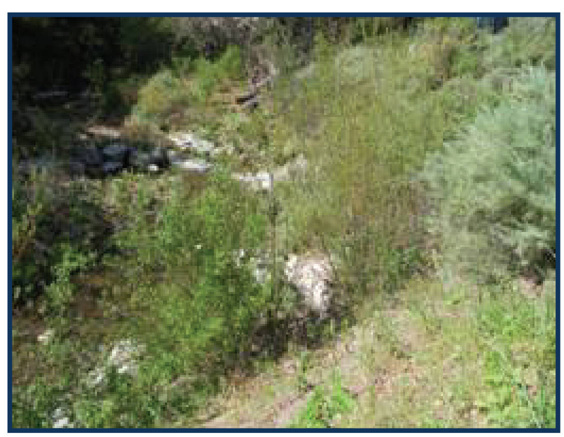
6. Enhancing soil wraps by seeding grasses and forbs under the fabric helps with erosion control, especially when using material with a more coarse and open weave.

7. It is critical that the proper compaction is obtained. Generally the excavator bucket can achieve this on small projects. On larger riverine projects dozers and other heavy equipment can be driven along the lifts to compact the soil. A compaction rate of 80% will help with slope stability without inhibiting riparian vegetation growth.

<u>Case Study: Soil Wraps with Armored Bank Toe</u>

In a particularly challenging reach of Upper San Luis Obispo Creek, soil wraps were used to stabilize the upper bank of an actively eroding "S" curve. In addition to negative impacts to steelhead and other aquatic life, the eroding bank threatened a historic stage coach trail and the only access to the northern section of a rancher's property. The site was stabilized with soil wraps in combination with cross vanes, gradient control, rock groins, rock toe protection, and revegetation. As of this writing, four years and one really wet winter later, the bank remains stable.

With this particular project the soil used for the lifts was fairly heavy in clay and held together well. In most cases working from the top of the bank is best, but channel access was done on this project to avoid disturbing the vegetated area above the bank. The fabric has held up well and the willows are almost 20 feet tall.



Revegetation Projects & Techniques

A great deal of restoration work includes revegetation. Vegetation is really the key to a functioning riparian habitat as it provides for bank stability, sorting of bedload materials, instream fish habitat, insect fall for fish food, and shade to keep water cool.

Replanting degraded streams sounds easy enough. You put water-loving plants in a place that has water and it grows. Well, it’s not that easy. Over the years we have been able to refine methods and learn a lot about revegetation in riparian areas. Below are some important lessons that you can adapt to your projects. First, it goes without saying that because riparian habitats vary greatly throughout the state, there really isn’t just one right way to do this. Planting in a wet conifer forest will be a lot different than planting in more arid areas of Southern California. The discussion that follows is based on experience in a more arid area with some natural and some not-so-natural constraints.

Project Planning

Starting with a team approach to planning a project is the best way to take advantage of local knowledge. Your local native nursery people and landscapers have already learned a lot about planting in your region and most are willing to share their experience. It is valuable to have a relationship with one or more local nurseries because they can be a source of materials and troubleshooting advice if things aren’t working well on a site. Much of what is recommended below is an outgrowth of more casual conversations with local growers out on project sites.

When planning a project, look at a host of factors that will need to be considered, including which plant species will be used, how many plants are needed, planting density, the size of plant stock, if and how they will be irrigated, soil characteristics, and what installation methods will be used.

Site Preparation

For most projects you will need to prepare sites for planting. This usually consists primarily of weed management. Invasive and nonnative plants should be well under control if possible before planting. If the project area has invasive plants, a plan needs to be prepared for successfully managing them or the project has limited chances for success. There have been volumes written on the subject of weed control and these should be consulted in your planning effort. Below are just a few observations on site preparation that might help in your planning.

