California Riparian Habitat Restoration Handbook

Second Edition
July 2009

Aerial view of riparian restoration in progress at the Drumheller Slough Unit of the Sacramento River National Wildlife Refuge. Photo by Tom Griggs, River Partners.

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Riparian Habitat Joint Venture Goal Statement for Handbook

California Partners in Flight (CalPIF) initiated the Riparian Habitat Joint Venture (RHJV) project in 1994. To date, eighteen federal, state and private organizations have signed the landmark Cooperative Agreement to protect and enhance habitats for native landbirds throughout California. The RHJV, modeled after the successful Joint Venture projects of the North American Waterfowl Management Plan, reinforces other collaborative efforts currently underway which protect biodiversity and enhance natural resources as well as the human element they support. River Partners is a RHJV partner.

The RHJV partners identified a need for guidelines for planning and implementing riparian restoration projects on the ground. In 2007 the RHJV convened a group of restoration experts for a workshop to produce a handbook of restoration strategies, standards and guidelines – the birth of this handbook. The goal 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 following pages will cover issues such as:

- What are the fundamental **ecological** criteria to consider for producing quality restoration on the ground?
- How can a restoration project be designed to meet key goals AND provide wildlife habitat?
- What partnerships, permits, tools and resources are required to implement a restoration project?
- Which field methods should be used to ensure the greatest success given a site's soils and hydrologic setting?
- What works and doesn't work in restoration?
- When and how should the restoration project be monitored to continue refining restoration techniques?

The handbook should be used for planning projects, creating budgets, and assessing restoration success. One aim is to provide a common language for riparian restoration, appropriate planning of projects and effective restoration on the ground. Ecological, biological, and regulatory components of a riparian restoration project are described. Additional resources of riparian restoration project support are provided including web-links and reference articles. Case studies of statewide riparian restoration projects that faced site specific conditions illustrate implementation of the principles presented in this handbook. This will be a living document that will be revised to include new information as it becomes available. This second version was revised in June 2009 (the first edition was completed in September 2008).

This handbook emphasizes the ecological river processes operating on floodplains and in river channels that create characteristic vegetation structure that forms wildlife habitat - as the foundation for planning a riparian restoration project. The goal of these guidelines is to explain the proposal/planning process for a site-specific riparian restoration project for wildlife habitat to the first-time as well as the experienced restoration project manager.

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Restoration on the Drumheller Slough Unit of the Sacramento River National Wildlife Refuge. Photo by Tom Griggs.

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Riparian restoration along Bear River in the Feather River watershed. Photo by Tom Griggs, River Partners.

I. Introduction

A. Audience

The intended audience for this California Riparian Restoration Handbook is anyone responsible for writing a proposal for a riparian restoration project, anyone beginning to plan and implement the project, or those responsible for compliance and mitigation monitoring of such a project. This handbook explains the elements of a site-specific riparian restoration project that must be addressed in order for a project to be successful.

B. Geographic Focus

River processes operate on all sizes of rivers from the major rivers of the world down to small rivulets flowing through a mountain meadow. The area over which they operate and the timing of their effects vary throughout the bioregions of the state. Restoration objectives and restoration practices are likely to be different on rivers and floodplains depending upon their topographic and climatic settings. The material in this handbook was developed primarily from experience with rivers in California's Central Valley, and is therefore most applicable to habitat restoration in the Central Valley and on the floodplains of coastal rivers. Many of the concepts are applicable to other bioregions of the state, though the timing and magnitudes of restoration tasks would likely be very different. An overview of the major restoration objectives as they apply to other bioregions throughout California is provided in Appendix 1. Case studies of riparian restoration projects outside of the Central Valley can be found in Appendix 2.

C. How to Use This Handbook

While this handbook is designed to assist with projects from start to finish and to anticipate potential challenges, it should not be used as a recipe book or without other resources. The user should have access to local expertise concerning river ecology, fluvial geomorphology, plant horticulture, flood-conveyance and local wildlife.

This handbook demonstrates how to approach riparian restoration design from an ecological perspective specific to the project location. This handbook describes the existing ecological conditions and physical processes at the watershed level that must be considered when developing an accurate, site-specific restoration plan that will successfully meet targeted objectives, with priority given to wildlife habitat.

The following handbooks contain additional information and resources for riparian restoration, and there are several other manuals that address riparian restoration methods that should be researched for specific regions of the state.

- CDFG (California Department of Fish and Game), 1998. California Salmonid Stream Habitat Restoration Manual (section VI).
- NRCS (Natural Resources Conservation Service), 2007. Stream Restoration Design National Engineering Handbook, Part 654.
- FISRWG (the Federal Interagency Stream Restoration Working Group), 1998. Stream Corridor Restoration: Principles, Processes, and Practices.
- CalPIF (California Partners in Flight), 2008. Bringing the Birds Back: A Guide to Habitat Enhancment for Birds in the Sacramento Valley.

II. Riparian Restoration Overview

A. The Value of Riparian Habitat

In the Riparian Bird Conservation Plan (RHJV 2004), riparian refers to areas that are "transitional between terrestrial and aquatic ecosystems, providing linkages between water bodies and adjacent uplands and include portions of terrestrial ecosystems that significantly influence exchanges of energy and matter with aquatic ecosystems" and the National Research Council devotes an entire chapter to defining this term (NRC 2002; RHJV 2004). For this Handbook, the definition of "riparian" will refer to land area that encompasses the river channel and its current or potential floodplain.

The riparian zone is characterized by a unique set of physical ecological factors in comparison to the surrounding regional landscape (Gregory et al. 1991). These factors include flooding by the river, rich and productive soils, a water table that is within reach of plant roots, and species of plants and wildlife that are adapted to the timing of fluvial events such as flooding, drought, sediment transport and channel movement. This dynamic habitat creates a wide variety of growing conditions for riparian plants, and over time they develop into various structural forms (forests, woodlands, shrublands, meadows and grasslands) across the floodplain. The heterogeneity of riparian forests creates numerous habitat features that explain why riparian forests in California support a greater diversity of wildlife than any other habitat type (Smith 1980). Riparian vegetation along river channels also functions as primary regional migration routes for most wildlife.

Riparian ecosystems support people as well as wildlife. Rivers and their floodplains provide many "river services" to the surrounding local community. (Also termed "Multiple benefits" by floodway managers.) These include:

- Conveyance and delivery of water supply
- Effective conveyance of flood waters – Native riparian plants on the floodplain attenuate flood waters and trap large debris.
- Maintenance of water quality – A living river will improve water quality through biological processing of pollutants and physical filtering of sediments and organic material.
- Wildlife habitat and regional migration corridor – Vegetated floodplains provide cover for wildlife during migration.
- Recreation Opportunities – Fishing, hunting, boating, and wildlife viewing are enhanced by native riparian plants.

River services are optimized when a river and its floodplain are healthy. Healthy rivers are free of intensive regulation such as dams and revetment and their floodplains support a mosaic of plant communities.

B. Riparian Decline

The rich soils and presence of water that make riparian areas biologically rich, also create productive lands for agriculture and desirable locations for urban development. In addition, sediment deposition by rivers over time has provided opportunities for gravel mining. The water that flows through rivers is often dammed and diverted for anthropogenic use and most of the large rivers function as primary flood conveyance structure for the purpose of human safety. These practices have removed the majority of riparian habitat available to wildlife and people and reduced the ability of rivers and floodplains to provide river services. It is estimated that 95 percent of pre-European acres of riparian habitat in California's Central Valley have been lost to recent human activities (Katibah 1984).

Transition of some of these lands back to a more natural state through riparian restoration benefits both the ecology and socioeconomics of a region. Often, rivers are seen only as a means to transport water to cities and farms, or as an unpredictable system that needs to be straightened and armored to prevent flood damage to developed areas. Healthy rivers and floodplains can protect developed areas from flood damage and provide water transport and other services to people that exceed the cost of replicating these services through human infrastructure (APEC 2005).

Native plants are a necessary component of healthy riparian areas, and not simply because of their importance to native wildlife. Vegetated floodplains and the organisms they support can clean water by removing the nutrients that runoff from agricultural fields and into drinking water supplies. The presence of vegetation also aerates the soil and creates places for water to slowly percolate underground to recharge aquifers that supply water for urban and agricultural uses. The dense forests also offer shady respite and recreational opportunities not available in developed areas.

C. Riparian Restoration

Riparian restoration occurs at a broad range of scales depending on the size of the river, the ecological health of the site, and the regional landscape. The goals for a restoration project will also vary, from flood control benefits to invasive species removal, but the project can still be designed to maximize habitat available to wildlife. (See Appendix 2 for case studies as examples). For example, large rivers in the Central Valley are managed today for irrigation water conveyance and flood-damage control. All are constrained by levees, with management and maintenance responsibilities carried out by local, state, and federal agencies. Consequently, river processes operate only within the floodway (a legally defined structure, often a levee-lined channel that is designed to convey a specific maximum flow during flood events). The floodway's primary design consideration is human safety and currently, relatively little emphasis is given to riparian vegetation and habitat function. However, riparian vegetation can have beneficial flood damage control impacts by slowing bank erosion, directing flows away from structures, and directing sediment transport. Furthermore, the local influence of restored riparian vegetation can provide both flood control benefits and quality wildlife habitat.

Smaller rivers, such as Sierra foothills and Coast Ranges, are tributaries to the larger rivers of California's Central Valley and have much smaller localized floodplains covering much smaller areas than those of large, meandering valley rivers. On these tributaries, levees are typically protecting small areas (rather than regional protection). The emphasis of human safety is usually not as strong on smaller rivers and in this way restoration design is influenced by river size. Restoration on small rivers typically involves manipulation/restoration of channel morphology and floodplain elevation (e.g., repairing abandoned open-

pit gravel mines). In these cases, earth-movement may be a large part of the implementation budget (NRCS 2007), with less emphasis on the actual plantings. However, through restoration of river processes such as flooding and sediment transport, eventually native vegetation will establish and support local wildlife.

Types of restoration. The amount of human input required by riparian restoration will depend on the site conditions. "Horticultural restoration" refers to a high level of site management and external human inputs that include site preparation (land-leveling, disking), planting of nursery-grown trees and shrubs in pre-designed patterns, irrigation, and chemical weed-control for three or more years. Horticultural restoration is appropriate along rivers where the river's physical processes have been severely modified by humans with dams, levees, bank stabilization, and water diversions. At the other extreme is "process restoration," which strives to reestablish river processes onto the site. Process restoration is appropriate on riparian sites along a river that retains functioning river processes (e.g. no dams, and few levees or water diversions). Process restoration attempts to restore a site by working with existing river processes. This may involve, for example, breaching a levee to reconnect the river to its floodplain behind the levee, or changing land-use, such as cessation of farming or a modified grazing plan, or creating topography by cutting swales or building low berms on the floodplain. The RHJV provide restoration recommendations for horticultural restoration (pages 79-82) and process restoration (pages 91-92) in the Riparian Bird Conservation Plan (RHJV 2004).

D. Mitigation

Mitigation is a regulatory process intended to offset the loss of natural resources resulting from human development. When mitigation is achieved through planting native species, it can superficially resemble restoration. Mitigation plantings are frequently permitted to serve as compensation for unavoidable "take" of imperiled species or habitats. Take refers to activities that will directly or indirectly harm individual wildlife species or habitat types, such as wetlands or vernal pools.

Mitigation plantings are typically narrowly focused on the habitat requirements of individual species or in the case of imperiled habitat types, they focus on specific plant associations to recreate targeted ecosystem services. This narrow focus of mitigation is in contrast to the broad scope of most restoration projects which aim to support multiple species and create plantings that will provide numerous ecosystem benefits (see Riparian versus Mitigation box).

Mitigation is a legal process and the regulatory agency depends on the location and status of the protected resource. Mitigation for federally protected species is regulated through the Fish and Wildlife Service for terrestrial species or through the National Marine Fisheries Service for aquatic resources. Take of state protected species in California may incur mitigation as mandated by the California Department of Fish and Game. Riparian areas often receive protection under the US Army Corps when they are within jurisdictional waters of the US. Cities and counties may have specific regulations for wildlife and plant communities, and accordingly mitigation plantings may be required to offset losses of the natural resources.

Mitigation versus Restoration

Ideally, restoration should be designed to meet the habitat requirements of multiple targeted wildlife species that require a variety of plant associations, densities and configurations. In this way, the targeted wildlife serve as umbrella species that will provide habitat resources for additional wildlife. Restoration plantings should also be designed to provide a broad range of ecosystem benefits. For example, restoration of native vegetation on frequently inundated floodplains will not only allow the site to improve water quality but could also support anadromous fish. Similarly, a diverse plant assemblage will attract a suite of wildlife that both bird watchers and hunters will appreciate.

Mitigation plantings are typically more constrained than restoration plantings. Since mitigation is a required process, too often, only the essential requirements are satisfied and the plantings are not designed to provide additional benefits. Mitigation for the federally threatened Valley elderberry longhorn beetle (VELB), for example, consist primarily of dense plantings of the beetle's host plant, elderberry, along with associated native plants at a ratio of at least 1 native plant for every elderberry planted. Beyond the numbers and densities of plants, there is no guidance about design of mitigation for the VELB or consideration of how other species will use the plantings. In addition, there is frequently minimal scientific review of biological data when the mitigation projects areplanned(Kareiva et al. 1999) and this means that losses of wildlife habitat or key ecosystem benefits may not fully be offset when low quality or failed mitigation plantings are produced (Allen 1994; Smallwood et al. 1999).

Mitigation for the Valley elderberry longhorn beetle (VELB). Elderberry shrubs impacted by development must be transplanted into a conservation area if the shrubs are large enough to possibly contain VELB larvae.

E. Setting Goals and Planning Restoration

The goals of a riparian restoration project should be established prior to the planning stage. Project goals with quantifiable objectives are essential for determining project success in the future. The goals of each restoration project may differ substantially depending on the primary funders and/ or managers, and their needs and priorities. One project may be solely intended for wildlife habitat; another may be used as a hunting preserve; another may be intended for recreation and research. The case studies in Appendix 2 describe the goals of different restoration projects and how they influenced project design. Once completed, the success of the project will be evaluated on how well the goals were met.

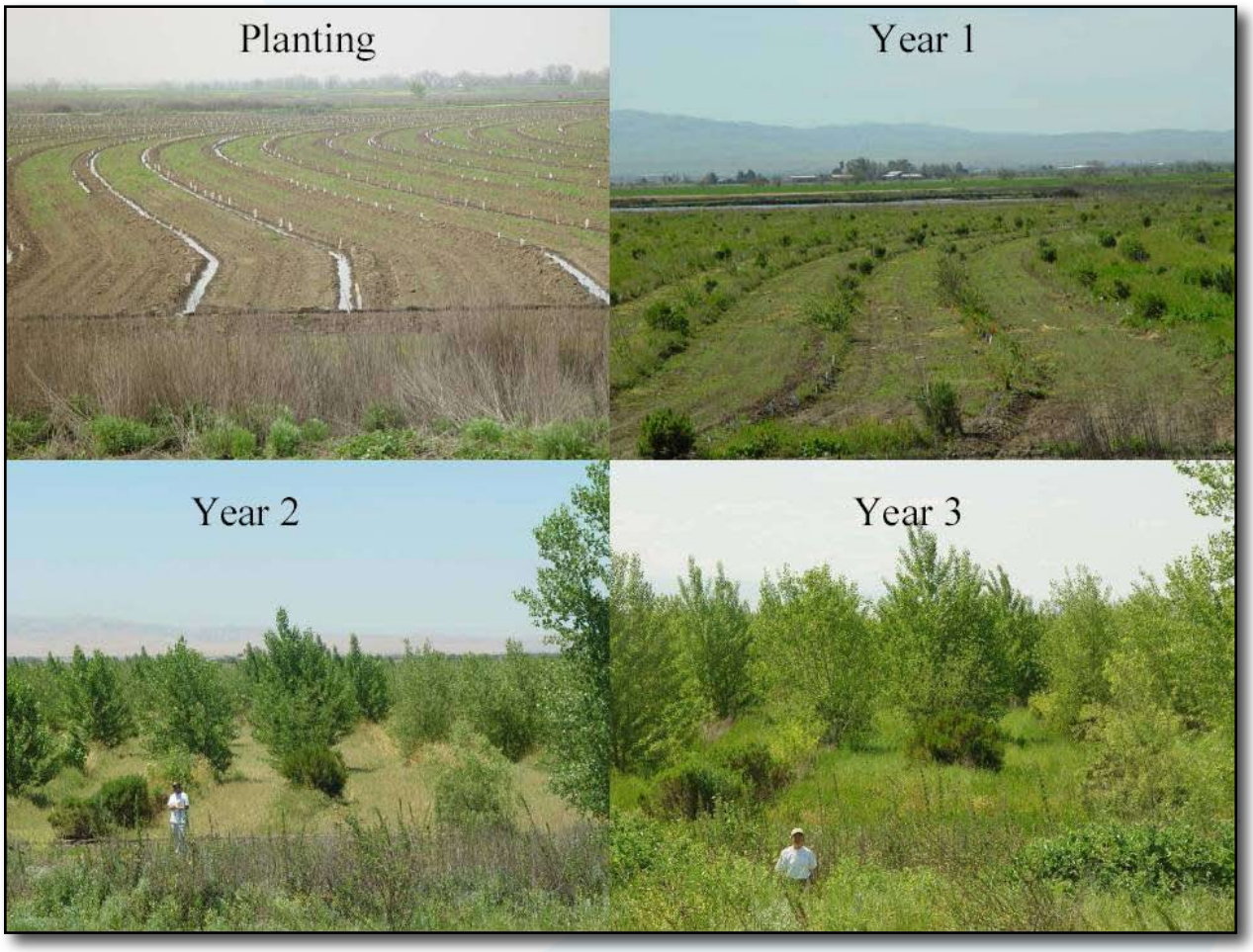
The goals and objectives of the project should be set forth clearly at its inception, to ensure that progress can be monitored and measured in that framework. Throughout planning, ask: Are we achieving our objectives? Is the timeline appropriate? Is funding adequate? Can we measure our progress against existing finished projects or remnant areas?

Some factors to be considered during the defining of goals for any riparian restoration project include:

- *Community Involvement:* Engage the local community in the planning and development of projects; encourage learning about native wildlife and benefits to the community that restoration will provide such as flood control and recreation opportunities; identify common goals.
- *Target species for wildlife habitat creation:* Design the plantings in a restoration project based on the structural habitat needs of one or more focal species. Restorationists often use wildlife species habitat requirements as targets for success of a restoration project. For example, the California Partners in Flight and RHJV Riparian Bird Conservation Plan has identified sixteen "focal species" of riparian birds as important indicators of riparian health throughout California. Other focal species in the Central Valley include Riparian Brush Rabbit, Valley Elderberry Longhorn Beetle, and Salmon. Creation of wildlife habitat is probably **the most important regional goal** that a riparian restoration project can have.
- *Flood Neutrality:* Consult with hydraulic engineers to ensure that the restoration project will not affect the flood conveyance properties of the site, such as transitory storage capacity and bank stabilization, velocity, depth and direction of flows. What are the flood protection benefits of the project?
- *Recreation:* Assess the recreation opportunities that are appropriate for the site – wildlife viewing, hunting, fishing, and hiking are some examples.
- *Environmental Improvement:* Riparian restoration projects can improve air quality because plants capture and store carbon as they grow. Restoration projects also improve water quality, by filtering nutrients from nearby point-source pollution, by filtering large debris, by stabilizing banks and reducing sediment load into the rivers, and by providing ground water recharge.
- *Weed abatement:* Restoration projects include weed control to suppress invasive weeds and replace them with native riparian plants, and this could benefit neighboring land uses by limiting the spread of weeds.
- *Water conservation:* Restoration projects typically require irrigation for the first three years. After this time diversions and well-pumping ceases, allowing water to stay in the river or in the ground. Therefore, in the long term restoration projects can reduce the amount of water consumption in the area.

Peer review at all phases of planning and implementation of a restoration project is essential for the development of quality wildlife habitat. Questions that should be considered during site evaluation and project development include: Is the system healthy? Is the site appropriate to support restoration? Is restoration possible? If so, what level or quality is possible? How might restoration affect neighboring land use? At this stage of site evaluation, it is critical to involve river ecologists and biologists, flood control engineers, fluvial geomorphologists, regional or county planning departments, and long-time local residents.