1. When doing the initial surface weed control, mowing has always worked better than disking. Consider mowing using a flail mower if possible. Flail mowers have a spinning cylinder with hundreds of tines with small blades on the end. The flail mowers are more resilient to rocks and uneven terrain, and they generally take the weeds down to the ground. Rotary mowers usually leave more of the plant on the surface. The soil disturbance caused by disking tends to favor colonization by weeds. Mowing leaves more of the soil intact and leaves topsoil on the top where it belongs.

2. Once the weeds are mowed, it is useful to do some simple seedbank management by applying irrigation and germinating the weed seeds. Once germinated, the young weeds can be manually removed with a hula hoe, regular hoe, or weed whip. All of these tools work better if the site has been mowed down to the soil. Sometimes several rounds of germinating is necessary. Manually removing the seedlings with weed whackers or a scraping instrument like a hoe is usually faster and easier than other methods such as solarizing.

3. Solarizing the plants by applying plastic sheeting over the area is another method used for seedbank treatment. The advertised benefits are that it kills weed growth and sterilizes the seed bank in the soil. In some locations this may work, but as is often the case, the plastic covering works to cook the seedlings, but it leaves the seeds viable in the soil. It is very difficult to get the ground hot enough to actually affect seeds. Solarization is less effective on windy sites because it is difficult to keep the plastic intact or the heat trapped under the plastic. The sheer volume of plastic can be a cleanup concern in the end, and having it photo degrade on the site just adds plastic to the environment. If solarization is used, use clear plastic rather than the black plastic. It generates higher soil temperatures while black plastic radiates much of its heat. Solarization may also take months to work, so this needs to be considered in the project schedule.

4. Herbicides are not usually necessary for this step unless the species to be managed has certain challenging characteristics. Ultimately, herbicides are expensive, may have unknown impacts to the site, and require the services of a licensed applicator. While they can be a valuable tool in some cases, in most cases it is possible to have the same success without them.

5. One weed in California is particularly invasive and harmful to riparian areas and should be placed as a priority for removal in the proximity of any restoration site and any watershed where funding is available to do so. Giant reed (Arundo donax) is a challenging plant to eradicate, however many watershed-wide efforts have yielded successful results. It is critical to use a “top down” approach for Arundo removal, in other words, from the upstream extent of the watershed downstream to the outlet of the watershed. There are many sources of information regarding how to successfully remove Arundo. For example, local Weed Management Areas can direct project proponents to information for specific counties and other groups working on Arundo eradication. The following tips provide some specific guidance and considerations for Arundo removal.

    a. Biomass removal, followed by two to four years of herbicide treatment, is required to effectively kill clumps greater than 3 feet in diameter. For smaller stands biomass removal is not required; the plant can simply be laid on the ground and sprayed to minimize herbicide drift and waste. It is best to treat Arundo during its active growing season, ideally during the summer months. Winter treatments tend to be ineffective and are normally impractical due to increased streamflow during the wet season.

    b. Leaving the root mass in-situ can help minimize negative impacts to streambanks. In areas where 500 square feet of ground and/or canopy area is disturbed, it is recommended that an appropriate tree or groundcover species be planted in its place to outcompete weed species that may colonize the site following removal.

c. Aquatically appropriate herbicides should be applied when working near any stream or other water body.

d. Biomass shall either be taken offsite to a waste facility or moved out of the floodplain and chipped onsite.

e. Consult with your local regulatory agencies to see if any permits are required for performing Arundo removal. Permit requirements will depend on the level of infestation and amount of disturbance required to perform the work.

Choosing Plants

Revegetation, by its nature, primarily consists of establishing native ecology on a site that has been disturbed. The parameter that can be best controlled in the site ecology is the species of plants used. Other ecological elements such as water availability, amount of sunlight, soil properties, climate, etc., are much more difficult to manipulate over a long period. The plants chosen for a site will be based on all these ecological parameters. When developing a plant palette, the goal is to influence the rate and type of seral development the site will exhibit over a time scale that is substantially longer than the term of most restoration grant contracts. For this reason, it is usually necessary to plant a combination of species that will include everything from the pioneer species, those adapted best for colonizing disturbed areas, to the "higher" plants that will characterize a more mature ecological stage. To understand this better, it is advisable to read up on ecological succession. Try to find some newer work on this topic, as biologists have changed the way they describe maturity in the last few years.

Plant palettes will use a variety of species. Pioneer plants are intended to grow quickly and shade the ground. This helps outcompete weeds and provides shelter for secondary plant, which represent the next stage that will replace the pioneers. Others will replace the secondary plants as the site reaches a more mature state. Just like natural recovery of disturbed areas, it is common for recovering areas to have a higher species diversity in the first years and over time the diversity tends to give way to fewer dominant species. Since a project must usually be installed just once, plant all types on the site so the building blocks of ecological succession are all present.

The first places to look when designing a plant palette are nearby reference sections of the creek that exhibit different levels of maturity. These reference sites should be in a similar part of the watershed because the species make-up in canyons, for instance, can vary considerable from areas that are wide open.

Tips for Plant Palettes

1. Plant a considerable variety of species on a new site so it is not over-reliant on fewer species to be successful. Simply, don't put all your eggs in one basket. With some experience, it will become evident which plants are best used for revegetation projects.

2. Be aware of the sun requirements for plants and the conditions on the site. Include shade tolerant understory plants in areas where some vegetation exists already. Some plants, such as willows, really require a lot of sunlight, so they are less effective in shady areas.

3. Not all plants have the vigor to make good restoration plants and poor performers can be crossed off the list for the next similar project site if careful notes are taken during project monitoring. This can save you from spending a lot of money on plants that won't survive.

4. When considering a planting palette, it is useful to know that plants grow better in natural plant communities. These are groupings of plants that occur frequently together in nature. The relationships of these plants vary from soil fungus relationships to solar influence and other situations where certain plants help others to be competitive. Selected plants should mimic palettes seen in nature.

5. Planning a plant palette should include consideration of how the site should mature over the years. Include plants of all seral stages in the planting so when the pioneer plants begin to die back, secondary plants are already in place to fill the voids. In the central coast region, coyote brush is a ubiquitous plant on restoration sites. These may only live five to eight years, therefore longer living plants are needed alongside them so the site matures as it would in nature.

6. A few points about selecting and procuring plant stock. It is advantageous to have the plants grown for projects on a contract basis. First, the plants will be available when you need them, and it also provides the opportunity to collect and grow out local cuttings and seeds to get local genetics. Contract growing also provides an opportunity to work with the growers to produce plants that are in good planting condition. For example, most commercial nurseries use a substantial amount of fertilizer to make the plants look good and healthy. This is fine for ornamental plants destined for a garden, but in the restoration field these plants will face substantial transplant shock when they are planted in native soil that does not have high nutrient levels. Highly fertilized plants also tend to have an imbalance between the amount of above-ground biomass and the root systems to sustain them, leading to a dieback when nutrients are reduced. On most sites it is not advisable to use fertilizer because the plants aren't naturally adapted for the nutrient levels and fertilizer is expensive. It also may run-off into watercourses and cause water quality problems. The only exception to this would be to include slow release packets in the planting hole during installation.

7. Using microbial inoculants may be recommended on severely degraded sites, or where soil has been substantially disturbed. These microbial mixtures contain essential soil fungi that assist plants in taking up available nutrients.

8. As mentioned earlier, consider climate change when designing a plant palette. As climatic regimes change, entire habitats will need to adjust. You can help them adjust by including some more drought tolerant species. If the site gets drier over time, there will still be native plants to provide some necessary habitats. If the climate doesn't change, there will be no harm to the site.

Planning for Irrigation

Planning for irrigation has a lot to do with when you are planning to plant. If planting in the spring or summer, it is likely that you will need an irrigation system to sustain plants until winter rains help the plants become established in their new homes. On the central coast, it is common to plan for irrigation for all projects because rain can be intermittent, unpredictable, and poorly distributed within the wet season.