The following sections focus on physical river processes and their interaction with riparian vegetation, wildlife, and communities. This understanding is the foundation for developing a successful ecological restoration design.



Photos document River Partners' San Joaquin River restoration project, showing dramatic growth after three years, and the ability of the site to become self-sustaining.

III. Ecology of a River

A. Physical River Processes

Physical river processes – flooding, sediment transport and channel meander - operate at all scales, from broad floodplains of the Central Valley that are several miles in width, down to rivulets in headwater mountain meadows that may be only inches in width.

Before one can develop a restoration plan for any site, an understanding of how existing river processes affect site conditions and determine the functional ecology is necessary. Physical river processes mold the form and topography of the river channel and its floodplain (this is termed fluvial geomorphology), they deposit sediment that will function as soil for plant growth, they regulate plant establishment and growth and drive plant succession through flooding and channel meander, and they affect the resulting vegetation structure that provides wildlife habitat for more species than any other vegetation.

The most important physical factors that define a river are the area, elevation and geology of its watershed (or catchment), the slope or gradient of the river's channel, and the regional climate.

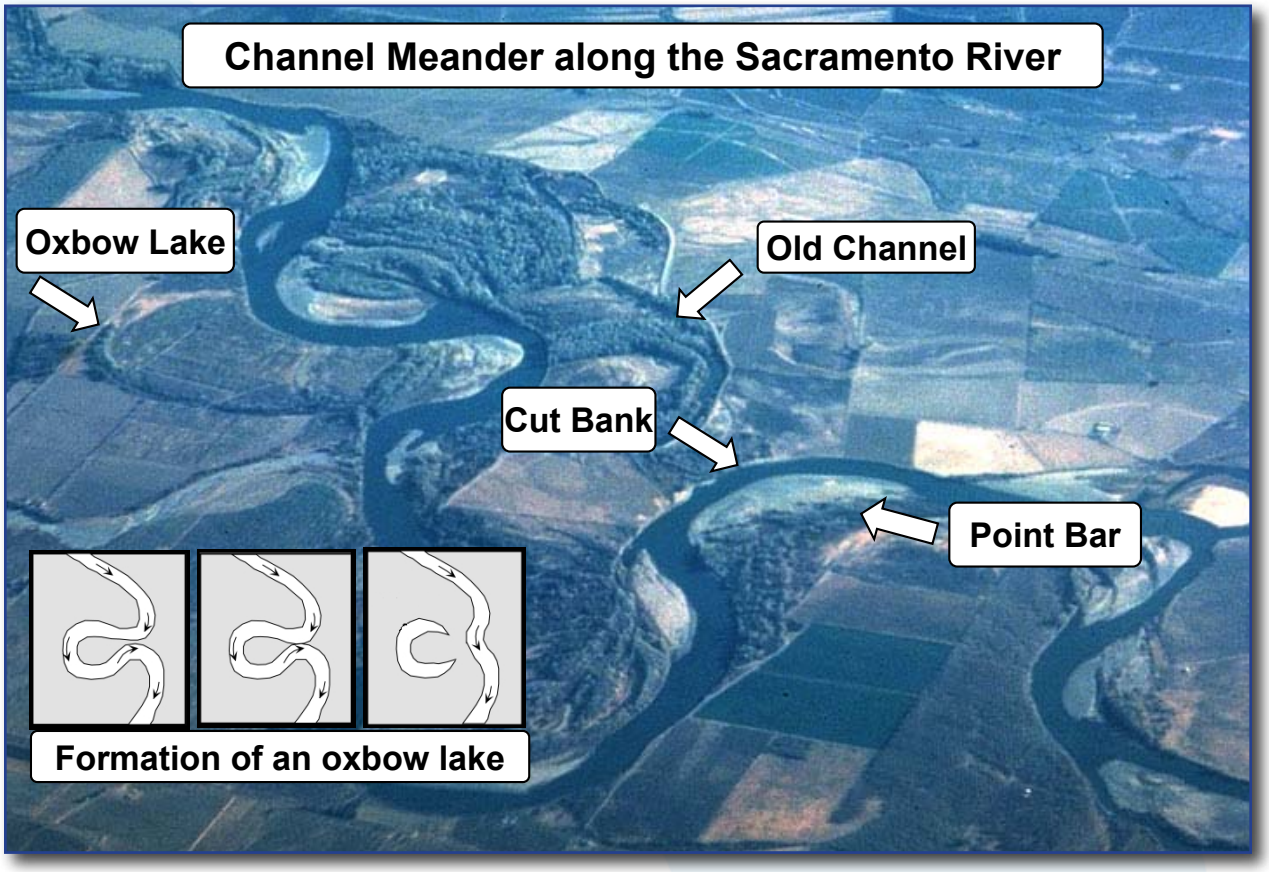
1. Watershed Area and Elevation

The area of the watershed and its elevation dictate the behavior of flows in the watershed. Watersheds with large areas have the potential to generate large flows that small watersheds cannot. Elevation of the watershed can dictate the size of the flow throughout the watershed. For example, many rivers in the San Joaquin Valley have large watersheds that are set at higher elevations which receive abundant snow during the winter. Typically, snowmelt runoff does not enter the river until late spring/early summer when it can then result in flooding relatively late in the water-year. Compare this to rivers of the Sacramento Valley where watershed elevations are not as high. The snowmelt runoff here is much less than in the San Joaquin, and causes relatively minor flow increases.

2. Watershed Geology, Sediment Transport Characteristics, and Channel Meander

Watershed characteristics affect the sediment load of a river. The sediment load is the result of geologic erosion of its watershed. Under natural conditions, the sediment will be carried eventually to the mouth of the river. Hydraulic forces during bank-full and higher flows distribute the sediments across the floodplain and overtime, layers of sediment are shaped into a characteristic geomorphology. Rivers that flow through wide valleys are typically depositing sediments and building their floodplains, while rivers that flow through narrow canyons are more erosive because of their increased velocity. The most important results of the sediment transport process are bank erosion and point-bar formation which overtime build floodplains by deposition of sediment. Together, bank erosion, point-bar formation and floodplain creation result in the lateral movement of the channel, or channel meander (Figure 1). After flooding, channel meander is the second most important ecological effect that a river has on the floodplain.

Figure 1: Channel Meander Along the Sacramento River



Some properties of channel meander exhibited by the Sacramento River. Where streams flow over low gradients through erodible banks, the velocity of the water causes the channel to meander. Erosion occurs on the outer bends where water moves fastest, and sediment is deposited on the inner bends (where water velocity is low) and forms point bars. If a meander bend is cut off from the rest of the channel, an oxbow lake is formed. Formation of an oxbow lake graphic adopted from Earth Science Australia.

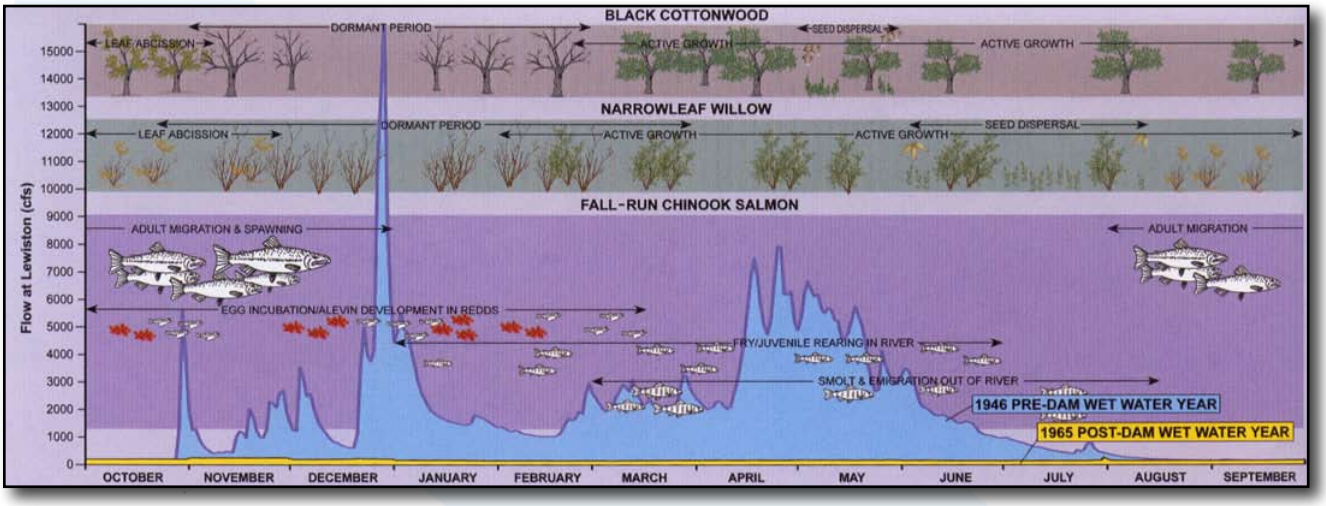
3. Channel Slope

The slope of the channel determines the velocity of the river flows. The velocity shapes the geometry of the channel and the patterns of sediment transport and deposition on the floodplain. Steep gradient rivers have more erosive power than low gradient rivers and may be deeply incised into the surrounding landscape and adjacent floodplain areas. Low gradient rivers are often depositional with large broad floodplains.

4. Regional Climate and the Hydrograph

The regional climate affects the quantity and timing of river flows throughout the year, termed the hydroperiod. Plants and animals adapt to a river's natural variation in flow volumes overtime and the habitat conditions that are a result of these river flow patterns. A hydrograph is a graphical display of average flow over a specified period of time. In other words, a hydrograph can be used to evaluate flow patterns in a day, over a year, or over several years. Most riparian species of plants and animals are adapted to the river's hydrograph for reproduction, growth, and survival. For example, Figure 2 shows a natural hydrograph of the Trinity River overlaid by the lifecycles of two riparian trees, black cottonwood and narrowleaf willow, and the fall-run Chinook salmon. The figure shows how the timing

Figure 2: Trinity River Hydrograph (McBain & Trush, Inc.)

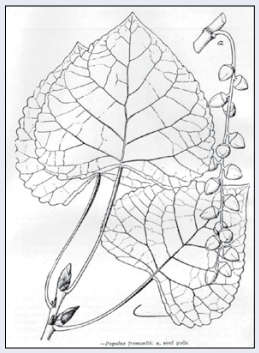


of the salmon arrival, their spawning, hatching and juvenile growth all occur at characteristic times on the hydrograph (Adaptation to Hydrograph Box 2). Likewise, cottonwood and narrowleaf willow seed release and seedling establishment rely upon the timing and magnitude of flows that are controlled by the hydrograph (Adaptation to Hydrograph Box 1). Note that the natural hydrograph before the dam was built is shown in blue, and exhibits high variability in flow, while the flows after dam construction shown in yellow exhibit very little variability and are in general low year round. The flow pattern after the dam is drastically different from the natural pattern before the dam. Plants and wildlife did not have enough time to adapt to such drastic changes, and as a result, their populations have declined. Restoration designs have to consider the altered hydrology of the site when selecting the species to plant, because natural plant establishment, survival, and succession are disrupted by changes to the hydrograph. Studying the hydrograph for a river is the most effective method for determining the ecological health of a river, and planning the appropriate planting design.

Periodic flooding by the river is a fundamental characteristic of floodplain and riparian ecology. The frequency (recurrence interval) and duration of flood events over time shape the physical habitat and create the ecological restraints that determine the species composition and community structure on a site. The natural hydrograph for rivers in California is an inverted U-shape, with peak flows in the winter and spring (November through June) (Figure 2). The slowing or reduction in magnitude of flows during late spring and early summer, as rainfall tapers to nothing, is biologically important to most plants that grow in the riparian zone. Seed-release, seed dispersal, and seedling establishment are adaptations to the hydrograph by most riparian plants. Cottonwood is the most studied in this regard (Adaptation to Hydrograph Box 1), although all species of willows have a similar behavior in response to the hydrograph. Likewise most species of fish are adapted to the hydrograph. The entire freshwater phase of the salmonid life cycle is adapted to natural flow regimes and associated water temperatures, including adult upstream migration, spawning, juvenile rearing and out migration (Adaptation to Hydrograph Box 2). Adult salmon require cold, deep holding pools and cool oxygen-rich waters flowing over and through spawning gravels. Juvenile salmon exhibit higher growth rates when they forage in the warmer shallow waters of inundated floodplains in the spring. Resident species such as the Sacramento splittail spawn on submerged floodplain vegetation during early spring floods.

Dams and seasonal water diversions for irrigation will change the hydrograph for a reach of a river that is below them. This modification of the hydrograph will result in major disruptions in the life cycle of both plants and wildlife, resulting in reduced reproductive success and increased mortality (adult and juvenile), leading to major changes in plant community structure and reduced wildlife (especially fish) populations.

Adaptation to Hydrograph, Box 1: Establishment of Cottonwood Seedlings



Fremont cottonwood reproductive timing and seedling establishment and growth are both tied closely to the timing of hydrographic events. High winter flows mobilize sediments at the edge of the active channels and create points bars composed of sand and silt, or floodplain soils are scoured of vegetative cover and mulch. Exposed mineral sediment substrate is essential for the germination requirements of cottonwood and willow seeds. Cottonwood trees flower in the early spring (April), seed matures rapidly, and is often mature by late April and early May. This coincides with the snow-melt recession phase of the hydrograph. The seed is released into the wind from the capsules when mature. Seed blows with the wind, coming to rest on the surface of the river or other water body, where they sail on the wind and water currents to the edge, and ideally come to rest on mineral sediments that will remain wet for several days. Here the seed will germinate and initiate rapid growth. The seedling grows a tap root that grows downward as the water table recedes downward into the sediments as snow melt runoff transitions into summer base flows. The tap root can grow at a rate of one inch per day. By November a 1.5 to 2.0 meter tall sapling can develop.

Changes to the shape and timing of hydrograph events can negatively impact seedling germination and development. Dams limit the high flows during the winter that create seedbeds. Irrigation diversions during seedling establishment and development phases can create rapid dry-down rates that the seedling root growth cannot keep up with. High flows released for irrigation during the summer often drown cottonwood seedlings on point bars. As a consequence of dam operations cottonwood rarely reproduces as large blocks of trees today along the Sacramento River.

Adaptation to Hydrograph, Box 2: Salmon Life-cycle is Keyed to Hydrograph

Chinook and Coho salmon and Steelhead spawning, juvenile development, and out-migration are all determined by the timing of hydrograph events. High winter flows are necessary to deposit and form gravel beds composed of specific diameter gravels that will function as spawning beds the following fall. Salmon entering the river from the ocean in fall typically spawn by laying their eggs in the form of redds that are excavated by the female in coarse gravels. Eggs are laid sometime in November by Chinook salmon and in December and January by Coho salmon. See Moyle, et al. 2008 for detailed life history accounts of California Salmonids. The eggs hatch in the gravel as alevins where they remain for several weeks before emerging into the river as juvenile fish. Juvenile salmon forage on aquatic and terrestrial insects in the water column during the spring into April. During winter and spring floods juvenile salmon swim with the water onto and over the floodplain. Floodwaters on the floodplain are several degrees warmer and support a greater abundance of invertebrates for food. Consequently, juvenile salmon grow faster while foraging over the floodplain than fish that remain in the river channel (Sommer et al. 2001). Sometime during late April, May, or June snow begins melting from the mountains surrounding the watershed. This snow-melt portion of the hydrograph provides higher flows that the juvenile fish, now termed smolts, ride down the river into the estuary where they prepare to exit freshwater and swim into the ocean.

Changes caused by large dams to the hydrograph that negatively affect salmon include reduction of high flows necessary for spawning gravel maintenance, and the reduction of floodplain flooding that results in slower juvenile growth rates, that results in smaller fish entering the ocean.

B. Plant Response to Physical Processes

Riparian plant species are characteristically adapted to the hydroperiod of a river, and rely upon it for seed dispersal and predictable water table depths to establish their seedlings. Fremont cottonwood is the most-researched tree species in regards to its dependence upon a river's hydrograph for reproductive cues and seedling establishment (Mahoney and Rood 1998; Cooper et al. 1999; Cederborg 2003)

In addition, cottonwood and willows, as well as all other riparian plant species, are directly dependent upon patterns of sediment erosion and deposition. For example, a meandering channel undercuts mature vegetation on the bank allowing trees to drop into the channel where they become important substrate for aquatic invertebrates and structure for fish habitat. Opposite the cut bank, the river deposits a point bar of sediments that will be colonized by seedlings of cottonwoods and willows. As these grow into saplings over time (decades), the point bar accumulates finer sediments and grows in elevation, eventually reaching the elevation of the local floodplain. The finer sediments allow other species of trees and shrubs to establish under and near the willows and cottonwoods. After several decades of sediment deposition and organic matter accumulation, a deep layer (1-3 meters) of "soil" allows valley oak and elderberry to establish. Thus, over a period of 40 to 100 years (Strahan 1984; Trowbridge et al. 2004) the plant association on a site will change from a willow-cottonwood woodland to a valley oak dominated forest.

The timing and duration of flooding are important factors in regulating species composition in the riparian zone. Riparian trees and shrubs are differentially adapted to the duration of flood events, most able to tolerate several days, or a few species can tolerate months, of flooding. Many non-native invasive weeds are killed by flooding.

Thus, interactions among the physical processes of flooding, sediment deposition, channel meander, and hydroperiod across a floodplain results in a vegetation mosaic over time that is structurally complex. Groves of trees, patches of woody shrubs, open grassy areas, and open woodlands with an understory of herbaceous perennials and native grasses are scattered and in places intermingle across the floodplain, and diverse habitat types created by channel meander form in the oxbow lakes and cut-off sloughs.

C. Wildlife Response to Vegetation Structure

The complexity of vegetation structural types results in a rich diversity of wildlife species that reside or seasonally utilize riparian zones. The abundance of surface water in the riparian zone (river channel and oxbow lakes and ponds) allows large numbers of individuals of these species to survive within the complex vegetation structure. Birds are the most diverse and most studied of the wildlife in the riparian zone. The types of species that riparian vegetation supports range from Swainson's Hawks that nest in tall cottonwood or valley oak trees, to House Wrens that forage on the floor of the forest and inside debris piles. Sixteen "focal species" of riparian dependent birds have been identified as important indicators of riparian ecological health (Figure 3). One or more of these twelve are often used as targets of a restoration project. The restorationist must, therefore, know the structural habitat needs of the target species as well as the growth characteristics of each tree or shrub in a restoration design, in order to design a vegetation planting that will function as useful wildlife habitat (See the Riparian Bird Conservation Plan, RHJV 2004, for detailed habitat descriptions for each of the riparian focal bird species; for research documenting songbird use of riparian restoration sites, see Gardali et al. 2007; and for a review of wildlife response to riparian restoration on the Sacramento River, see Golet et al 2008).

Restoration of Wildlife Habitat

Each species of wildlife lives in its own characteristic habitat and shares this habitat with a community of other wildlife species. Within its habitat an animal carries out all of its living-functions: foraging for food and water, seeking cover to hide from predators and the weather, and nesting or denning for reproduction. Habitat provides the physical needs of life for an individual and its species. Habitat is typically described by its physical composition – elevation, topography, availability and seasonality of water - and the species composition and structure of its vegetation. Management and manipulation of vegetation species composition and the arrangement of individual plants on the site are the methods that the restorationist can use to build or restore the vegetation structure that target wildlife will view as habitat.

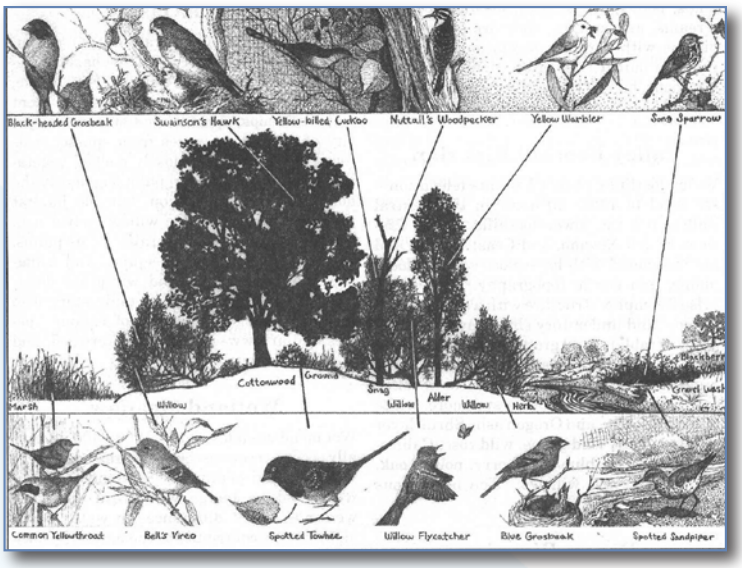
The restoration planner must have an understanding of the structural needs of the target wildlife species and have the knowledge to cultivate these species into the desired habitat structure. On many rivers without dams and water diversions, river processes can be considered "natural" and process restoration may be accomplished by actions that return river processes to the site – berm/levee/rip-rap removal, swale construction, land use change. These actions are assumed to be sufficient to provide the growing conditions that riparian plant species require in order to develop into a vegetation structure that will function as high quality wildlife habitat. However, on most low-elevation rivers in California, dams, levees and diversions are common and land use on the floodplains is either agricultural or urban. Thus, the physical river processes are not "natural" and the vegetation that develops under them will likely not be of the proper species composition or structure for wildlife use as habitat. Therefore, it is the responsibility of the restorationist to develop a planting design for horticultural restoration of the site that will result in wildlife use and be considered high quality habitat for an array of target species (Gardali et al. 2007).

To design restoration for wildlife habitat, the restorationist should research the target species to understand their structural habitat requirements. For example, the Riparian Bird Conservation Plan (RHJV 2004) provides a usable synthesis of known habitat requirements of birds that use riparian areas. The Riparian Bird Conservation Plan selected the following 16 focal species of landbirds to represent the diversity of niches that occur in riparian habitats in California. The species accounts provide information synthesized from many studies to document the habitat needs and specific vegetation structure required for different behaviors and life stages of these birds.

- Bank Swallow
- Bell's Vireo
- Black-headed Grosbeak
- Blue Grosbeak
- Common Yellowthroat
- Song Sparrow
- Swainson's Hawk
- Swainson's Thrush
- Tree Swallow
- Tricolored Blackbird
- Warbling Vireo
- Willow Flycatcher
- Wilson's Warbler
- Yellow-breasted Chat
- Yellow-billed Cuckoo
- Yellow Warbler

Additionally, the California Department of Fish and Game created the Wildlife Habitat Relationships (CWHR) database which describes the life history and habitat requirements of all birds, mammals, reptiles and amphibians that use riparian areas. The California Natural Diversity Database (www.dfg.ca.gov/biogeodata/cnddb) is another resource for information about the status and locations of rare plants and animals in California. Their online database can be queried to produce local maps and species lists for a project site.

Figure 3: Riparian dependent birds and their habitat. The Riparian Bird Conservation Plan (RHJV 2004)



Most terrestrial mammals found in California spend time in (or require) riparian areas. Common low-elevation mammal species include raccoon, striped skunk, opossum, coyote, and black-tailed deer. Where large cavities exist in old, large trees, ringtail cats can be locally abundant. Rodent species that rely on riparian vegetation are few: beaver and gray squirrel. Ground squirrels, pocket gophers, and meadow voles live only around the margins of riparian areas where woody vegetation is sparse or non-existent. Special status mammals documented using restored riparian habitat in the San Joaquin Valley include the Riparian Brush rabbit, and along the Sacramento River Western mastiff bats, Pallid bats, Western red bats, and Yuma myotis. (Golet et al 2008).

Riparian corridors are the main migration routes for regional movement of all wildlife species. Riparian restoration can have important impacts for the local and regional wildlife diversity and abundance by connecting patches of riparian vegetation that improves the connectedness of the riparian corridor. This function of the riparian corridor will be as important, or more so, in the future with Climate Change scenarios predicting changes in vegetation and consequent need for wildlife populations to migrate.

Trees and shrubs growing on the bank and over-hanging the channel provide shade for the water column adjacent to the bank and deposit insects and nutrients into the river. The vegetation provides Shaded Riverine Aquatic (SRA) habitat for fish and other aquatic life. The shade from the vegetation helps to cool water temperatures in the river and seasonally provides insects for fish to forage. SRA is important to the juvenile salmon and steelhead as they migrate down the river to the sea. Terrestrial insects that live on riparian vegetation fall into the river and provide an important food source for fish. Riparian trees and shrubs will eventually end up in the river channel as floods erode the bank or sweep them from the floodplain. Once in the river channel, the stems, trunks, and branches become very important structural habitat components for aquatic life, including fish. Most of the aquatic invertebrates found in the river occur on the woody debris. These invertebrates, in turn, are the primary food of juvenile salmon and steelhead. Large wood affects the hydraulics of flows around it that results in a more complex channel geomorphology and the storage of spawning gravels. (For more information on fish and invertebrate use of riparian habitat see Moyle et al. 2004, RHJV 2004, USFWS 2005, and the UC Davis California Fish Website.)

IV. Human Impacts on Riparian Systems

A. Altered River Processes

Riparian vegetation and wildlife are adapted to the physical river processes of flooding, sediment transport, and channel meander. River and floodplain management by humans through the use of dams, levees, bank stabilization, and water diversions significantly modifies the timing and magnitude of these processes.

California's Central Valley riparian areas have a long history of human use. Native Americans lived in villages on the higher portions of the floodplain near the river channel. They harvested salmon with the use of in-channel weirs. At the time of contact with Europeans a well used road paralleled the channel of the Sacramento River (as described by Spanish explorer Moraga in Kelley 1989). The European settlers of California learned early-on that a consistent living could be generated by farming the rich alluvial soils found along most of the major rivers in the Central Valley. The annual threat of flooding limited permanent development of much of the floodplain. Throughout the Central Valley levees were constructed to protect farmland from scour and sediment deposition during floods. The construction of dams for flood control and water supply started in the 1930s and continued into the 1970s, allowing most riparian lands to be converted to agriculture. Today, major dams block virtually all the large rivers in the Central Valley, with the resulting loss of 95 percent of pre-European acres of riparian habitat (Katibah 1984). The dams have also modified the river processes, including the cut-off of sediment and organic matter transport and the greatly altered seasonality of flows below the dams. Rock and gravel mining in-channel and on the flood plains causes major disruptions to river flows, sediment transport, and the aquatic ecology required by fish. These changes have altered the ecology of the river channels and floodplains to such a degree that many characteristic riparian species reproduce only on rare occasions. In addition, the structure of the vegetation has changed thereby eliminating habitat for many wildlife species, and allowing many non-native invasive species of plants to dominate the floodplain.

1. Dams

Dams for flood control and for water storage probably have the most significant ecological impact on floodplain biology:

- Dams severely modify the amount and timing of flows in the river below the dam (modified hydrograph), which in turn impacts the life histories of both plants and animals, resulting in many species being unable to survive or reproduce. Over time, this results in altered plant and animal community structure and function.
- Dams cut-off sediment transport. Incoming sediment carried by the river from its watershed is trapped in the reservoir behind the dam. Consequently, floodplain building may cease below the dam, yet channel and bank erosion may continue, resulting in entrenched channels that are much lower than the floodplain and flood it less frequently.
- Dams cut-off organic material transport, e.g. large wood and vegetation detritus. These materials provide nutrients, food, and shelter for aquatic life.

The resulting impact on the river below a dam is often a dramatic change in the quality of the sediments.

The finer sediments (sand, silt, and clay) are washed downstream and only the coarser gravels and cobbles remain. This situation can affect plant species ability to establish and grow, and may also negatively affect anadromous fish spawning success. In addition, a dam usually reduces the magnitude of the high flow events that historically reshape and rejuvenate the channel through erosion and deposition of sediment. For more on the effects of dams, see a list of potential effects on the environment (CDA 2008).

The flooding recurrence interval for a site under the influence of existing flood control projects, such as dams, should be determined in order to evaluate the impacts upon the succession of a planting through time. A review of historical flood flows and flood elevations will give insight into probabilities of flood frequency on the site. Quantitative historical flow data for sites throughout the state can be found at the California Department of Water Resources California Data Exchange Center (CDWR 2009a) and the Real Time Water Data for California (USGS 2009). Evaluation of current and future flooding recurrence on a project site by a fluvial geomorphologist or hydraulic engineer is usually necessary to develop a plan that will succeed over time, and in many cases, consultation from these experts is required to complete the necessary permitting for projects in major floodways.

2. Levees

Levees that are constructed to protect riverside property from flooding effectively disconnect (or isolate) the river from its floodplain. The biological response to this isolation is ecological degradation of the plant and animal communities and the invasion of many weedy species that ordinarily would not be present due to flooding. Flooding is essential to the definition of riparian as used in this Handbook, therefore restoration should take place on the waterside of levees to ensure physical river processes affect the project area.

3. Bank Stabilization

Bank stabilization often is accomplished by the use of rip-rap rock placed upon the bank from its toe to its crest in order to prevent bank erosion. In meandering systems, rock used in this way may halt natural river movements, effectively eliminating one form of natural sediment recruitment, and halting or impeding channel meander responsible for creating and rejuvenating plant and wildlife habitat.

Levees or bank stabilization that extends for long distances on both sides of a channel (termed channelization) will cause hydraulic forces in the channel to be more intense/extreme due the increased depth of flows. This will result in increased rates of bank erosion and channel-scour, and the development of an entrenched channel.

4. Water Diversions

Water diversions reduce the quantity of water in the downstream channel and greatly change water temperature, affecting river processes and hydrology. How these diversions impact the hydrograph for a project site must be understood if the restoration planting is to be successful. Specifically, the timing and duration of high water releases resulting from water diversions must be known.

Ground water pumping, including conjunctive use programs may affect local and regional water table depths, possibly affecting restoration project success because the local water table may drop below the rooting depth of vegetation. For more information about conjunctive use, see the California Department of Water Resources Groundwater Conjunctive Use webpage (CDWR 2009c).

B. Altered Geomorphology

1. Gravel Mining on Floodplains and In-stream

Historic gold mining and modern gravel mining have resulted in extreme modification of in-stream and floodplain geomorphology. Large mining pits (covering many acres) are left behind after mining ends. These pits are unnaturally deep, they often capture the active channel, and they support non-native predatory fish (bass). In addition, the mining process literally turns the sediments upside-down; the channel and floodplain end up composed primarily of cobbles and gravel with most of the fine sediments (clay and silt) washing away during mining activities. Cobbles and gravel do not support plant growth. For examples of restoration projects with mining pits see this San Diego River project (SWRCB) and section 24.8 of Lessons from the California Campaign (SFU 2009).

2. Land-leveling for Agriculture

In the Central Valley most agriculture fields have been leveled. High water channels on the floodplain are filled and the natural drainage is altered. Land-leveling changes the local patterns of flood flows such that care must be taken when interpreting/comparing historical aerial photos during the site evaluation process. A hydraulic engineer should be consulted to determine the project site specific flow properties.

Reconstructing natural topography can be expensive because of the high cost of the heavy equipment that is required. Opportunities for reconstruction of the natural topography may be funded if flood conveyance can be demonstrated as a benefit.

C. Land Use Conversion

1. Agriculture

Agriculture conversion physically replaces the complex, multi-layered riparian vegetation with a uniform vegetation pattern composed of one crop species. Most wildlife only use agricultural fields for movement to adjacent forest patches, or for seasonal uses such as foraging by waterfowl. Agriculture land cover typically cannot sustain wildlife populations because they do not provide enough cover types or food (Bellemore et al. 2003, Waltert at al. 2004). Agricultural conversion can result in a highly fragmented (non-contiguous) riparian habitat. These remnants are usually too small to support the needs of wildlife. For example, the vegetation structure might be perfect for nesting for a focal bird species, but the number of acres is not large enough to support the insect food that the species requires to raise a brood.

Agriculture often generates irrigation drain-water that finds its way into the river. This drain water can deliver pesticides and fertilizers into the river, changing aquatic communities and compromising water quality. Drain-water is typically a much higher temperature after it has flowed through a field and can have deleterious effects to local fish populations, depending upon the water volume into which it drains.

2. Livestock Grazing

Livestock grazing impacts the watershed by affecting the timing of flows and the transport of non-point fine sediments throughout the watershed. The livestock compact the ground, slowing percolation of water, and grazing shortens the vegetation. Compacted soils and reduced vegetation cause the velocity of water runoff to increase, which in turn causes more surface erosion in the watershed and adds abundant fine sediment to the river (Swanson 1988). Intensive grazing over many years in the riparian zone often results in a reduction of the cover and density of the understory, the deepening of the stream channel (entrenchment),

and the consequent reduction in many species of wildlife that rely upon dense understory vegetation near open water. In recent years government land management agencies – Bureau of Land Management and the Natural Resources Conservation Service – have been actively fencing riparian areas to keep out the livestock.

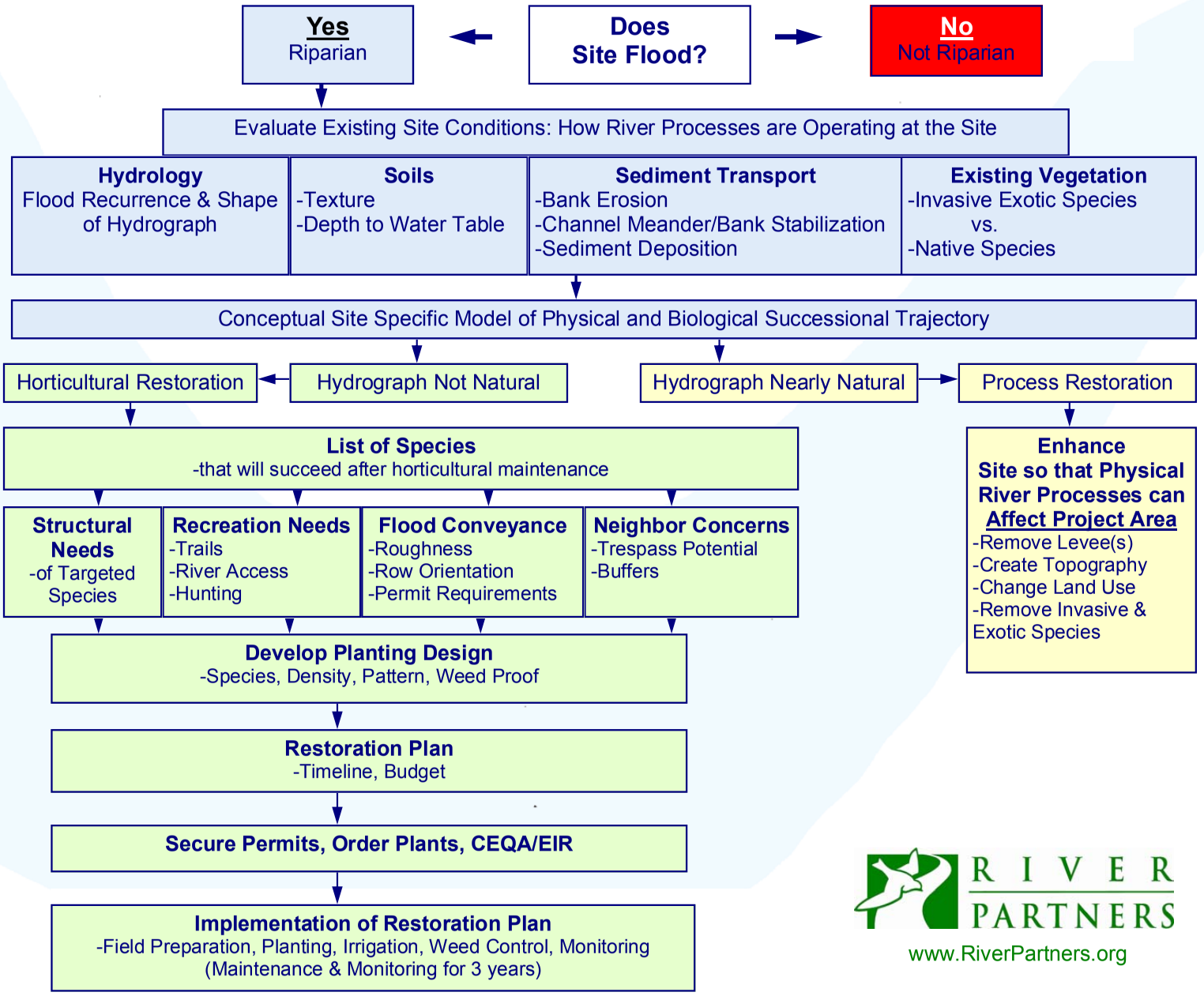
3. Logging

Logging and the road-building required to support it can have major disruptive impacts upon a river and its watershed. Logging practices in the watershed usually results in an increase in fine sediment run-off that can fill the river channel. The geology of the Coast Ranges of California is especially susceptible to erosion after logging. Redwood Creek in Del Norte County (Crater Lake Institute 2009) is an example of a watershed negatively impacted by logging practices, where the riparian zone has been buried under the sediment eroded from hillsides.

4. Urbanization

Urbanization along a river results in its channelization and typically reduction or removal of all riparian vegetation and an increase in impervious cover such as concrete and pavement. Impervious cover can result in increased run off and eliminates permeable ground where water can recharge underground aquifers (US EPA 2009). Where patches of riparian vegetation remain as parks, wildlife use is minimal because of the lack of proper vegetation structure, high density of human use, and feral animals, most usually domestic cats.

Flow Chart for Site-Specific Riparian Restoration Planning and Implementation



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A. Flow Chart Planning Process and Explanation

The following descriptions of each step in the flow chart provide more detail about the factors to be considered at each stage of restoration planning and implementation. In Section XII, several restoration projects are presented that illustrate how many of these steps were addressed.

Does the Site Flood?

A fundamental question. If the site does not flood, then river processes are not operating on it and it will not function as riparian habitat.

Evaluate Existing Site Conditions

Determine how river processes affect the site. Existing site conditions will determine the growth and reproduction of each species that will be planted. What is the potential for future changes to existing conditions?

Land Use History

Interviews with former land owners and neighbors, agriculture records of the site, and Federal and State Agency personnel familiar with the site can provide a history of land use that can be useful in current plant design. If the site was previously farmed, the farmer might have useful tips such as what crops grew well in which locations and where the problem areas of the site (e.g. poor soils, patterns of flooding, sediment deposition) were that needed extra irrigation or were avoided all together. This information can give a head start on selecting the appropriate planting design.

Hydrology

Using several sources of information, such as stream flow data, aerial photos, and input from hydraulic engineers, evaluate the flood recurrence interval on the site, both currently and historically. Flood events have been photographed from the air over the Central Valley since 1937. Certain areas (e.g., around the Delta) have had detailed land surveys carried out since the early 1900s such that channel locations are known from that time. The channel location of the Sacramento River is known for every year since 1896, based upon the records of steamboats from that time.

Soils

Evaluation of soil features will be the most important ecological factor that determines the growth of each individual plant of all species. Back-hoe pits or soil auger holes should be excavated at several locations across the restoration site with guidance from an NRCS web soil survey map. Particular attention should be given to depth to water table (winter vs. summer levels), and stratification of soil textures (presence of sand lenses or clay layers) from the top to the bottom of the pit. This information, coupled with knowledge for each species about its rooting-depth and patterns of root growth in various soil textures will allow the restoration planner to develop a palette of species that will likely grow on the site.

Sediment Transport

Evaluation of bank erosion rates on the site and consequent channel meander across the site. Sediment deposition across the site after a flood should be evaluated. The existence and age of point bars will tell much about the magnitude of sediment transport at the current time.

Existing Vegetation

Map out the existing vegetation on the site. Native trees and shrubs can be incorporated into the planting design, whereas invasive species should be targeted for removal. Do not forget about native herbaceous understory species.

Conceptual Site Specific Model of Biology and Physical Succession

Based upon the site evaluation, a conceptual model can be developed for plant succession under the influence of current physical river processes. This model is essentially a synthesis of the information gathered during the site conditions evaluation. The conceptual model helps visualize the biological trajectory of the site under the current conditions with and without restoration. For examples of conceptual models, refer to the case studies in Section XII.