The conventional wisdom associated with revegetation is that plants should always be installed in the fall. This is a good idea because it can dramatically reduce irrigation needs and associated costs as winter rains sustain and establish the plants. There are, however, exceptions to this general rule. Many revegetation sites, for example, are on active floodplains. On these sites, floods threaten to carry new plants to the ocean. Plants should be in the ground at least 5 months to really sustain a scouring flood. In the San Luis Obispo Creek Watershed, like other urbanized or semi-urbanized watersheds, flow downstream of the urban areas can rise quickly and floods are a lot more common. Upstream of the urban areas the streams generally do not flood as often and flows are reduced. This is why it is common to plant upper watershed projects in the fall and lower watershed projects in the spring.

For project sites that will be irrigated, you'll need to identify a water source. Wells, streamflow, fire hydrants, water trucks, and municipal systems can all suffice but have varying costs. The critical factors are how much water you can get and is there sufficient pressure. Designing irrigation systems can be tricky if you have to move water any distance. Factors such as water volume and pressure needs, slope of pipes, pipe friction losses, and pump sizes all need to be considered. Usually local agricultural irrigation suppliers can provide advice to determine the optimal choices for delivering the water you'll need and they can run the calculations of water volume and pipe friction to ensure that proper pressure is delivered at the project site.

Water quality is also an issue when irrigating. Along the central coast, it is common to have groundwater that is high in mineral salts that can have an adverse effect on the plants. Even using stream water can be an issue in some places. In San Luis Obispo, for instance, much of the summertime flow in San Luis Obispo Creek is treated sewer effluent. While it has substantial nitrates, the salts can alter absorption of nutrients into the plants. In some cases you may need to filter the water, but in other cases you can get away with just not overwatering.

There are a number of irrigation strategies for revegetation projects and they all have their pros and cons, below are some thoughts gleaned from field experience.

1. No matter the time of year the planting occurs, it is vital the plants receive a lot of water on planting day. Using a hose to fill up the hole and allowing it to percolate into the adjacent native soil is recommended before placing the plant in the whole. Doing this more than once is even better. When the soil around the plants is saturated, the roots will expand into the native soil more quickly. Having roots find the more compact native soils will give them the strength they need to withstand floods and support the biomass above ground.

2. Generally, watering with a hose has shown the best results for plant growth. The hose provides the most water to the soil where it is needed and allows the time interval between watering to be longer. Another benefit of hose watering is that water is not being provided for all the weeds that may invade the newly planted site. This can bring down maintenance costs. That being said, hose watering has its pitfalls. First, it is slow and requires lots of pipe, hose, water pressure, and labor. With some plantings consisting of up to 10,000 plants, hose watering gets less practical. Another drawback of hoses is that the scattered wet sites may attract gophers. For sites that

have been seeded, watering with a hose is not practical, making the timing of the project all the more important to take advantage of winter rains. In other words, seeding should occur in late fall if hose watering is the only option.

3. Overhead irrigation has an advantage on very large sites with a lot of plants. When using overhead systems, it is important to put a lot of water on the site before planting. The soil should be well saturated a day or two before planting, allowing it to drain some before installing plants. Overhead systems require a lot of pipe because coverage needs to be complete. A disadvantage of the overhead system is that they water everything, including weeds. While this does provide more food for gophers and reduce gopher predation on plants, it does drive up maintenance costs for weed management. Overhead irrigation does take a lot more water than individually watering plants, so the capacity of the system needs to be scaled with the size of the planting. To effectively water a site may take 8 or more hours of operation, so the water system needs to be high volume and continuous.

   Overhead irrigation does have a certain advantage if you are planning to use seeds to establish native cover, such as native grasses, between the potted plants. This, of course, assumes that weed management over the planting area is complete in advance through the use of pre-emergent herbicides (not usually approved for aquatic areas) or manual labor. Using mulch as a weed suppressant with native grass seeds in the mulch is effective and less potentially damaging than pre-emergent herbicides.