State of the Hydrograph

All plants and animals that reside on the floodplain of a river are adapted to the timing of flows throughout the year. The seasonality, frequency, and duration of flood events today should be compared with historical data. A natural hydrograph shows low flows during the summer and fall, with higher flows during the winter and spring. It is the springtime recession limb of the hydrograph (moving from spring into summer) that is ecologically critical for seed dispersal and seedling establishment on exposed mineral substrate of several important riparian plant species. How can you determine which path to take for an effective restoration? Existing site conditions and local knowledge should be sufficient to answer this. However, a way to obtain an independent source of information would be to study historical and current records of river flows. All rivers and streams in California have gaging stations located somewhere along them that continuously measure the water-elevation of the river. See real-time water data for California (USGS 2009) and the California Data Exchange Center (CDWR 2009a). Plotting the daily water surface elevation for the entire year will reveal a graph that rises during rainfall events and remains higher during the winter and spring compared to summer and fall elevations. If the hydrograph indicates smooth rising and falling relative to rainfall and run-off, then the river has a natural hydrograph. On rivers with dams, the hydrograph can be a straight, horizontal line through the entire season, or even have higher flows during the summer than in the winter, and peak stream flows may be much less variable over time. Native plants will never re-establish under a flat-line hydrograph because the timing and duration of flooding is not-natural or non- existent (flat line hydrograph). Horticultural restoration would be called for on such heavily managed rivers. Process restoration would be indicated where the flows mimic the natural hydrograph.

Horticultural vs. Process Restoration

Based upon the site evaluation, specifically the existing hydrology as displayed by the hydrograph, the restoration planner can determine the probability that the site can "restore itself." Typically, a river in California with a dam will require horticultural restoration because the river processes cannot provide the needed conditions for regeneration of most species (seedling establishment and growth). Process restoration may be a viable way to restore a site if river processes are still functioning. Intervention in the form of levee removal, modification of topography, land use changes, and removal of non-native weeds may be required to initiate natural biological processes.

List of Species

Based upon the conceptual model, develop a list of plant species that will survive and grow on the site after three years of irrigation and weed control.

Structure Needs of Target Species

With the list of plant species that will grow on the site, and knowledge of the habitat needs of the target wildlife, the restoration planner can arrange individuals of each plant species into a pattern that the target wildlife will use. That is, the planner can design groves of trees, shrub thickets, and herbaceous openings, all at whatever area or proportion of the site might be needed. Work with a broadly trained wildlife ecologist to apply information in restoration planning efforts. Plenty of good qualitative and quantitative information is available in the scientific literature and published species accounts describing wildlife habitat preferences, such as the CalPIF focal bird species and CWHR discussed earlier.

Recreation Needs

As part of the restoration, recreational facilities may be included. Hiking trails, river access, and hunting may be incorporated into the planting design.

Flood Conveyance

On the large rivers that function as floodways, a restoration design must be flood neutral, that is, the planting must not change the depth of flood waters both upstream and downstream of the site, and the planting must not direct flows into bridges, levees, etc. Planting designs can be developed to assist in flood and sediment conveyance by directing flows away from structures or protecting levees from erosion. A certified civil engineer, specializing in flood conveyance, may be needed to verify the flood neutrality. This may involve a hydraulic model examination of the planting design.

Neighbor Concerns

How does the project affect adjoining lands and other conservation efforts? Neighbors of a restoration planting can usually offer useful information about the site. They may also have concerns about wildlife and human trespass. Often trespass concerns can be mitigated by planting buffers or borders along the edges of the planting that will discourage human trespass, such as rose, blackberry, and poison oak hedgerows that also have wildlife benefits.

Develop Planting Design

The above evaluations should provide sufficient information to develop the final planting design. Proportions of each species across the site, density of plants, the pattern of the plants across the site, understory planting that will prevent non-native weed species from colonizing and/or spreading on the site can be determined from this information.

Restoration Plan

Develop a document that pulls together and explains ecology and implementation aspects of a restoration project, provides a project timeline, provides a budget, describes implementation methods, describes monitoring and adaptive management protocols for the site.

Implementation of the planting design

Implementation involves planting, effective weed control, irrigation, and monitoring over a three year period.

B. Tools for Planning

During the planning process of a restoration project, these tools will be needed at hand:

- **River Atlas** – Several years of maps of the river on your project site will help illustrate the meander of the river overtime. Many can be found online, for example, an atlas of the Sacramento River from the Sacramento River Area Conservation Forum in 1997 and 2007.
- **Aerial Photos** – Like the atlas it would be good to have several years of aerial photos from your project site, to visualize how your site floods during major flood events, and to see any pre and post dam changes to flows. Many can be found online for free or ordered especially for your location and the year specified.
- **Flood Control Reports** – Quantitative historical flow data for sites throughout the state can be found at the California Data Exchange Center (CDWR 2009a). This information will be necessary for designing the restoration plantings in a way that will keep a site flood neutral and increase chances of plant survival.
- **Watershed Plan** – For information on watersheds throughout California, check out the UC Davis California Watershed Assessment Manual, the UC Davis ICE California Rivers Assessment Interactive Web Database, and the California Department of Water Resources Watersheds Page. A project will be influenced by the area and elevation of its watershed, the presence of dams and river channeling, and the land uses throughout the watershed.
- **NRCS web soil surveys** – Soil surveys will provide a baseline of understanding of the soil types present at a given project site, and these surveys can help decide how many soil cores should be taken throughout the project site.
- **Wildlife Habitat Relationships** – Use information about wildlife species that could occur at the project site, to design a restoration that will provide nesting, food and cover. The California Department of Fish and Game wildlife habitat relationships provide life history and habitat relationships for 694 wildlife species throughout the state. For specific habitat descriptions of focal bird species, see the RHJV Riparian Bird Conservation Plan.
- **Hydraulic Models** – All the large rivers in California have hydraulic models that estimate water depth and velocity at given flows at specific river reaches. In consultation with a civil engineer, a hydraulic model can tell the planner how a site floods and at what flows flooding starts. Potential planting designs can be tested using the hydraulic model for the river to determine any impact that a vegetation planting may have.
- **Bay Delta Conservation Plan (CALFED)** – Regional conservation plans may exist for your river. The California Bay-Delta Plan encompasses the entire watershed of the Sacramento River and identifies areas where habitat restoration should be taking place.
- **Central Valley Joint Venture (CVJV) Implementation Plan** – Provides quantitative objectives for the conservation of focal species of riparian birds by geographic regions of the Central Valley. www.centralvalleyjointventure.org.

VI. Design Objectives

A. Objective 1: The Local Community

A restoration plan must describe how the proposed restoration will interact with the local needs and uses of the river. Local residents can offer a perspective of the local ecology based upon many years of experience. Engaging neighbors early in the planning process is always a good idea so that their experience and concerns can be incorporated into the restoration plan.

1. Flood Damage Reduction

How the restoration project affects local flood control structures and their management must be described in detail. Consultation with local levee maintenance districts, the Central Valley Flood protection Board, or the Army Corps of Engineers may be required. An evaluation of the planting design by a civil engineer that specializes in the hydraulics of flood flows may be needed. Modification of a design may be required based upon modeling results to ensure a flood-neutral restoration design.

A flood-neutral riparian restoration project is defined as a restoration planting that does not cause any change in the existing local water surface elevation or velocity of water flow during a flood, and does not direct flows into levees or other structures. In other words, the water elevation during a flood will remain within the threshold of maximum flow that the floodway was engineered to contain after the restoration plantings have grown.

2. Improve Water Quality and Increase Supply

The conveyance of agricultural and urban water for the local community is a major use of the large rivers in California. Diversions affect quantity of water in the channel and the hydrograph of the river. The restoration planner must accommodate the existing water management regime into the proposed plant design. For example, irrigation conveyance often causes the river to flow relatively high (sometimes this is the highest flow of the year) at a time of the year when flows would naturally be receding. This can raise havoc with the native plants and animals that are adapted to the natural flow regime (see Adaptation to Hydrograph boxes 1 and 2). On the other hand, the ecologically artificial high flows may result in an elevated water table that will benefit some species of plants.

3. Recreation and Public Use

Recreational use will happen on the restoration site, regardless of signage or patrols. The restoration plan should address future opportunities for hunting and fishing, wildlife viewing and nature appreciation. This may involve development of trails that direct users away from sensitive areas or planting buffers such as rose, blackberry or poison oak that physically keep people away from sensitive areas and private property. A special use in some regions is for the restoration project to also function as a Native American collection site for plant material for traditional uses.

4. Watershed Benefits

Riparian restoration can have many positive benefits to the surrounding regional landscape and the local community, and these should be communicated to the public to increase awareness. Often, the potential sites for restoration are agricultural fields that are not economically viable because of their proximity to the river and frequency of flooding, and these lands can then be purchased from willing sellers. There are also several federal cost share programs to assist with exchange of land and habitat improvement on private lands (Budget Section IX). Restored riparian habitat can provide several benefits to the surrounding communities such as:

- Enhancing Flood Control by directing flows, stabilizing banks, and trapping large debris and sediment (Chagrin River Watershed Partners, Inc 2001).
- Improving air and water quality through carbon sequestration and by filtering nonpoint source pollution.
- Providing and enhancing recreation on the site (hiking, canoeing etc.) and by supporting fish and wildlife (bird watching, hunting, and fishing) (Opperman and Merenlender 2004).
- Supporting adjacent agriculture by attracting beneficial insects and through suppression of non-native invasive weeds (California Farm Bureau Federation 2008).

B. Objective 2: The Horticultural Potential

One of the fundamental components of a restoration plan is the identification of reference sites to use as guides for developing the list of species to be installed, their densities and associations to be planted across the restoration site. From an ecological perspective this, arguably, cannot be done because the influence of riparian ecological processes are very different today in the Central Valley than when the rivers were not regulated by dams, levees and diversions. In other words, today's functioning of riparian ecological processes is not natural, and this impedes our ability to predict plant succession and survival decades into the future. However, reference sites are especially useful for communicating a restoration vision to clients and the community. A series of reference sites that are shared with others during a peer-review of the restoration plan can be very useful and important as the planner develops the plant design. Information and knowledge gaps can be identified early on in the planning process.

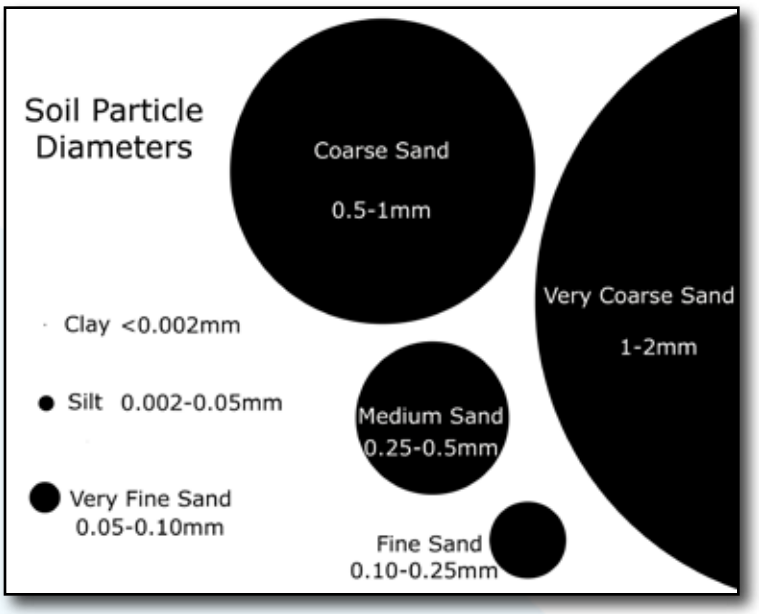
Horticultural restoration requires knowledge of local site conditions in order for a planting to successfully establish. It is common for restoration projects to include a three year maintenance regime, during which the plants are irrigated, weeds are controlled and mortality is kept under a specified level by re-planting. Beyond this period of maintenance, species will only survive if they are well matched to the site conditions. Species of plants must be matched to soil types and hydrologic conditions under which they will grow and prosper. Consequently, the first step in developing a plan and a list of species for any riparian restoration project is a detailed site evaluation that describes soils and local hydrology. Ecological preferences of select riparian plants are provided in Appendix 3.

An important design strategy is to plant more individual plants per acre than can possibly survive to a mature size. This will force competition among species and individuals, with some individuals of some species dying over the years. The result will be a plant community composed of species that are well-adapted to the existing ecological conditions of the site. This strategy forces the planner to carefully consider what species to install and to pay attention to the tree to shrub ratio of the design. For example, too many cottonwoods per acre can result within five years in a closed canopy cottonwood forest with no understory because of competition for sunlight. What is too many cottonwoods? The answer will involve an understanding of both cottonwood growth characteristics and the ability of the site to provide favorable growing conditions.

1. Soils

Soil conditions are the most important factors that determine the survival and growth of any species. (If any species cannot grow in the soil on a site, then the restoration planting will fail). Examination of the NRCS web soil surveys for the project site will help determine how many soil cores are needed to ground truth the soil maps. Soil cores will also provide information about the soil texture and stratification across the site. Depth to the water table must also be determined at multiple locations throughout the site. The number of soil cores and measurements to water table depth will vary by site but soil surveys, river atlases, and aerial photos can help determine this.

Figure 4: Soil Particle Sizes

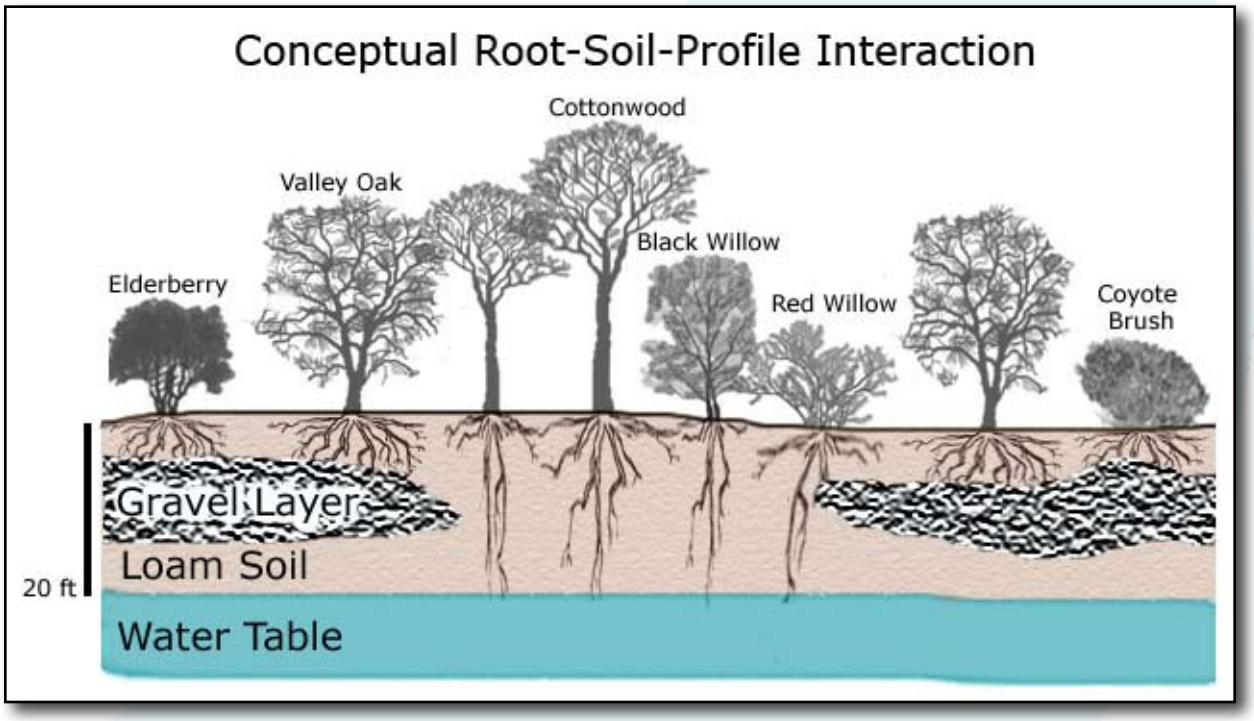


The diameter of soil particles determines their classification as either clay, silt, or sand.

a. Texture and Stratification

Soil texture, the proportion of gravel, sand, silt, and clay (Figure 6), usually varies greatly across the entire site. Often this variation is because riparian floodplains receive coarse sediments – sand and gravel – during

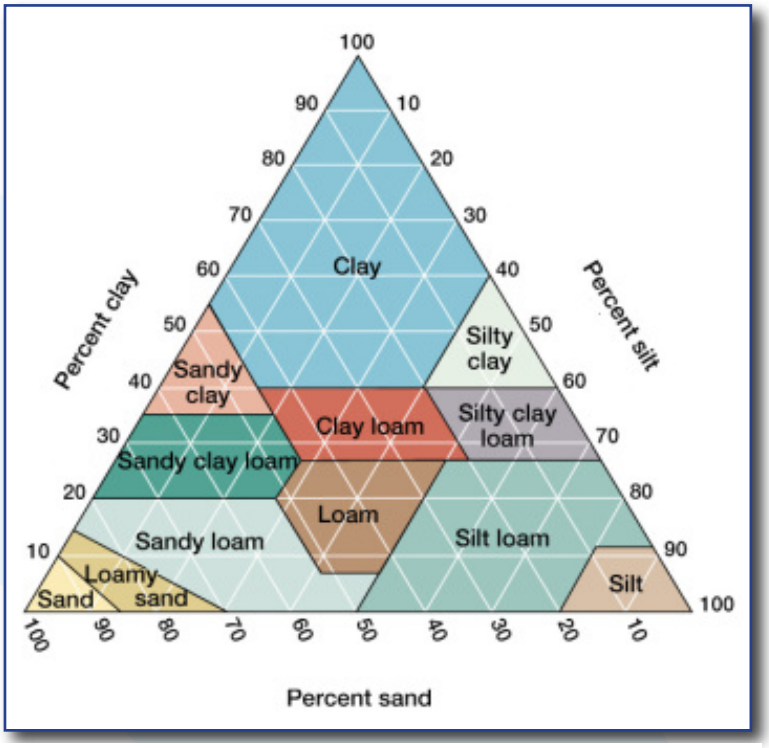
Figure 5: Root-Soil Profile Interaction



Lenses of course soil in the soil profile will affect the growth of plants; lenses of gravel may prevent species that require access to the water table from surviving.

overbank flows which deposit on top of finer sediments. Likewise, soil texture can dramatically vary with depth, resulting in stratification of the soil profile. This layering of different textures can result in coarse sediments – sand and gravel – lying above or below much finer silts and clays. Plant root growth will be greatly affected by these discontinuities in the soil profile. The movement of irrigation water through the soil profile also will be affected by these discontinuities, which in turn will affect root growth (Refer to Section XII, Buffington Case Study to see how soil profiles influenced planting design).