4. Drip irrigation systems are a third option, but these should be considered carefully before this method is chosen. The main potential benefit is that they use less water than overhead systems and they can be automated like an overhead system. The principal drawback is that they just don’t emit the volume of water most plants need and the water is so concentrated on the root ball that surrounding soils do not get saturated. On sites with drip systems, it is common for plants to exhibit very little root growth since the water is delivered in such a small area. With slow emitters, water tends to go straight down and less water goes laterally than using a hose with higher volume.

   Drip systems are also easily clogged. On projects using stream water for irrigation, or connecting to a large agricultural irrigation system, you need to account for algae and small pebbles being pulled into these systems. While the larger overhead systems and hoses can pass this material, drip emitters don’t. Therefore the water needs to be filtered or the emitters will clog. When using filters, it is often necessary to clean them every 3 hours of run-time on the system. This high maintenance need runs up costs and reduces efficiency. Plus, all that plastic needs to be cleaned up someday.

   Finally, wildlife frequently use drip systems as water fountains. It is common for animals to chew through the hoses to get at the water and these systems need to be constantly repaired.

5. One last method is flood irrigation. A flood system involves the construction of small berms around a planting area and filling the planted area with water. Normally it is not efficient to disturb the soil in this way and the berms require extensive maintenance.

6. Be sure you are not overwatering the plants. The goal with restoration is to have plants become established in a natural setting as soon as possible. If too much water is applied, plants do not send roots out looking for water. This slows the growth of the plant and leaves them more vulnerable to flood scour. Overwatering may also cause roots and stems of plants to rot. Before irrigating, always check soil moisture. A simple way to do this is to just dig your finger down 3 inches under the surface. If the soil is moist, then it is not necessary to irrigate. By giving just enough water for the plants to survive, they will adapt to become stronger. Hydrometers can also be useful in identifying soil moisture.

7. Finally, as the plants get established irrigation intervals should be increased. When first planted, plants need abundant water. As time goes on, lengthening the time between irrigating stimulates the roots to seek water deeper in the soil profile, thus improving plant establishment.

Planting Methods

Planting for native habitats is fairly straightforward, but a few tips can help your plants survive and adapt to natural conditions quickly. On the Central Coast, one gallon potted stock is the preferred size for plants, having the best level of survival in relation to cost. Begin the planting by laying out the potted plants on the planting area and arranging them into plant communities by grouping certain species. You can also evaluate your plant spacing easily at this stage. After experimenting with varying planting densities it was determined that 3 to 4 foot centers for shrubs and 8 to 10 foot centers for trees were optimal densities. This isn't necessarily the spacing one would see in nature, but it produces appropriate densities to reduce weed competition in the first 3 to 5 years. Also, when pioneer species begin to die back, the secondary species are already in place to take over.

Dense spacing addresses overall project costs because it directly affects the level of maintenance that will need to be budgeted for any given project. Generally speaking, the installation of the project is relatively inexpensive compared to the stewardship costs over the following two years. By planting more densely, the plants will grow into each other rather quickly. This has the effect of closing the low canopy and preventing sun from hitting the soil surface. This method substantially reduces weed growth in the two to three years following installation. See the mulch discussion below for more information on weed management for the first year.

Digging a hole and dropping in a plant in sounds simple enough, but the size of the hole is an important consideration. For restoration plantings, it was found that digging holes with a diameter of only 1 to 3 inches bigger than the diameter of the new plant's root mass helped the roots move into more compacted natural soil faster. These soils tend to hold water better and are more resistant to flood scour. If the holes are too big, plants tend to be easily excavated by high flows even after they have been in the ground for months.

Two other considerations for planting include flooding the holes prior to installing plants and being careful of the root mass. The holes should be filled with water and allowed to drain before installing plants. This gets water deep into the surrounding soils and will help roots move into the native soil sooner. Doing this several times can be a great advantage, but if it takes too much time then it may not be cost effective. When planting the plant, carefully pull the plant from the pot by holding it upside-down and gently squeezing the pot to dislodge the plant. Once the plant it out of the pot, place it directly in the hole without disturbing or roughing up the root mass as is often done with ornamental plants at home. The roots will expand on their own and the intact root mass will hold more moisture.

When placing soil back in the hole around the plant, be sure the soil is only lightly compacted. Compaction should only close most air pockets, but not inhibit roots from reaching the native soil nearby. Over-compacted fill soil also doesn't accept as much water from irrigation. If planting in heavy clay soils, it is important to break up the clods before placing that soil back into the hole. When the plant is installed, the top of the disturbed soil should be flush with the surrounding soil. When backfilling the holes, put a small amount of soil immediately around the stem of the plant so water does not accumulate around the stem. On wet sites this can result in stem rot.

The last stage of planting is to build a small water well around the plant. This consists of a low berm in a circle around the plant about 2 feet in diameter. These berms hold irrigation water and allow it to soak into the soil where the plant can utilize it. These are primarily used when the irrigation methods include hose watering. The deeper parts of the water well should be on the perimeter where water will soak into the native soil around the potted plant. Once the water well is complete it is very important to soak the new plants completely. The more water the plants get on planting day the longer they can go before they need to be watered again. This is helpful when planting a lot of plants because it might be a while before you get to watering the first plants installed.

Below are some recommendations regarding other aspects of restoration planting based on field experience.

1. Mulch – Mulch retains soil moisture and suppresses weed and grass growth. Particularly in drier areas, mulch can play a vital role in ensuring moist soil conditions and plant vigor. When applying mulch, the most important part is to ensure that the layer is at least 4 inches deep. This makes the weed suppression function work well. There are a number of different grades of mulch and some are better or worse for some situations.

    a. Shredded redwood, or "Gorilla Hair", is a superior mulch for several reasons. First, it does not float. So, when your site is underwater, most of the mulch will remain on site. Gorilla hair also does not have any substantial nutrients, so it is not acting as a fertilizer that can spur some weed growth. This mulch also works like a sponge to hold moisture better than other products and is not a known source of wood-borne plant diseases. One drawback is that in some places this product can be more expensive than alternatives.

    b. Wood chip mulches that are mostly all wood can make a great mulch because it is quite dense and often less expensive than redwood mulch. Wood chips are usually in good supply too, so it is easy to get. It may also be procured from local tree services that are often looking for places to get rid of excess mulch. Like other mulches it will do a good job with weed control and moisture retention. This type of mulch does break down faster than the redwood. One thing to take note of when using wood chips is where they came from. This is because woodchips can carry with them some plant diseases. For example, do not use chips collected from areas with pine pitch canker or sudden oak death syndrome. Project managers should all be wary of using material shipped in from out of the area. Mulch can also carry weed seeds, so it is important to get clean mulch that did not come from an area heavily infested with weeds.

c. Coarse compost can be obtained from facilities that compost wood chips with finer materials from yard waste and other sources. This mulch can provide slow release nutrients, builds organic matter, and is a great product to use with seed in areas where weeds are not a significant problem. Fine compost is not appropriate for most restoration sites since it breaks down faster, and can be prone to promoting weeds and adding nutrients to streams in runoff.

d. Lower grade wood chip mulch from local tree cutters is very easy to get and it is often free. Much of this mulch, however, has a lot of leaf biomass included. This mulch generally doesn't hold its loft, or thickness. It breaks down rapidly so it needs to be applied generously. This mulch also tends to act as a nutrient to the soil and it can add vigor to weeds as it breaks down. It has been used on some sites with good success though, particularly sites with very nutrient poor soil or for planting in sterile fill material.

1. Fertilizer/Nutrients – Using fertilizer or additional nutrients for planting projects is generally discouraged because the fertilized conditions do not approximate the soil the plant will have to live in the rest of its life. You'll want your plants to "go native" right away and send their roots out looking for native nutrients. Fertilizers can create a sort of "happy place" for plants and can inhibit the spreading of roots in the critical first months of plant establishment. Microbial additives are not considered fertilizer and may have beneficial effects.