Figure 6: *Soil triangle illustrating the classification of soil textures based on the percent clay, silt and sand.*



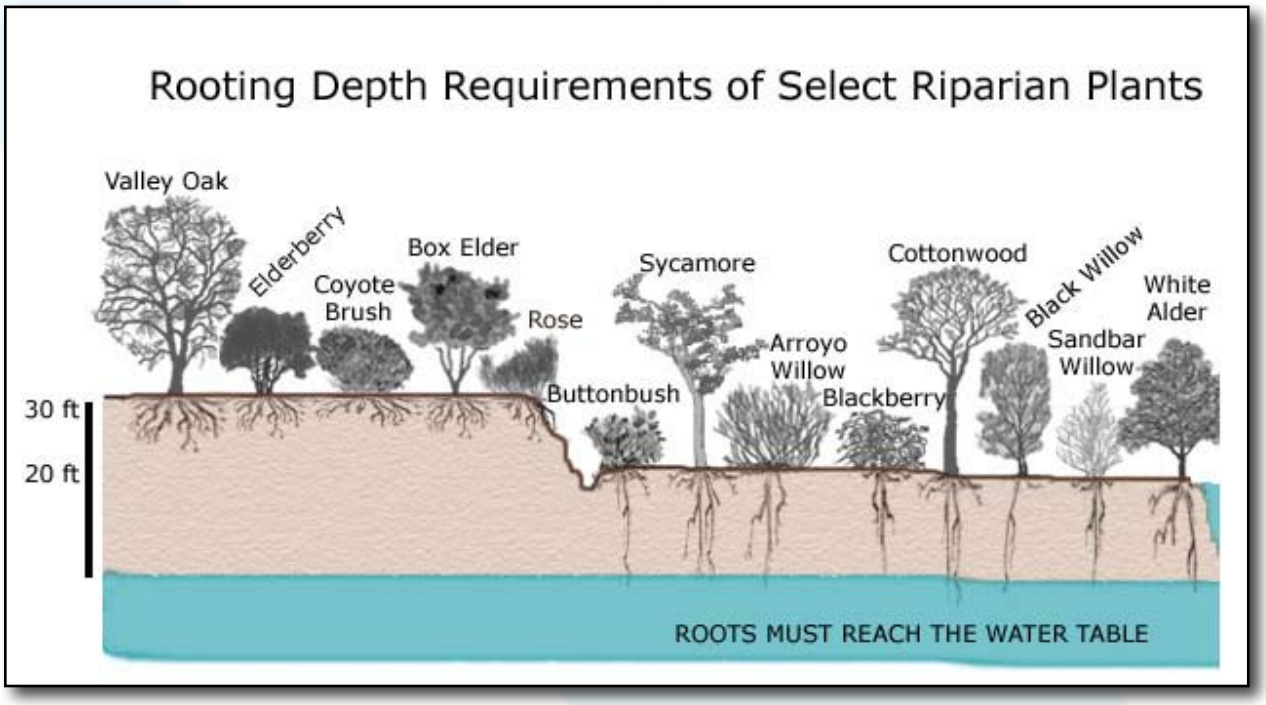
http://wps.prenhall.com/wps/media/objects/1411/1445480/FG12_15_wo_arrows.JPG

To a large extent, soil texture, determines the survival and growth rate of each species (see Section XIII for a comparison of ecological tolerances among selected riparian species). For example, species such as cottonwood and sycamore grow rapidly in soils that have a high proportion of sand, while valley oak grow best in heavier soils composed mostly of silt and clay. Soil texture is critical to plant survival and growth because the soil particle sizes determine the water holding capability. Large particles such as sand allow water to drain quickly and cannot hold water for extended periods. Smaller particles such as silt do not allow water to drain quickly and as a result water is available to plant roots for a longer duration. As a result, soil texture can determine the method of irrigation. For example, a predominantly sandy site may not allow for the use of flood-irrigation due to rapid drainage, so a drip-irrigation system may be required. Other management practices are affected by soil texture. If the profile is highly stratified, root growth may be restricted to only the layers with finer textures resulting in poor root system development and consequent loss of top-growth. On a site with highly stratified soil, a post-hole auger or backhoe may be required to dig planting holes that will homogenize the soil profile, allowing root development to penetrate downward.

b. Depth to Water Table

Depth to water table is second in ecological importance behind soils for determining species survival, growth and the community structure of the vegetation (Figure 7, next page). Depth to water table must be known for several points across a site, as it may vary by several feet. Deep soil-augur cores and soil pit samples taken on the site will allow the depth to water table to be measured if water is reached, or estimated if soil becomes moist at the bottom of the pit. Depth to the water table can also be measured with multiple piezometers placed into the ground that reach the ground water table. Cottonwood and willows absolutely must grow their roots into the upper portion of the water table within the three-year maintenance period, or they will die when irrigation is stopped. Other species of trees and shrubs will prosper by growing their roots into the water table, however, this is not a requirement for survival. Soil profile and depth to water table interact and can be a problem for root growth if the top of the water table is within a layer of cobbles or gravel where roots cannot grow well, making the water table functionally out-of-reach of the roots.

Figure 7: *Rooting Depth Requirements of Select Riparian Species*



Rooting depth requirements of riparian species must be known, along with the depth to the water table across the site, so that planted species will survive and thrive after irrigation is no longer applied.

c. Nutrients in Soils (natural vs. fertilizer)

Riparian soils are some of the richest in the state. Deep loamy soils, in combination with a water table within reach of plant roots, support rapid growth throughout the growing season for all species. Naturally occurring nutrients in the soil are abundant and readily available for plant growth. For example, stem cuttings of willow and cottonwood can grow to 6 feet tall the first season and valley oak grown from an acorn can grow to 4 feet the first year. With this kind of plant performance, additional fertilizer at the time of planting is not necessary.

d. Irrigation and Weed Control are Determined by Soils

When implementing restoration, characteristics of the soil on the site will determine the hardware needed for irrigation, the timing of application of irrigation, and the timing and logistics for weed control. Soils composed predominantly of sand will drain rapidly after irrigation or a rainstorm. On sandy soils, irrigation must be by sprinklers or drip system; flood-furrow method will not work efficiently due to the rapid drainage. By contrast, on soils composed predominantly of silts and clay, drainage of irrigation and rain is much slower. For this reason irrigation by flood-furrow may be feasible. However, rain will turn these soils into mud that will not allow tractors and spray-rigs to enter a field for many days longer than when compared to sandy soils, affecting the logistics of weed control.

2. Hydrology, Flood Frequency, and Geomorphology

Flooding frequency on a site, or the flooding recurrence interval, will determine the plant species that will be able to prosper on the restoration site. The geomorphology of the site (its topography) will interact with flooding recurrence interval to provide a broad range of hydrologic conditions over a small amount of

area. For example, plant species can adapt to different flooding durations or regimes that vary in elevation on the scale of inches and feet. Flooding frequency will also determine weed community composition and the level of rodent populations. For example, a site that floods annually will have a very different weed community and much lower rodent populations compared to a site that may flood once every five years.

3. Plant Material for Propagation

Seeds and stem-cuttings from local sources will generate the best results for success. All plant species are composed of populations that are adapted to the local soil and hydrologic conditions where they grow. Populations that are separated by great distances, elevation, or grow on different soil types within the same watershed are genetically adapted to these different ecological sites. In a restoration plan, the source of the local plant material should be identified. What is the definition of local? Local refers to the ecological similarity of the plant material collection site to the restoration site. Ecological similarity is defined by soils, hydrology, and geographic distance. Plant material collected from a site with the same soil type and flooding regime and a short geographical distance away would fit the definition of local. When contracting for plant material from a commercial nursery, be sure that the contract specifies propagation from local genetic sources. Many of the plant species used in low-elevation riparian restoration grow throughout California, yet they are all adapted to the local hydrologic conditions of the watershed that they grow in. For example, Oregon ash growing in the Sacramento Valley begins new growth in late March, while the same species at the south edge of the Delta waits until May first. The initiation of spring growth is controlled by different genetic makeup of the ash in the two geographic regions.

Native Plants and Genetics

The following links describe genetic issues involved in restoration, conservation, and landscaping in great detail due to the significance of this issue.

- California Native Plant Society, Guidelines for landscaping to protect native vegetation from genetic degradation
- University of California Genetic Resources Conservation Program, factsheet on genetics
- USDA Forest Service, Genetically appropriate choices for plant materials to maintain biological diversity
- Society for Ecological Restoration, An Introduction to Restoration Genetics

Locally collected seed and cuttings will always perform better than seed from outside the watershed. Populations of all species that we see today have been present since the distant past, at least since the last ice-age 20,000 years ago; most probably for much longer. These populations have experienced climate change before and they have adapted. Thus, there is likely sufficient genetic variation within today's populations to meet the environmental challenges of global warming and climate change. In order to capture the genetic variation present in a population one should collect from as many individuals as is possible, over a range of elevations, and throughout the flowering and seed-set season (early and late bloomers).

The restorationist may be asked to plant a genetic "super-tree" that can grow faster and taller than any wild individual. This is a forestry approach to restoration, not an ecological approach. The problem with the "super-tree" is it's relative genetic uniformity (they are all the same) and consequent inability to adjust to future climate changes because they have no genetic variation to call upon for adapting to climate change.

C. Objective 3: Designing the Plant Association

Keeping in mind current and future site conditions, plant an association of species that will proceed through ecological succession into a sustainable community OR that will maintain a desired physical structure.

1. Conceptual Model of Riparian Plant Succession

When selecting plant species for a restoration project, it is important to understand how each species will respond over time to the site-specific ecological conditions. The development of a conceptual model of plant community succession over time relative to river processes is an important exercise during restoration design. Four conceptual models are shown, one for each case study in Section XII.

The conceptual model for succession on the restoration site allows the planner to estimate future conditions of the proposed restoration design. The restoration planner must have some prediction of the successional trajectory for the plant design. The term successional trajectory refers to changes in the species composition of the plant community over time (years and decades) on a site. For example, on an intensively managed river with multiple dams and diversions, river processes are virtually not operating because high flows and flooding rarely occur. A planting along this type of river will follow a different successional trajectory compared to a river which still is capable of flooding its floodplain on a frequent timeline. The changes in species composition will be a result of the magnitude and timing of ecological river processes that operate on the restoration site. Each species' adaptation to these processes will determine its growth and reproductive abilities on the site. The restoration planner must have some knowledge of each species' ability to persist under the ecological processes that exist today, and those that are expected in the future on a restoration site. Is the water table within reach of the rooting depth of species that require abundant soil moisture through the entire year? Will the soil texture profile support the development of the size of plants (large tree/shrub vs. small) after decades of growth?

A possible solution is to plant early successional species – willow and cottonwood – along with later successional species such as valley oak and elderberry – or planting of "two forests". The first will provide structure from rapidly growing species, while the slower growing oaks and elderberry will become dominant in the future.

2. Climate Change and Restoration

Climate Change in the future will alter river physical processes, modifying the survival of plants, and further confusing riparian ecology in California. What can the planner do to account for the largely unknown magnitude of changes in the future? The answer is to plan for ecological resilience. Ecological resilience means that a population of organisms will adapt to environmental changes over decades and centuries and persist into the future. Ecological resilience of a restoration planting might mean that it will persist into the future providing habitat as the climate changes. Planning for ecological resilience might involve the planting of "two forests" composed of species from both early and later seral stages. At the level of individual species, plant material for the restoration should be composed of the range of local genetic variation of each species that will allow for future adaptation to climate change.

Before, during, and after climate change, riparian areas will remain important corridors for wildlife as their local habitats change. As changes in climate become better understood, the optimal locations for riparian restoration may move, in order to keep these corridors as contiguous as possible. Methods in riparian restoration will have to respond to climate changes as they occur.

D. Objective 4: Habitat Structure for Wildlife

Plant an association of species that can support high native wildlife richness through a diverse structure, pattern, and density of vegetation.

1. Planting Design for Wildlife Structure

All species of wildlife require characteristic types of vegetation structure for breeding, foraging, and nesting. Vegetation structure can be defined as the foliage volume (or cover of foliage) by height for a defined area. For example, a mature cottonwood forest provides a high (tens of meters above the ground) layer of canopy cover that shades out the shrub and ground layers of vegetation, depending on the density of the cottonwood trees. Where there are gaps in the trees, enough sunlight is available to lower growing species. Shrubs planted too densely will not allow sufficient herbaceous cover to develop. A planting of a mixture of trees and shrubs will have vegetative cover at a wide range of heights and volume above the soil surface. A mixture of density of the plantings of trees and shrubs is also important. Ground cover such as low herbaceous and forb species survive best in openings of cover where tree and shrub densities are low. Any restoration design should include a shrub and herbaceous understory component. An understory composed of woody shrubs, herbaceous perennial forbs, native grasses, sedges and rushes is an important habitat structural component for many species. In addition, a dense understory will keep non-native weeds from flourishing. Mosaics of structure and density in restoration plantings provide a range of nesting, foraging, and cover for wildlife.

If fish are known to use the floodplain during flood, the restoration planner can design vegetation to accommodate their needs. For example, the Sacramento splittail spawns on flooded floodplains in mid-spring, attaching its eggs to submerged herbaceous vegetation where they hatch before the water recedes. Several recent studies have linked high levels of floodplain primary productivity (Schemel et al. 2004, Lehman et al. 2007) with increased fish growth and survival rates (Sommer et al. 2001, Feyrer et al. 2006). Riparian vegetation is a vital component to the quality of floodplain habitat to anadromous fish, and fish species richness increases where there are a variety of riparian plant communities (Feyrer et al. 2004). The movement of water is typically slower on floodplains than in the main channel, temperatures are higher and large quantities of phytoplankton, invertebrates, and plant materials such as leaves, fruits, and seeds are abundant. These conditions allow fish to lower energy expenditures and increase metabolism, resulting in faster growth (Sommer et al. 2001).

As discussed earlier, the RHJV has identified sixteen "focal species" of riparian dependent birds that are often used as targets of restoration projects in California. Other non-bird species that are often the focal species for a restoration, include the Riparian brush rabbit and the Valley Elderberry Longhorn Beetle, both are listed species under the Endangered Species Act. Designing and planting a vegetation structure for a target species can be accomplished by adjusting the density and pattern of individual plants. Pattern refers to the relative placement of trees and shrubs that will result in various structures. For example, planting clusters of a tree species can affect wildlife that use the tree species by appearing as a large plot of habitat, larger than a single tree would appear. Likewise, density of planting, which refers to the number of plant species per area, affects how the habitat is perceived by wildlife. The density of plant species can be altered to meet the needs of target wildlife species. Plant species that are important for pollinator insects can be installed in relatively larger numbers. Likewise, clusters of fruit-bearing shrubs can be planted to benefit frugivorous birds throughout the year.

Predators and/or nest parasites are critical mortality factors for riparian wildlife in altered systems. Close examination of these factors is necessary for setting management goals in conjunction with restoring vegetation structure.

2. Improving Mitigation for Wildlife

The single species design and narrow focus of mitigation plantings restrict the ecosystem benefits that the plantings can provide. However, mitigation plantings can be incorporated into larger restoration projects, increasing the value of the overall project. Regulatory agencies responsible for overseeing mitigation projects can be flexible. Ultimately, their goal is to optimize the value of the plantings for the targeted species or ecosystem function, and this can be in line with the goals of broader scoped restoration projects.

3. Non-native Invasive Plants

Riparian areas in the Central Valley support the richest soils in California. This coupled with the high water tables within reach of roots allows for rapid growth by plants. Non-native invasive plants (weeds) rapidly colonize and dominate these soils in the understory and exclude seedlings of native trees and shrubs. Abandoned farm fields typically remain dominated by invasive weeds for years and decades, especially on sites that rarely flood. Woody invasives, such as Arundo (Arundo donax) and Tamarisk (Tamarix spp), can develop large stands composed of dense stems. These species provide little, if any, habitat value to wildlife and can cause flood conveyance problems. Restoration plans should address short term weed management on site and attempt to design weed-proof plantings so that invasive species cannot gain a foothold in the future. Care should be taken to limit the spread of invasive plants to adjacent areas of the project site.

References for Invasives Identification, Impacts and Control

For references about invasive identification, impacts and control, see:

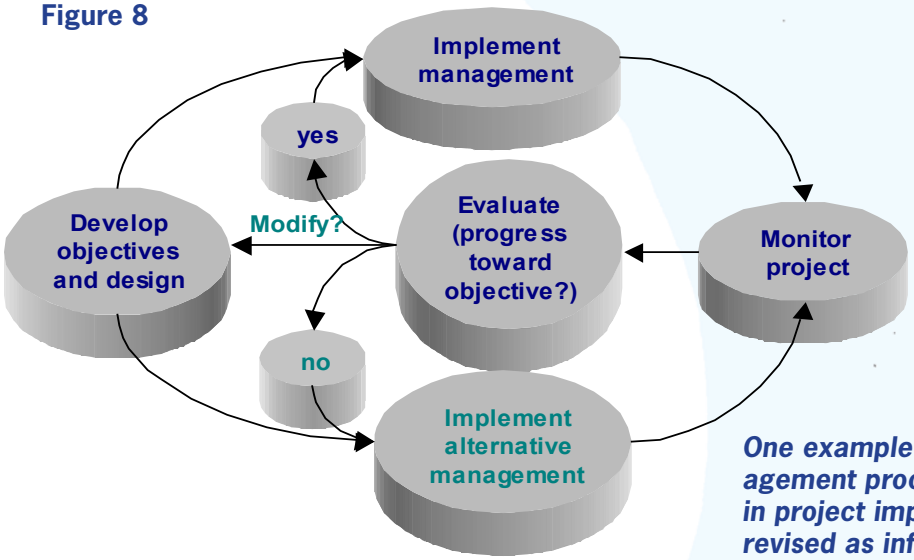
- California Invasive Plant Council
- Invasive Species Defined in a Policy Context: Recommendations from the Federal Invasive Species Advisory Committee
- University of California Weed Research and Information Center

VII. Monitoring Riparian Restoration Projects

A. Implementation Monitoring

The purpose, significance, and success of a riparian restoration project can be, and at times are required to be, monitored throughout the entire process. This means monitoring can take place before implementation, during restoration, and after implementation. The California Rapid Assessment Method (CRAM) is a statewide, standardized method to monitor wetlands (which include riparian areas) in a cost-effective and scientifically defensible manner. The methods and handbook are available online (www.cramwetlands.org). Given the ecological complexity of any restoration site, many unknowns will affect the performance of the plants. Consequently, implementation requires an adaptive management approach to the timing and level of intensity of management actions during implementation. Adaptive management requires the field manager to carry out small-scale experiments in the field that will influence his management actions in the future.

Figure 8



One example of an adaptive management procedure, where any step in project implementation can be revised as information is gathered, including the original objectives.

For example, how often should irrigation be applied? All plant species have inherently different requirements for soil moisture for optimum growth. In addition, soil profiles vary across a site. Together, the plant species' individual requirements and the variability in soils means that uniform irrigation levels across the site will not impact all plants equally. The field manager must carry out simple experiments, or "test-plots", to determine the optimal irrigation schedule and amounts at different times of the year that will result in the active growth of all species.

Timing of implementation tasks is critical to project success. Delaying weed control or irrigation by even a few days can have disastrous impacts on the growth and survival of plants. Monitoring to determine maintenance needs must take place weekly, and during certain times of the year (e.g. mid spring) daily monitoring may be required.

B. Measuring "Restoration Success"

Restoration success of the project will be determined by how well the goals for the project were met. Not only will success therefore be different for each restoration project, success can also be measured at several different levels.

1. The Contract Level

Contracts require some kind of quantitative measure of performance to evaluate success. Most call for a cumulative survival of all plants and trees after the maintenance period of at least 70 percent. Percent cover of the entire site by native species is a reasonable performance goal when grasses or other herbaceous species are planted.

2. Horticultural Success

In addition to survival, height and cover, or diameter at breast height of individuals of all species can be measured annually to track growth. Permanently marked sample plots are the ideal design, since they can also be used for post-project monitoring. Recent advances in the restoration of riparian understory species allows for restoration success to be defined as the percentage of the entire site that is covered by native species.

3. Wildlife Use

Monitoring of use of the restoration planting by wildlife species is the ultimate measure of success of any riparian restoration project. The methods of monitoring depend on the original goals of the project and wildlife for which the restoration was designed. Monitoring methods will also depend on the resources available for monitoring, including time. Long-term monitoring is the best way to understand how wildlife respond to the project site. It is best to select wildlife that are considered umbrella species, which are species that represent many other species, and to select a range of umbrella species that represent multiple habitat requirements (Block et al. 2001). Landbird monitoring is an excellent way to measure restoration success, because birds are relatively easy to locate and observe and they cover a wide range of habitat types (RHJV 2004, Gardali et al. 2007). A diversity of birds on the site means the restoration successfully provided a diversity of habitat to them. Presence and absence monitoring is a useful indicator of the wildlife present on the site. More detailed surveys that can provide demographic data such as nesting success, mortality rates and monitoring over many years will indicate whether the site is functioning as quality habitat for breeding or as a site that wildlife use temporarily.