2. Plant/grow tubes or protectors – Ostensibly designed to protect plants from browsing wildlife and to promote rapid growth, plastic growth tubes may have very mixed results. In foggy areas, plants often rot from too much moisture, and in hot areas they may be subjected. Plants grown in tubes may also take on a more slender morphology with poor trunk strength. They also add a project cost that may not be justified because the strategy for reducing long term care costs is based on plants growing into each other, and the tubes inhibit lateral growth. Finally, these tubes introduce a lot of plastic onto sites that would need to be removed later or could break down and enter the environment. In cases where wildlife predation is heavy, wire fencing may be more effective. See the section on gophers and deer below.

   All that being said, young oak trees benefit greatly from the use of well-ventilated grow tubes.

3. Gophers and Deer – Nothing appears to be tastier to these creatures than a fresh native plant offered by a restoration group. One thing to remember is that restoration projects are usually in areas frequented by wildlife for feeding. Ultimately, feeding wildlife is a great benefit of these projects, but in the early phases of planting it is often necessary to protect the plants from browsing wildlife such as gophers and deer.

   Gophers have been ubiquitous on many sites, and the most effective overall strategy is called "plant enough to share". The density of planting has been one hedge against mortality caused by gophers. On some sites with many gophers you can reduce plant mortality by going with an overhead irrigation system. This can reduce the targeting of plants that happens when they are the only wet areas on the site. Overhead irrigation stimulates more weed growth, but gophers can eat weeds too. So, try hiding plants among weeds. This isn't ideal, but a tradeoff to consider.

Gopher cages made of chicken wire inserted into the planting holes before placing the plant can protect the immediate root ball from damage. These are time consuming and expensive to build, but they work. These are mainly used on certain sites with very heavy gopher predation. They will break down over time, so they do not need to be removed.

It is strongly discouraged to poison gophers or actively trap them. Poison is a poor choice because poisoned gophers may be consumed by other wildlife and the poison can have collateral impacts in the food chain. Trapping gophers one by one has never seemed to be a good use of time.

Deer are also ubiquitous in many restoration areas. Again, plant enough to share. On occasion, however, wire cages above the ground are necessary. Generally, deer browsing is a seasonal activity and after the plants are a year or more old they tend to stand up above the browse level. When planting larger five gallon trees or more expensive stock, you may choose to provide more protection. Monitoring the browsing levels will be a good guide to choosing a strategy for addressing it. Once plants have grown together, deer tend to avoid working hard to browse into the middle of the plants, most of the browsing happens to plants on the periphery of a planted area.

On one non-riparian site in the Guadalupe-Nipomo Dunes, the deer browse was so substantial that 2 acres were fenced for a two year period to let plants get established prior to allowing deer to browse in the area. When fencing, use high wire fences (at least 6 to 8 feet high), and be sure to remove the fence once the plants are well established.

4. Planting Live Cuttings. When installing live cuttings, such as willows, remove the leaves from the cuttings prior to planting. This prevents transpiration and water loss from the stem while the roots get established. Be sure to drive the cuttings in as deep as possible, and then cut the top off clean to insure 80% of the length is below ground with 20% above. Soak cuttings ahead of time to initiate rooting, and soak the soil they will be planted into. It is also a good idea to cut the bottom end of each cutting at an angle to provide a sharpened point that facilitates driving it into the ground, and to cut the top horizontally to form a blunt surface for pounding with a soft mallet. These cuts also help people identify which end is which. Much of the literature encourages project proponents to harvest cuttings only in the dormant season. It has been found, however, that if handled properly cuttings can be successful in any season. This is a good thing, since many projects have to be implemented outside of the dormant season. For example, many construction projects in riparian areas have to occur during the summer and cuttings need adequate time to get established prior to the wet season.

Project Monitoring

Monitoring is a vital part of any project. It is the mechanism by which we learn what does and does not work, and will inform the planning process of all future projects. The precise methods used for monitoring will vary depending on the permit requirements (if any), the size and shape of the monitoring area, and the standard measures of success (performance criteria). There are many resources available to learn monitoring methods, so they are not specifically stated in this guide. Ideally, a method is chosen that best expresses the progress you have made toward creating a self-sustaining project and allow an objective measurement of the project with respect to the established performance criteria.

Often times, specific monitoring methods and performance criteria are prescribed in project permits. Anyone who has had to debate the relative merits of one method versus another knows that this is not a perfect science. It can be argued that performance criteria and monitoring methods often influence the project design, sometimes at the expense of long term project success. For example, if a performance criterion is simply to achieve 80% native plant cover on a site, then it can easily be attained with a monoculture of a single pioneer species. Does this mean the project was successful? Probably not. Sometimes it is best to use several different methods so the monitoring reports can show other factors such as seral development and native plant recruitment. On some sites bird counts over time can be used to show functional habitat improvement. It is encouraging that scientists are always working on new methods to try to capture the essence of project success in a way that links more closely with long term success measurements.

Below are some tips for making monitoring easier, more effective, and more meaningful.

1. In advance of project implementation make sure to consider what the objectives of the project are and to select monitoring methods which will detect whether or not these objectives have been met. Note: project objectives and the performance criteria for the project as prescribed by project permits are not necessarily the same thing.

2. Monitoring begins before the project starts, not following completion. Often the only way to determine whether a project has met the stated objective is to have accurate pre-construction baseline information.

3. Photographic monitoring is a valuable tool. When setting up photographic monitoring points on the site, make sure the photo point itself is outside of the planting area. The reason for this is that if your project is successful, your photo will be a close-up of a single large plant. You want photos of the whole project area, so it is better to take a few steps back from the planting zone.

4. When taking photographs, record the photo point location and direction of the photo using a GPS receiver and a handheld compass. Additionally, make sure to record the actual photo number associated with each photo point. It is easy to believe that you will remember which photos were taken where, but this is actually a lot harder to do. If a recognizable landscape feature can be incorporated into the photo, such as a distant ridgeline, it makes it easier to catch photos taken of the same site in different years.

5. When using survivorship as a monitoring metric, assess survival on a species by species basis. While this alone does not tell you much about project success as a whole, it can reveal which plants are poor performers on restorations sites. Even if it is not required under permits to do this, it should be done anyway until it is known which plants work and which don't under site conditions. In some cases, the survival of a certain species may also be influenced by the planting method and location, so it pays to note any trends happening on the site as part of site monitoring.

6. As with photo monitoring points, the location of all transects should be recorded using a GPS receiver. Additionally, the start and end points for all transects should be clearly marked using brightly painted rebar which will assist in relocation as vegetation fills in. Using rebar rather than wood stakes is best in riparian zones because they will not break down or float away in a large flood event.

7. Transects in riparian corridors can present challenges. Because most riparian planting corridors are quite narrow and occur along a gradient, a perpendicular transect does not accurately reflect site conditions. Transects that run diagonally from top of bank to the water better capture situational gradient and species zonation.

8. When using transects on a site with a long linear extent, it is helpful to establish monitoring zones, where the transect location is randomized within the zone. Randomization increases monitoring area, reduces bias, and yields better information for planning remedial actions.

9. Remember that in addition to determining success, monitoring is part of a management feedback loop. Monitoring results should always be used to inform management actions; therefore it is critical when creating the project budget to include management for at least as long as the monitoring requirement.

Conclusion

The field of riparian habitat restoration is an exciting one, and one where continued growth yields new information and methods every year. The information in this field guide has come directly from field experiences over a 15 year period and represents an evolution of methods. While some of these practices have been a result of careful planning among a multidisciplinary team, many of these lessons were learned the hard way. Only by sharing our successes and failures will the state of the art progress. The concepts presented here are not meant to be static, they are meant to be built upon over time. As a practitioner, you will be part of the effort to refine these methods with your own experiences.