4. Mitigation Success

Mitigation can take the form of creating new habitat to replace the lost or enhancing existing habitat through for example, additional plantings and invasive species removal. Whether or not mitigation is successful depends on how suitable and accessible the habitat is for the targeted species, or how well the created habitat replicates the ecosystem services of the disrupted natural system. Unfortunately, evaluations of the mitigation process from the scientific assessment and quantification of the resources, to the monitoring of completed mitigation projects, have revealed many shortcomings (Holyoak et al. 2009). For one, multiple small scale mitigation projects that replace intact ecosystems, result in fragmented habitat (Noss et al. 1997). The timing of mitigation plantings with respect to take of natural habitat is also rarely addressed. Mitigated habitats may take decades or even centuries before they develop fully to provide all the resources needed by the imperiled species (Morris et al. 2006). All forms of mitigation require a monitoring plan, but these are frequently lacking in quality or missing altogether (Kareiva et al. 1999, Holyoak 2009). Too often mitigation allows development to proceed under the incorrect assumption that the losses of natural resources are offset through mitigation activities. New information (2009) suggests the effect of these habitat offsets on conservation is more placebo than clearly beneficial.

C. Post-project, Long-term Evaluations in the Distant Future

Long-term evaluations of the success of restoration projects will be critical for refining methods and objectives. However, restoration contracts fund only implementation tasks for three to five years. The question for the implementer, as a contract approaches its end, is what can be left behind that will allow for future evaluation of the project? The most important items include the final draft of the implementation plan and an as-built drawing of the final planting patterns and species compositions. The careful placement of permanent monitoring plots and permanent photo points across the site will also provide some long term monitoring opportunities.

VIII. Permits

A. Pre-project Approval Permits

1. CEQA or NEPA

California Environmental Quality Act (CEQA) or National Environmental Protection Act (NEPA) environmental compliance is dependent upon the funding source for the restoration project and the ownership of the project area. Typically, restoration on federal lands requires NEPA compliance. Funding from a state program (for example the Wildlife Conservation Board or Department of Water Resources Flood Protection Corridor Program) necessitates CEQA compliance.

2. Encroachment Permit

An encroachment permit must be secured from the Central Valley Flood Protection Board for all projects which encroach into rivers, waterways and floodways within and adjacent to federal and state authorized flood control projects and within designated floodways adopted by the Central Valley Flood Protection Board. Depending on the district and river, there may be additional encroachment permits required by one of the several flood control districts throughout the state. As part of the encroachment permit application process, adjoining landowners and local levee districts must be contacted and informed of the restoration project. An endorsement must be obtained by the local levee district. If an application contains an endorsement from the local levee district, the General Manager of the Central Valley Flood Protection Board may issue an encroachment permit. If an application does not include such an endorsement, the Central Valley Flood Protection Board must meet to review the application and vote to issue a permit. During the review process by the Board, the project design and hydraulic analysis are examined. Once an encroachment permit is issued, a levee inspector from the Department of Water Resources must be notified and requested to conduct a site inspection 10 days prior to the start of the restoration project.

General information regarding an application for encroachment permit can be found at the California Department of Water Resources encroachment permits page (CDWR 2009b).

3. Lake and Streambed Alteration Agreement (1600)

Section 1600 of the California Fish and Game Code requires that, prior to implementing a restoration project, activities that could significantly modify a stream, lake or river be identified. The California Department of Fish and Game must be notified and consulted with to determine whether or not an activity could substantially adversely affect an existing fish and wildlife resource.

Notify the Department of Fish and Game if any activity will:

- Substantially obstruct or divert the natural flow of a river, stream, or lake.
- Substantially change the bed, channel, or bank of a river, stream, or lake.
- Use any material from the bed, channel, or bank of a river, stream, or lake.
- Deposit or dispose of debris, waste, or other material containing crumbled, flaked, or ground pavement where it can pass into a river, stream, or lake.

If it is determined by the Department that there is an adverse effect on natural resources, a Lake or Streambed Alteration Agreement is required. For more information, forms and instructions see the California Department of Fish and Game's Lake or Streambed Alteration page.

4. Army Corps of Engineers 404

Section 404 of the Clean Water Act requires that permits are obtained prior to activities that could result in discharge into wetlands, streams, rivers and other U.S. waters. The Corps is responsible for issuing these permits. For an overview of Section 404, see US EPA 2009.

5. Water Quality Certification (401)

Section 401 of the Federal Clean Water Act grants each state the right to ensure that the State's interests are protected on any federally permitted activity occurring in or adjacent to Waters of the State. In California, the State Water Resources Control Board is the agency mandated to ensure protection of the State's waters.

A project that requires a federal permit or involves dredge or fill activities that may result in a discharge to U.S. surface waters and/or "Waters of the State" are required to obtain a Clean Water Act Section 401 Water Quality Certification and/or Waste Discharge Requirements (Dredge/Fill Projects) determination from the Regional Water Quality Control Board, verifying that the project activities will comply with state water quality standards. If a project does not require a federal permit but does include dredge or fill activities, the Regional Water Quality Control Board may exercise the right to issue either a Water Discharge Requirements or Waiver of Waste Water Discharge Requirements determination.

It should be noted that CEQA compliance must be completed before consultation with the Regional Water Quality Control Board.

6. Archaeological Survey

Several federal and state regulations, such as the National Environmental Policy Act (NEPA), National Historic Preservation Act (NHPA) and California Environmental Quality Act (CEQA), may require an archaeological survey or disclosure of known archaeological or cultural resources within or near the project area, and an assessment of potential impacts to these areas. If the restoration project is on state or federal land, an archaeological survey may have already been conducted. Consult with the state or federal agency and identify any known sensitive areas. Depending on the scope of the project and the potential impacts to culturally sensitive area, a more detailed archaeological survey and/or consultation may be needed.

Another source for obtaining information on archaeological and historical resources information is the **California Historical Resources Information System (**CHRIS**), which** includes the statewide **Historical Resources Inventory (HRI)** database maintained by the Office of Historical Preservation (OHP) and the records maintained and managed, under contract, by twelve independent regional **Information Centers (ICs)**. Individuals and government agencies seeking information on cultural and historical resources should contact the regional IC which services the county in which the resource is located. The locations, contact information, and counties served by each regional IC can be found on the CHRIS regional information center.

7. County Land Use Conversion Ordinances

During the planning stages for the restoration project, research local land use conversion ordinances. There could be county ordinances that require a permit to convert agricultural lands to habitat, e.g., Butte County.

Many farms are under the Williamson Act which freezes property taxes at some historic rate. When farming is no longer carried out on the land, back taxes must be paid.

8. Voluntary Neighbor Agreements

Special planting areas to function as trespass barriers/buffers with neighboring property often are a constraint that can affect restoration design objectives. A neighboring land owner may request that the restoration design include such a barrier that can be designed using blackberry, rose, and poison oak. Another barrier might involve planting a dense hedgerow of trees to intercept pesticide drift from neighboring properties. Such hedgerows can also function as extremely valuable habitat.

9. Endangered Species Consultation

Projects on federal property should be reviewed by the U.S. Fish and Wildlife Service or the National Marine Fisheries Service to determine potential impacts to federally listed species and designated critical habitats. Under the authority of California State law, the Department of Fish and Game (DFG) has jurisdiction over the conservation, protection, and management of wildlife, native plants, and habitat necessary to maintain biologically sustainable populations. DFG serves multiple roles in dealing with the California Environmental Quality Act.

B. Implementation Permits

1. Burn Permits

Preparing a site for a restoration project may include burning to eliminate debris and control weeds. A burn permit, which is issued by the local (County) Air Quality Control District, must be secured prior to any burning of vegetative material.

2. Well Drilling Permits

Prior to drilling a new production-well within the project area, a county well drilling permit must be issued. Contact the county public health department or environmental health department for well construction/deconstruction permit application. Every county will have different requirements and processes. For example, Glenn County will allow applicants to decommission their wells, while Tehama County requires that licensed C-57 drillers to perform decommission. An inspection is required prior to installing a sanitary seal after drilling a well and a final inspection and receipt of a satisfactory abandonment report and disinfection statement is necessary for decommissioning a well. Pumping irrigation water from the river requires a fish-friendly screen over the intake and the legal right to take the water – for information on water rights and permits contact the State Water Resources Control Board.

3. Herbicide Permits

Depending on the ownership of the project area, several permits are required prior to the initiation of an herbicide maintenance program. Work on federal lands, such as areas under U.S. Fish and Wildlife Service jurisdiction, requires a federal Pesticide Use Permit. Restoration projects on properties under California Department of Fish and Game jurisdiction requires a State Pesticide Use Recommendation Form (880).

All herbicide applications should be calibrated and/or conducted by a Pest Control Advisor (PCA) or personnel with a Qualified Applicator's License (QAL) or Private Applicator's License (PAL). All applications should be documented and reported to the County Agricultural Commissioner, which will then be reported to the Department of Pesticide Regulation.

IX. Coordination of Permits, Regulations, and Activities

How is my project incorporated into the surrounding landscape?

A. Central Valley Flood Protection Board Encroachment Permits

The Central Valley Flood Protection Board is charged with regulating development in designated floodways in the Central Valley. A permit must be secured from the Board based upon the construction/restoration plan. Planting density, pattern, and row orientation are important design factors. A flood-neutral planting design is required for the Board to issue a permit.

B. Title 23. Waters (California Code of Regulations)

This State Code of Regulations describes the responsibilities of the Central Valley Flood Protection Board. It includes a long list of species of plants that can be planted on or near levees, a list of unacceptable species, and specifics of management of plants in close proximity to a levee.

C. Department of Water Resources (DWR) Flood Management Division

The State of California Department of Water Resources (DWR) operates and maintains the State Water Project, including the California Aqueduct. The DWR also provides dam safety and flood control services. DWR is responsible for the maintenance of 1,600 miles of levees within the state, which is funded by the General Fund. The remainder is the responsibility of local levee and reclamation districts.

D. Army Corps Operating & Maintenance (O&M) Guidelines

The U.S. Army Corps of Engineers (Corps) influences restoration projects from two perspectives-infrastructure development and regulation. Corps engineers have designed, built, inspected and certified levees to flood recurrence standards (Rivers and Harbors Act of 1890). Construction activities within the Nation's waterways must be issued a permit from the Corps. In addition, the Corps is responsible for issuing Corps 404 permits for the filling or other disturbance of wetlands and other waters of the US (Federal Water Pollution Control Act amendments of 1972). The Corps writes the O & M guidelines for levee and floodway maintenance and gives these to DWR. These same regulations are transferred to local levee and reclamation districts for implementation.

E. Levee and Reclamation Districts Responsibilities

Local levee and reclamation districts, under the authority of State Water Code, were developed to protect lands from overflow through the erection of levees, dikes and other flood control systems. These local districts are responsible for monitoring levee integrity and for the maintenance of these flood protection systems. Planning for restoration should include notification of the local levee maintenance district as it may affect the district's maintenance activities. Properties within the district are taxed to help fund maintenance.

F. Regional and County Organizations

Resource Conservation Districts (RCDs) are typically organized at the County level. RCDs work closely with private landowners to implement government-funded land management projects on private property with the direct assistance of the Natural Resources Conservation Service. Watershed groups are organized around watershed boundaries and are often the sponsor of riparian restoration projects. An example is the Sacramento River Conservation Area Forum (SRCAF).

G. Endangered Species Act (ESA) Considerations

If a restoration project will potentially affect a listed endangered or threatened species, then a consultation with the Endangered Species Office of the U.S. Fish and Wildlife Service will be required. The restoration project must not negatively affect a listed species, even if at the completion of the project the species will benefit. If the restoration project should attract listed species that previously were not present on the site, then future liabilities under the ESA can be managed by a USFWS Safe Harbor agreement.

There are several examples of private land owners and water services that have Safe Harbor Agreements that allow for normal management activities around listed species.

H. Adjacent and Nearby Land Use

1. Agriculture

If a restoration project site is adjacent to agricultural land, there are several considerations that will have to be discussed with the land managers and owners. Many farmers worry that a restoration project will have direct negative impacts to their crops, for example by increasing the populations of pest species such as pheasants, deer, ground squirrels, voles and rats. These fears can sometimes lead to drastic measures, such as the removal of adjacent riparian vegetation to spinach farms in Salinas Valley for the unlikely assumption that wildlife (as opposed to cattle) were responsible for infecting the crop with E.coli bacteria (for more information see the Wildland Farm Alliance). Insect pests that overwinter in restoration sites are a common worry, but just as many beneficial insect predators such as preying mantis and parasitoids that kill harmful insects overwinter in restoration sites. Pollinators like native bees may also spread from restoration sites to farms. Riparian vegetation can reduce the impacts of flooding by slowing flows and trapping large debris. Riparian areas can also clean water by filtering and trapping nutrients and pesticides. Restorationists should also be aware that adjacent land use can negatively impact the project, for example, livestock grazers could get onto the site. One measure to reduce interaction between the restoration project and adjacent land use is to create setback zones or buffers between the two areas.

One common concern restoring lands previously used for agriculture or rangelands, is that the restoration sites take land out of production resulting in a net loss of economic value to the community. Often, these

sites are purchased because they are not productive lands in the first place, because they are prone to flooding. Furthermore, the impacts riparian areas provide to a community do not have a quantitative value.

2. Urbanization

Restoration projects adjacent to urban areas must also consider the impacts of one land cover type on the other. For example, depending on the county requirements, mosquito abatement may be required as a component of the restoration project. The restorationist should contact the local mosquito abatement program for specific details. At the planning stage, the urban setting of the project site will also need to be evaluated. If there are lights adjacent to the site that will remain on all night and disrupt wildlife, perhaps a dense row of tall native trees could help lessen the impact. Restoration projects adjacent to urban areas will likely have to deal with feral animals, especially dogs and cats, that can harass and kill wildlife. Often, residents encourage feral animal populations by leaving food out at night, either deliberately or accidently. Pet animals can be equally disruptive. Active engagement and education of neighbors to restoration projects may help reduce these activities. Finally, there will be specific zoning laws and land use changes restrictions within the county that should be complied with during project planning.

I. Different Definitions of Restoration in Labor Laws

Differing management approaches to, and definitions of Riparian Habitat Restoration by agency managers can be constraints that affect restoration project implementation in terms of labor codes. There are numerous inconsistencies in the way that riparian habitat restoration is defined by various agencies because of the recognition, or lack thereof, of restoration as a unique project activity. Therefore, different labor codes may apply depending on the classification given to restoration by granting agencies, which could be Restoration, Landscaping, Construction, or Agriculture.

1. Worker's Compensation

Under workers compensation law definitions, there is no category called restoration. Restoration work is classified as Landscaping. Therefore, in order to install a restoration project that is defined as Landscaping, a state-issued Landscape Contractor's license must be held by the restorationist.

2. Prevailing Wage Requirements

Restoration projects funded through Federal grants or in contract with the United States that exceed $2,000 are required to pay workers at the site no less than the prevailing wages of the project locality (Davis-Bacon Act and McNamara-O'Hara Service Contract Act). Prevailing wage requirements are dependent upon several factors, which include the funding source, project location and type of work. The grant agreement or contract will have specific language that states whether prevailing wages are required. The designation of the type of work that is being done is significant. Restoration may be defined as either landscaping or construction, depending on the scope of work for the restoration project. Typically, a classification of construction will require prevailing wages. To determine which classification the restoration project falls under, contact the Department of Industrial Relations.

3. Agricultural Labor Law

Restoration projects often are installed using conventional, large-scale agricultural technology and equipment. Agricultural labor laws, which typically impact agricultural operations (e.g., 60 hour work week, instead of 40 hours), are not a factor in riparian habitat restoration. These labor laws apply to operations that

produce a marketable commodity. Restoration is not defined as having a marketable commodity. Therefore, these labor laws do not apply.

4. U.S. Department of Agriculture

The Natural Resources Conservation Service, an agency of the U.S. Department of Agriculture, provides technical assistance and funding to support landowners in protecting and conserving their soil, water, and other natural resources. Restoration is defined as an agricultural practice in this case and not landscaping or construction. Because the nature of their program is collaboration with landowners, usually farmers, restoration projects are categorized as agriculture, in which agricultural labor laws then apply.

5. California Department of Pesticide Regulation

Most herbicides do not include riparian species on the labels. The Department of Pesticide Regulation recognizes the use of herbicides on restoration projects as non-agricultural uses.

6. Wildlife Conservation Board, U.S. Fish and Wildlife Service, and California Department of Fish and Game

Funding agencies, such as Wildlife Conservation Board, and state and federal agencies, such as the U.S. Fish and Wildlife Service and California Department of Fish and Game, define these projects as restoration. Unlike other agencies, restoration work is not classified as agricultural, landscaping or construction activities.

7. County Agencies

The County Agricultural Commissioner and the County Air Quality Control identifies restoration as agricultural activities.

8. Occupational Health and Safety Administration (OSHA)

OSHA regulations and requirements should be reviewed during the planning process. They regulate the depth of unreinforced excavations (soil test pits) plus they mandate requirements for worker health and safety.

X. How to Build a Budget

Building a restoration budget for a project that has not yet been proposed is a challenging affair. However, potential funders will require a reasonable level of detail when a proposal is submitted.

- Obviously, more than one bid per product or service should be solicited.
- When estimating a budget for a proposal, be aware that many years may pass before funding arrives for your restoration project. Costs will be different, typically increasing with time. Yet the funder will most likely require that the original budget, as presented in the proposal, be followed.
- A contingency line item is always a good idea. Ten percent is most often used.
- Be aware of the billing requirements of the funder, as well as its payment schedule. Payments are typically after the work to be billed has been accomplished and may be several months after you submit your invoice.
- Some funders may require retention, usually 10 percent, be withheld until completion of the project.
- Funders may require substantial support be included in billings. This may require more time and attention by the project administrator.
- Some funders may not cover all expenditures. Refer to OMB A-122 (Circular No. A-122 issued by the US Office of Management and Budget) for allowable costs.
- Be aware of your own organization's administrative costs over the life of a contract. Do not short-change yourself.
- Be aware of what the funder will pay for project administration. The percentage may be limited and less than your actual costs.
- Be aware of any additional costs required by a funder such as the cost of an easement on the project site, or a management endowment to cover long-term management costs.

Table 1: Federal Cost Share Programs for Habitat Development

Program Name	Description	Incentive
Wildlife Habitat Incentive Program (WHIP) http://www.nrcs.usda.gov/programs/whip/	Voluntary program for people who want to develop and improve wildlife habitat primarily on private land.	Up to 75% cost share for 5 to 10 years
Conservation Reserve Program (CRP) http://www.nrcs.usda.gov/programs/CRP/	Assistance to farmers and ranchers regarding soil, water and natural resources concerns and compliance with Federal, State and tribal laws.	Financial and technical assistance
Environmental Quality Incentives Program (EQIP) http://www.nrcs.usda.gov/PROGRAMS/EQIP/	Voluntary conservation program for farmers and ranchers to implement structural and management practices to improve environmental quality.	Financial and technical assistance, 1 to 10 years and up to 75% cost share
California Wetlands Reserve Program http://www.nrcs.usda.gov/programs/wrp/states/ca.html	Farmers can sell easement of lands for conversion to wetlands and riparian habitat, and may also benefit from sale of hunting rights.	Financial and technical assistance

XI. Technical Methods of Project Implementation

There are many different ways of installing a restoration planting. The exact methods will be determined in part by site history. If the site has been farmed in the past, it may have an irrigation system in place. The site may have an unique suite of weed species due to past land uses. If the site was once in farming, why was it sold for restoration? The answer will usually be due to economic reasons – the site does not produce an economically viable commodity, due to poor soils, poor water quality, high water table, expense of clean-up after floods. This knowledge will allow the restoration planner to adjust the plan to accommodate these site-specific characteristics. Table 2 lists various field methods that can be used to accomplish implementation tasks and compares their advantages and disadvantages.

What Can Go Wrong - Why Projects Fail

Implementation of a restoration plan into the field requires a special skill set that few people possess. Planners and most biologists are not implementers. Only someone with many years of farming experience possesses the judgment, knowledge, and skill to make timely decisions that result in a healthy, weed-free restoration planting.

Restoration projects typically fail due to problems that arise during the first year of implementation. Many problems can be avoided through considerable planning and preparation. Skilled personnel and good communication among workers, along with familiarity with the site will improve the chances of success. Frequently, projects fail because of inexperience or a lack of preparation for the following considerations:

- **Scale:** a five-acre project will be managed very differently from a 100 acre project. Methods for weed control and irrigation are completely different – requiring different tools – if the goal is to produce a healthy, successful project. The manager must Think Differently, according to the scale of the project.
- **Weed control:** Weeds often win by overwhelming (burying) native plants, causing them to die or grow much more slowly. This is a common problem that inexperienced managers usually suffer because they do not understand weed ecology and the life history characteristics of individual weed species. Control measures are typically applied too late in the plant's development. Large costs, including plant mortality, and significant time are required to remove the large weeds from the field.
- **Planting day unpredictability:** Many things can go wrong, even with careful planning. The weather can be hot with a dry wind blowing at planting. The irrigation pump breaks down, resulting in no water for new plants. The nursery delivers small plants one day early, meaning no irrigation until installed. The nursery delivers the plants one day late, meaning the planting crew has nothing to do.
- **Irrigation system failure due to delivery problems,** e.g., pump breaks down and cannot be repaired for several days during hot weather; water lines break (and head-ditch failure) compromising entire system; river level drops out from under the pump intake, resulting in no water. Failure due to water quality issues usually involve the concentration of salts in the irrigation water which either kills plants or slows their growth.

- **Rodents:** beavers (*Castor canadensis*), meadow mice (*Microtus sp.*), gophers (*Thomomys sp.*), ground squirrels (*Spermophilus beecheyi*). All rodent species are capable of eating and destroying a young restoration planting.
- **Site conditions are not as described in plan/construction drawings**, or the construction drawing cannot be installed as drawn. This is especially demoralizing to the implementer.
- **Planner and Implementer work for different companies**, meaning that the implementer had no input into the plan.
- **Implementer not a farmer.** Knows how to manage golf-courses and lawns.

TABLE 2 . RESTORATION FIELD METHODS SUMMARY

METHODS	ADVANTAGES	DISADVANTAGES
I. FIELD PREPARATION	Proper field preparation will ease planting and hasten plant establishment. Field preparation methods listed may be used in combination. See Also Weed Control.	
• Discing	Good for large or small-scale field clearing. Turns weeds into soil keeping aisles clear. Conserves soil moisture.	Seed bank is turned over exposing seeds to light and water, seeds germinate with rain or irrigation. Field must be cleared of all large debris to properly operate disc.
• Burning	Good for large- or small-scale field clearing. Removes weeds and debris from field.	Burn permits are required, not allowed at all sites. Must be carefully planned and timed for best burn. Experienced personnel required. Won't suppress perennial weeds, such as Johnson grass.
• Land Leveling	Required for flood irrigation systems and for improved operation of equipment.	Additional costs with temporary benefits.
II. PLANTING	Individual species may be planted using different methods for the optimum establishment and cost savings. Using nursery grown container stock is the conventional horticultural method.	
• Ripping	Rips and fractures planting row to 3 feet deep. Allows easier planting and improved root development.	Can't be done on site with existing tree stumps and irrigation systems. Creates air spaces in soil. Firmly tamp soil when planting.
• Auguring	Mixes stratified soil layers to eight feet deep. Improves root development, especially with dormant cuttings.	Adds to field preparation time and costs. Limited benefit in soils with sand, large gravel, cobbles, or deep water table.

METHODS	ADVANTAGES	DISADVANTAGES
• Direct Seed	Highly successful method for oaks (acorns) and good success with rose. Cost savings without propagation costs. Short term planning time required with most seeds collected in fall and planted in winter.	Limited success for some riparian species in experiments. Seeds washed away or buried on flood-prone sites. Seedlings will not compete with fast-growing exotic weeds in spring and summer.
• Nursery Grown Container Stock	Highly successful conventional method for all species. Can be planted from fall to late spring. Established seedlings with developed root systems.	Increased costs with lengthy propagation process from seed stratification to hardening-off. Approximately twelve to eighteen months needed. Requires planning and estimating two years in advance.
• Dormant Hardwood Cuttings	Highly successful method for Fremont cottonwood and willow species. Easily collected, stored, and planted for small- and large-scale sites.	Winter rains and floods will limit access to collection sites during critical collection time. High mortality in dry winters and springs if irrigation can't be applied. Refrigerated storage required if can't be planted immediately.
III. WEED CONTROL	Thorough weed control is needed in field preparation and the first year after planting. In the second and third year after planting, weed control can be reduced. The listed weed control methods can be used in combination.	
• Discing	Turns weeds into the soil. Low equipment costs and investment. Removes rodent cover. Conserves soil moisture.	Must be repeated several times during the season because newly exposed weed seeds will germinate with next irrigation or rain.
• Herbicides	Effective clearing of aisles, rows and irrigation mainlines. Spot applications at individual plant locations. Apply at critical times to limit seasonal exotic species.	Costly for large-scale and repeated application. Restrictions on use. Careful use required to reduce hazards. Limited by weather conditions such as temperature and wind.

METHODS	ADVANTAGES	DISADVANTAGES
• Mulching	A thick, organic mulch will suppress weed seed germination. Replenishes soil organic matter. Conserves soil moisture.	High cost with labor and materials. Difficult to apply on large-scale sites. Decomposes, short-term benefit. Mulch floats away if site is flooded.
• Landscape Fabric/Weed Mats	Suppresses germination of weed seeds.	High costs with intensive labor and material costs, especially in large-scale applications. A 3'x3' square is required for each planting location. Paper fabrics suppress weeds for only one year. Synthetic fabric lasts many years and may need to be removed.
• Cover Crops	Replenishes soil nutrients. Successful weed suppression when managed.	High costs for a short-term application (one to three years). Conventional cover crop seed mixtures are not designed for restoration applications and contain primarily exotic species.
• Mowing/Flail type	Efficient in large-scale applications. Keeps aisles clear of weeds. Allows light to reach saplings. Inexpensive application costs.	Can't be used on rows or individual planting locations. Field must be laid out to accommodate equipment. Equipment requires well-trained operators, because mower may harm irrigation lines or plants.

METHODS	ADVANTAGES	DISADVANTAGES
IV. IRRIGATION	Factors such as water quality, soil conditions, and existing equipment will determine irrigation system design. The methods listed below have been used successfully to establish restoration sites. Each system will require regular maintenance during the irrigation season. First year irrigation should be applied to push maximum growth. In the second and third year irrigations should be less frequent and longer to encourage deep root development and finally adjust to site conditions.	
• Drip	A highly efficient system, especially in small applications. Low fuel or power costs for pumping. Deep and thorough at individual planting locations. Individual emitters water a small area. Limited weed growth in aisle, where no irrigation is applied.	A high-maintenance system that requires the cost of equipment that usually cannot be reused, i.e., drip lines. Must maintain individual emitters with some systems. Difficult to remove and reuse equipment. Rodents chew lines. Considerable damage and repairs to systems on flood-prone sites, since it cannot be removed at the end of season.
• Sprinkler Solid Set	A moderately adaptable system that will apply large amounts of water. Can be installed on uneven sites. Covers rows and aisles to encourage lateral root growth.	High equipment costs to install permanent system with buried laterals and mainline. Cannot be reused. Damage to risers from floating debris on flood-prone sites. High power costs for pumping. Abundant weed growth.
• Sprinkler Handline	A highly adaptable system with movable mainlines, laterals, and sprinklers. Good in small to large-scale applications. Equipment can be moved across site and reused on other sites. Covers planting rows and aisles to encourage lateral root development. Can be partially removed in fall from flood-prone sites and reassembled in spring	High energy costs. Abundant weed growth across site. Additional labor costs to move system across site.
• Flood	Deep and thorough irrigation. Low equipment costs.	Site must be engineered, leveled, or contoured to accommodate. Abundant weed growth. Furrows must be re-established after each irrigation.
• Water Tank	Direct placement and quantity of water determined by operator.	Most inefficient method due to high costs for labor and time required. Usually cannot irrigate large field in a timely manner.

METHODS	ADVANTAGES	DISADVANTAGES
V. PLANT PROTECTORS	Critical to protect individual plants from rodent damage and herbicide drift first two years. Should be installed in late spring on flood-prone sites.	
• Blue-X/Tube-X	Retain heat and humidity to encourage new growth in early spring. Protect from rodent and herbicide damage. Gradually breakdown over several years. Variety of sizes available.	More expensive for one- to two-year use. Cannot be reused and may need to be removed from site after third or fourth year. Weeds inside protector difficult to remove.
• Cardboard (milk cartons)	Protect from rodent and herbicide damage. Inexpensive.	Breakdown after one season with reduced protection in second year. Mouse nests in a few. Shades seedlings during critical first months.
• Wire cages made of field-fence or chicken-wire.	Effective protection from herbivory by rodents and deer; reuseable.	Material and construction costs; must be removed at some point so as to not impede plant growth.
• Raptoor perches and barn owl nesting boxes	Effective rodent-control by raptors in new plantings.	Material and construction costs. Good project for a Boy Scout.
VI. LABOR SOURCES	A variety of labor sources can be used to accomplish restoration.	
• Volunteers	Willing to do light tasks usually for one day. Low costs. Unique skills for special projects. Develops community support for project.	Staff time needed to recruit and coordinate from local communities. Usually will not work under harsh field conditions, such as rain or extreme heat.
• Short-term Staff	Career or training opportunity. Can be hired for short-term project needs. Low costs.	Retraining of new staff needed every six months.
• Permanent Staff	Skills can be developed over time.	Long-term financial commitment.
• Contract Labor	Can be hired for specific project of short duration. Meet emergency labor needs.	May lack specific skills. May damage plantings.

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XIII. Appendices

1. California Bioregional Restoration Considerations

2. Restoration Case Studies

3. Ecological and Landscape Considerations of Riparian Plants

The Bay/Delta Bioregion

*Gualala River * Napa River * Petaluma River * Russian River*

Local Community	Horticultural Potential	Optimal Plant Community	Wildlife Habitat
Heavily populated region that supplies two-thirds of California's water. Public concerns include bank erosion and loss of personal property and water quality. High biodiversity and range of vegetation types in this region, big potential for community awareness and involvement (volunteers) with restoration.	Potential for large restoration projects is low because of few areas with large floodplains. Where rivers are smaller, scale plantings may be implemented. Design restoration based on hydraulic models that will decrease bank erosion resulting from human infrastructure and increase bank stabilization to protect personal and public property. Process restoration ideal for some smaller streams.	Plant species that will achieve public goals of bank erosion and decreased sediment loads but that can also survive and persist under the site conditions. Altered hydrology in this area from intense regulation of the rivers means many plants will not naturally colonize and establish, so planting can jump start the forests. Invasive species require eradication for successful establishment of natives.	Plant species that stabilize banks and provide terrestrial wildlife forage, cover and breeding habitat, and provide shade for aquatic habitat. Riparian plantings can also reduce sediment load into the rivers, which can improve steelhead and salmon habitat. Can also enhance gravel beds at the site with appropriate sized gravel.

The Central Coast Bioregion

*Big Sur River * Carmel River * Guadalupe River * Nacimiento River * San Benito River * Salinas River * Santa Ynez River*

Local Community	Horticultural Potential	Optimal Plant Community	Wildlife Habitat
Heavy population growth, big agricultural industry, valley riparian habitat is rare. Water is heavily regulated, streams channelized for flood control. Erosion and bank stabilization also concern in some areas. Water quality compromised from urban runoff. Opportunities for volunteers and education, plus, recreation and aesthetic value of riparian areas.	Expansive development means fragmented riparian areas. Stream channelization can be removed from some streams and restoration can be implemented on widened floodplains, on others, revegetation can only occur on bank tops. Opportunities and challenges from adjacent land use: some private owners want to restore lands. Vegetation must not increase flooding into urban areas.	Plant species that can stabilize banks, improve filtering of nutrient load of waters from urban runoff, and maintain flood conveyance properties of streams. Invasive species control needed for plant establishment and survival.	Plant species appropriate to targeted wildlife for food and cover. Vegetation should connect with existing stands and blend appropriately so abrupt vegetation differences do not deter wildlife passage.

The Colorado Desert Bioregion

*Alamo River * Lower Colorado River * New River * White River*

Local Community	Horticultural Potential	Optimal Plant Community	Wildlife Habitat
Second least populated area. Desert region, so water is scarce and thus diverted for urban drinking water and irrigation for agriculture. Education needed to reduce plantings in urban areas of invasive tamarisk, and to encourage native plantings of riparian species.	Biggest threats to scarce riparian areas are reduced water supply and saltier water that favor establishment of invasive tamarisk. Priorities are to protect native riparian stands and remove tamarisk. In some areas, restoration of natural flow and flood regimes is possible, this can help reduce tamarisk and favors native vegetation establishment.	Establishment and survival of native riparian species is deterred by altered flow and flood regimes, lack of sediment deposition (nutrients for plants) and invasion of tamarisk. The natural interval between floods can be years to decades, therefore, planted species must either be able to reach the water table or irrigation may be necessary.	Tamarisk does not provide suitable wildlife habitat. Native plants are necessary for the rich biodiversity of species in the region which includes high number of endemic species. Riparian areas in this region are particularly important as migratory stopover and wintering grounds for neotropical migratory songbirds.

The Klamath Bioregion

*Eel River * Klamath River * Mad River * Mattole River * Russian River * Salmon River * Scott River * Shasta River Smith River * Trinity River*

Local Community	Horticultural Potential	Optimal Plant Community	Wildlife Habitat
Vast area of national forests and not heavily populated. Past land use of mining and logging have led to erosion problems, which pose threats to public and private developments. Water diverted for agriculture. Public concern over erosion, sedimentation of rivers and increased river temperatures. Opportunities for education, volunteering – strong interest in preservation of natural vegetation, wildlife.	Large floodplains available for restoration, but often have been cut off from river by berms formed from willow growth in previously high flood prone gravel bars. Removal of berms and reconstruction of floodplain often necessary (see Trinity River Case Study). Vegetation can help stabilize banks. Flood conveyance is a priority. If natural high flows are released, natural vegetation recruitment may occur.	Local plant stock and native vegetation will survive best. Riparian areas in this region are adapted to infrequent fires, fire suppression in the area could impact natural plant succession. Region receives lots of precipitation, though less falls in the valleys than at higher elevations.	Vegetation that shades the river is particularly important for smaller streams that have rapidly fluctuating temperatures. Plantings used to stabilize bank should be planted in associations and densities that will provide multiple structures to be used by wildlife.

The Modoc Bioregion			
*Fall River * Pitt River * Susan River*			
Local Community	**Horticultural Potential**	**Optimal Plant Community**	**Wildlife Habitat**
Least populated area. Land ownership is 40% private and 60% public. Most private lands are used for agriculture, livestock and forestry. Bank erosion is a concern for private landowners. Increased sedimentation from channel widening (due to grazing practices) and high water temperatures are also concerns. Involvement of community in restoration is necessary for land acquisition and funding.	Though the valley floors are mostly flat, there are only narrow strips of riparian vegetation, most of which has been removed. Restoration can involve channel stabilization and riparian plantings. Fire risk may necessitate prescribed burns to reduce fuel loads. Conifer stocking has also reduced natural riparian vegetation establishment, and clear cutting is necessary to implement riparian vegetation.	Grazing management practices will help riparian vegetation establish and survive. If channel incision and lateral widening are reduced, ephemeral streams can once again become perennial, and sustain larger riparian vegetation stands.	Riparian vegetation that can stabilize the river channels should be native and from local stock. This will support native wildlife. The stable channels will continue to provide water adjacent meadows and the wildlife that depend on these habitats.
The Mojave Bioregion			
*Amargosa River * Colorado River * Mojave River*			
Local Community	**Horticultural Potential**	**Optimal Plant Community**	**Wildlife Habitat**
Large in area, moderate but growing rapidly in population. Large portion of public lands, but off-highway vehichle (OHV) use is common, and land resource use impair riparian areas. Invasive salt cedar is a huge problem, private landowners needed to take part in removal of salt cedar on private lands. Education about OHV and grazing impacts to land could help.	History of mining, ranching, grazing, altered flow and fire regimes and off-highway vehicle use have degraded riparian areas and made them susceptible to invasive saltcedar. The stands of salt cedar can be monotypic and leave no room or resources for native vegetation. Removal is feasible, especially with burning followed by herbicides.	Plant native vegetation before reintroduction of saltcedar. Re-route OHV trails and enclose plantings from grazing to allow native vegetation to establish and survive. Removal of upstream sources on private lands can reduce future introduction of saltcedar.	Native vegetation provides the habitat structure and resources that native wildlife are adapted to. Monotypic stands of saltcedar extract water and nutrient resources from not only plants but wildlife, in an area where resources can be scarce.

The Sierra Bioregion			
East of crest: *Carson River * Owens River * Truckee River * Walker River* West of crest: *American River * Consumnes River * Feather River * Kaweah River * Kern River * Kings River * Merced River San Joaquin River * Stanislaus River * Tuolumne River * Yuba River*			
Local Community	**Horticultural Potential**	**Optimal Plant Community**	**Wildlife Habitat**
Extensive water diversions and regulation, mining, logging, grazing, agriculture, rural sprawl and invasive plant species impact the riparian systems. Water quality and bank erosion are major concerns. Resource managers and landowners are willing to invest time and money into conservation practices and are open to designing more ecologically sound management practices. Community involvement and education are likely to find support, to protect the area's natural high biodiversity and protect the many threatened and endangered species.	Logging, road construction, grazing and water diversions have degraded mountain streams. Loss of riparian vegetation and erosion caused channels to migrate and incise deep channels, leading to further erosion, high sediment loads downstream, and cutoff from mountain meadows. On these streams, physical plugging of new channel can re-direct stream to historic channel. Along the eastern sierra, in arid regions, restoring more natural flow regimes has been successful in allowing riparian vegetation to naturally restore itself.	Reduced and modified grazing practices and active planting can speed recovery of mountain meadow streams and in more arid regions. Enclosures and managed grazing are needed to ensure vegetation can survive. Restoration of natural flow regimes needed to continue recruitment of new riparian species and to allow plant succession. Decisions about functional flow regimes and grazing practices will require adaptive management on individual rivers.	Restoration of mountain streams supports wildlife that use riparian vegetation and also reconnects to meadows which support additional wildlife species. With mountain stream restoration, there are opportunities to create additional wildlife resources such as ponds for waterfowl and other wildlife that can be created when soils are excavated to fill in the new and deeply incised channels.

The South Coast Bioregion

*Otay River * Los Angeles River * San Diego River * San Gabriel River * San Jacinto River * San Luis Rey River * Santa Ana River *Santa Clara River * Santa Margarita River * Ventura River*

Local Community	Horticultural Potential	Optimal Plant Community	Wildlife Habitat
This bioregion is characterized by having major cities and heavily populated areas among a diverse mosaic of natural areas and resources. Fires in the summer and big storms in the winter lead to huge landslides, erosion is a continuous problem from loss of vegetation, poorly located roads, mining, grazing, logging, agriculture, and development. Riparian areas are natural fire barriers due to high moisture content of fuel, but when invaded by arrundo they are very flammable. Arundo also increases flooding. Concern over erosion, fires and landslides provide opportunities to acquire land for restoration and educate the public about natural cost effective solutions.	Multiple land uses have reduced riparian vegetation, stream banks erode, floodplains are removed, and large floods tear through the streams causing more erosion and greater downstream sediment loads. Dredging and sediment disposal are expensive, it is more clear now that the cost of land aquisition and floodplain rebuilding is less expensive and more successful. A major focus of restoration is removal of Arundo (see Santa Margarita Case Study). Revegetation alone is not always enough to stabilize banks, and floodplains are often physically recontoured to manage overflow of banks. Levees are set back or removed.	Grazing must be managed to keep riparian vegetation in place. Erosion control and bank stabilization are priorities, therefore vegetation that establishes and grows quickly is preferred. However, efforts to select appropriate species adapted to the local conditions will be successful in the long term. Similarly, floodplain vegetation should not only meet the hydraulic modeling needs and direct flows properly, but include a well adapted suite of species that can survive the current hydrologic regime. Invasive species such as arrundo will require removal and management until native vegetation is well established.	Riparian vegetation on many rivers and streams in this region is much reduced, though once established it can provide the complex vegetation structures and species needed to support diverse wildlife in the region. Though flood control, erosion and fire control are the major priorities, the riparian vegetation can be designed with wildlife species in mind. Arrundo does not provide adequate habitat for multiple needs of wildlife, removal and revegetation with native and diverse species can meet the multiple needs.

2. Restoration Case Studies

Case Study #1: Restoration at Buffington Tract on the Stanislaus River: Horticultural Restoration

Project Summary

This horticultural riparian restoration project was implemented to connect with existing riparian vegetation on the site and remnant riparian forest and shrub lands adjacent to the project boundary to increase the amount of riparian vegetation for specific wildlife species. A major goal of the project was to build habitat requirements of targeted wildlife. Specific wildlife needs were incorporated into the restoration planting design through plant species selection, community associations, and density of plantings.

Restoration took place on the Stanislaus River, which is a tributary to the San Joaquin River, and is human-impacted to a degree that natural processes can not regulate the riparian ecosystem. Water diversion, flow regulation, floodplain leveling and clearing, and invasive species have stressed the native plant and wildlife communities. Very rare flood events on the site occasionally reconnect the floodplain to the river, but restoration planting design had to consider the decrease in frequency and magnitude of natural disturbances (flooding and possibly fire). The altered hydrograph that riparian species are adapted to modifies survival and succession of planted species, therefore, a conceptual model of plant succession for the site was created during the planning process. The relatively flat topography of the site resulting from previous land uses lended itself well to horticultural restoration techniques and continued irrigation and weed control for three years. Because horticultural restoration design for specific wildlife was the major focus of this project, site evaluation was a considerable portion of the planning process, along with development of the planting design.

Project Name	Buffington Tract
County, River, Bioregion	San Joaquin/Stanislaus Counties, Stanislaus River, San Joaquin Valley Bioregion
Project Goals – Primary reason for restoration	Restore riparian vegetation to connect with existing vegetation to increase amount of potential habitat for targeted wildlife species, including: riparian brush rabbit, riparian woodrat, least Bell's vireo,Valley elderberry longhorn beetle, neotropical migratory songbirds, resident songbirds, and quail.
Long term goals and considerations	Establish self-sustaining, plant communities within a three year period
Partnerships	U.S. FWS, California Bay-Delta Authority, CSU Stanislaus, PRBO, RHJV, Caswell State Park, private land owners

Restoration Planning Process (Steps in Flow Chart)

Here, a few of the steps in the flow chart that were a major part of this restoration are discussed, for more specific details see above link to the complete restoration plan.

1. *Designation of Site as Riparian*

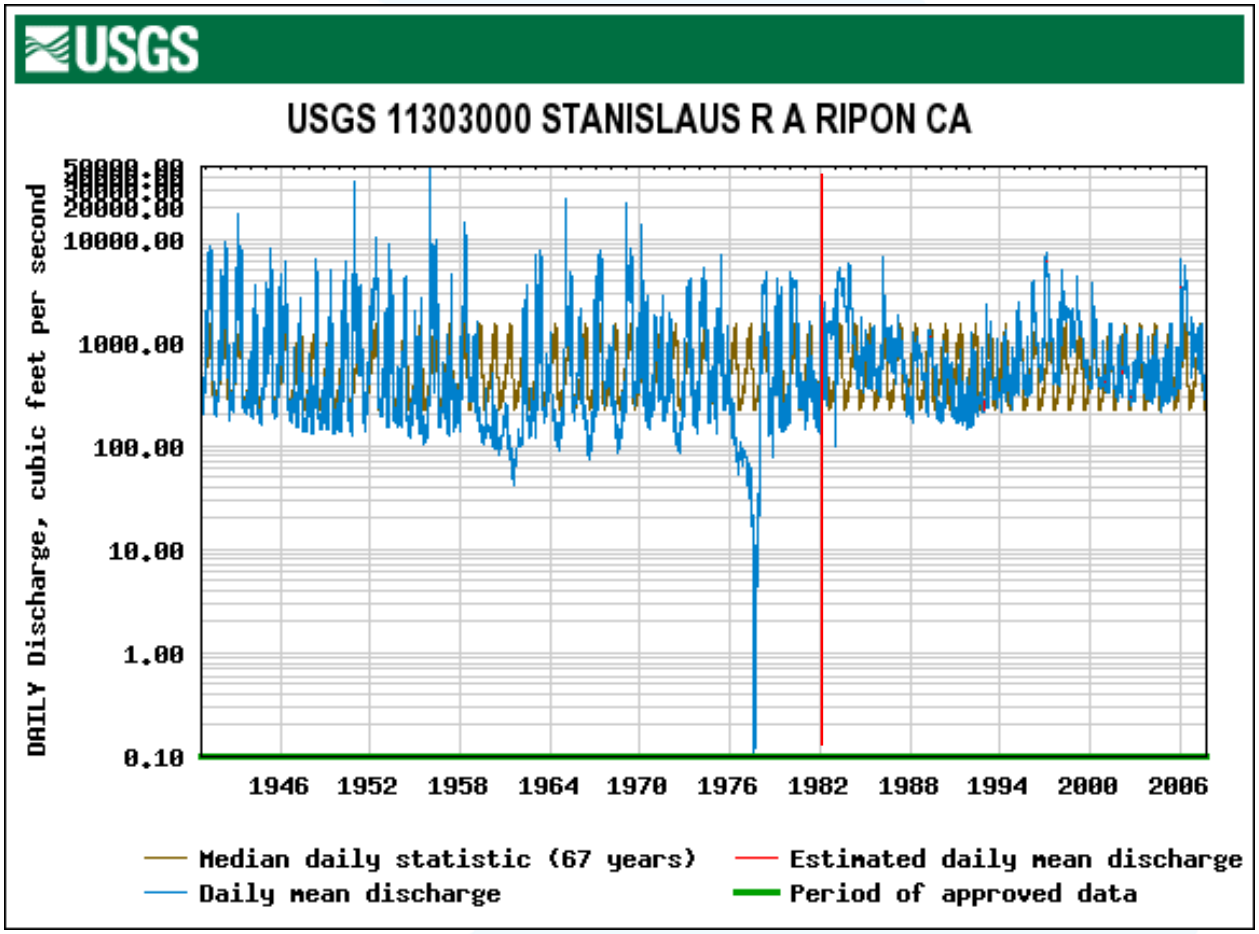
The site was considered riparian because even after the regulation of the Stanislaus by the New Melones dam in the early 1980's, the site still experiences occasional (though very rare) flood events.

2. *Evaluation of Site Conditions: How river processes operate on the site*

Hydrology – The historic and current hydrologic conditions at the site were determined by examining historic flow data and aerial photographs from several decades both pre and post dam construction. Daily streamflow discharge data from the USGS of the Stanislaus River from 1946 to 2006 showed much higher variability in amount of water in the river before dam construction in the 1980's (Figure 1). The natural hydrograph for rivers in these regions is characterized by peak flows during winter storms and late spring snow run-off. With regulation of river flows by the dam, the resulting hydrograph is characterized by smaller, shorter high flow events. Less water flowing through the river means there are few opportunities for water to flow over the river banks onto the floodplain and into oxbow lakes and side channels. Regulation of river flows also keeps the river in its current channel, so there is no more sand deposition, bank erosion or lateral channel migration. Tree species, such as willows and cottonwoods, which depend on a natural hydrograph for recruitment and survival, are therefore unlikely to establish naturally at this site.
Figure 1. Stanislaus River streamflow at Ripon, California for the period of record 1940-2007.

Figure 1. Stanislaus River streamflow at Ripon, California for the period of record 1940-2007.

Data shows much higher variation before the New Melones Dam became operational in the early 1980's.



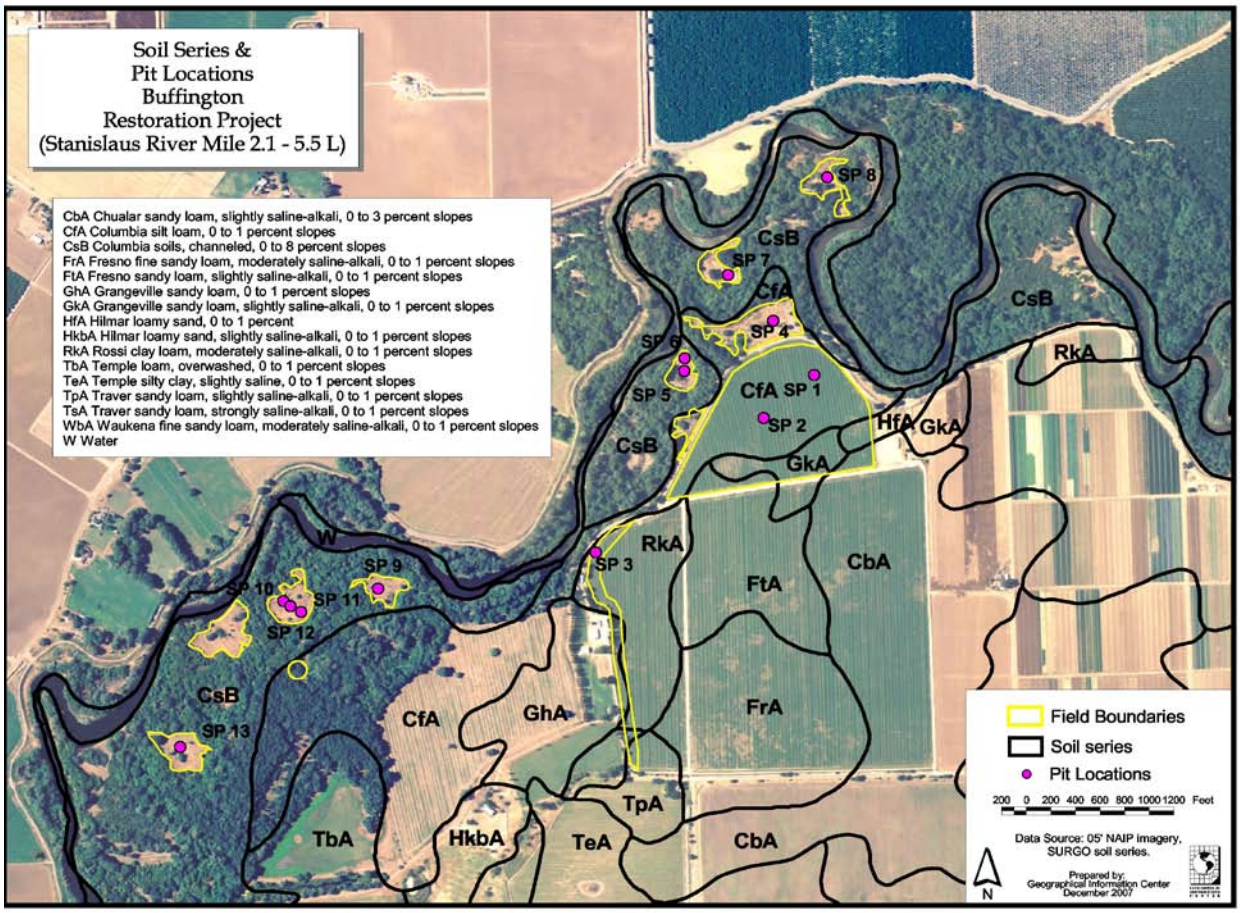
Vertical red line indicates 1982, the year New Melones Reservoir filled.

Aerial photos showed the pre-dam dynamic nature of the river, which created oxbow lakes, side channels and newly exposed sand bars. Like the flow data, these pictures reveal a post-dam river that is relatively static and likely to remain in its current channel. A photo of a large post-dam flood event (Figure 2) provides evidence that the river is capable of overflowing its banks and recharging oxbow lakes and side channels, even though this is a rare event.

Figure 12. 1950 aerial photograph of Buffington project area. Courtesy of McHenry Museum, Modesto, CA.

Soils – A detailed site evaluation of soils included analysis of soil texture, stratification, depth to the water table, and history of land use by consulting the NRCS soil maps, digging soil pits, and consulting with neighbors and previous landowners. Soil survey maps showed that soils on this site are a mosaic of loamy, alluvial soil types derived primarily from granite, moderately well drained, with little to no slopes (Figure 3). Excavation of several backhoe pits during summer, fall and winter to capture seasonal variation in ground water depth revealed the water table to be below 12 feet. In some locations, sand filled the pits at 3 feet in depth. There are areas in this project site that retained natural topography, and areas of higher elevation were used to build flood refugia for the riparian brush rabbits during high water events.

Figure 3. Soils Map and Soil Pit Locations for the Buffington Tract, Stanislaus County, California.



Sediment Transport – The streamflow data and aerial photos indicated that the Stanislaus River in this stretch below the dam is likely to remain fixed in its channel. Therefore, deposition is not occurring on this site and there are no newly exposed sand bars, which means there is little chance of natural recruitment of cottonwood and willows at this site. There is some scour of the river channel, so bank stabilization was enhanced by planting riparian vegetation.

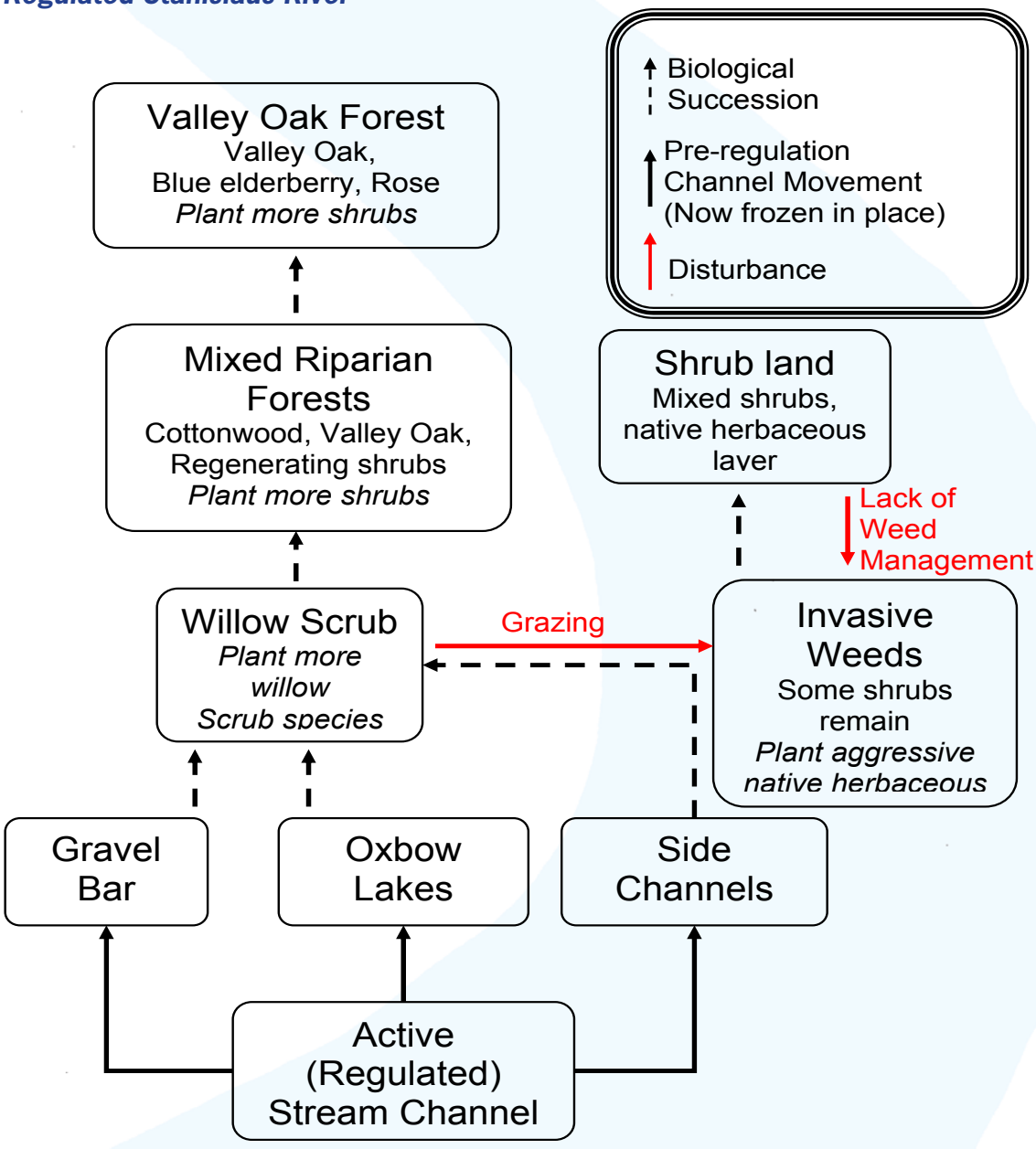
Existing Vegetation – Several areas of old riparian species are present throughout this site. A few of these provide foraging and nesting habitat for the riparian brush rabbit and riparian woodrat, and provided a reference condition of the vegetation structure that is required by these species. Restoration on this site connected these areas of riparian vegetation.

3. *Conceptual Model of Physical and Biological Successional Trajectory*

A conceptual model is essential in choosing location, type and density of species to plant, because it forces the restorationist to consider how site conditions and plant succession will change the plant communities overtime. The aerial photos showed evidence of pre-dam channel meander and flooding, that created oxbow lakes and side channels, and deposited sediment and built sandbars. Post-dam photos showed a lack of re-charge into the lakes and channels, shrub colonization of point bars and no new sand deposition, and large trees next to oxbow lakes and side channels appeared to be senescing. Without restoration on the site, slow shrub succession would take place with heavy weed competition. Trees like willows and cottonwoods would not be able to naturally recruit and survive on this site. Based on the soils profiles and hydrology of

the site, it was determined that the project area could support riparian forest, shrub and herbaceous species, but the targeted wildlife species primarily required shrub and herbaceous species. Therefore, a selection of shrub species was chosen to be planted in several communities, and their predicted successional path along this river with its very rare flood events, is shown in Figure 4. Because of the variation in soil profiles and textures throughout the site, it was expected that not all plants would survive uniformly throughout the site. Such variable survival is likely to create a patchwork design of vegetation throughout the site, with openings that promote ground cover species and provide basking locations, and therefore the variability was not considered to be a problem. To retain the goal of 70% survival at this site, however, some species were planted at higher densities to limit the need for replanting.

Figure 4: Conceptual Model of Restoration and Plant Succession on the Regulated Stanislaus River



References: River Partners. 2008. Restoration Plan for the Buffington Unit, San Joaquin River National Wildlife Refuge. S. Small and T. Griggs. Modesto, California.

Case Study #2: Restoration on the Santa Margarita River: *Arundo donax* Removal

Project Summary

The focus of restoration on the Santa Margarita river has largely been control of the non-native invasive, highly vigorous and rapidly spreading *Arundo donax*. Introduced into southern California originally for bank stabilization, this weed from Asia is resilient, grows rapidly, and unlike native riparian vegetation, it is highly flammable and regenerates quickly after burning (Bell 1997). Though its seeds are not viable here, it can spread vegetatively and sprout from pieces of the plants that tear off and float downstream where they rest on river banks (Lawson et al. 2005). Where *A. donax* establishes, it quickly outcompetes native vegetation and forms monotypic cultures of a vegetation type that has not proven to be a resource of food or nesting structure for native wildlife (Bell 1997). In addition, to meet its rapid growth rate requirements, *A. donax* consumes water at such a rate that even wildlife must compete with the plant for water. *Arundo donax* displaces native trees and shrubs such as willows, cottonwood, and mulefat that provide nesting habitat for the Federally Endangered Least Bell's Vireo, which is a target species for restoration along this river.

Restoration is guided by coordinated, large scale removal of A. donax, and long-term monitoring and re-treatment to ensure long term eradication of the weed. Removal is the active phase of restoration, which allows physical processes such as floods to regenerate native vegetation along floodplains without the oppressive competition. The Santa Margarita watershed retains flood regimes that are sufficient to cause overbank flooding, deposit sediment, and distribute seeds of native plants, but the hydrograph is altered by river regulation and water diversions. A second focus of restoration on this river is adaptive management; the most successful methods have been learned throughout the process, with changes made to the methods as needed. Experimental plots were set up and monitored to learn the most effective techniques. In addition, small scale horticultural techniques were tested to determine cost-effective methods of enhancing revegetation.

Project Name	Santa Margarita River *Arundo donax* Control Project
County, River, Bioregion	San Diego County, Santa Margarita River, South Coast Bioregion
Project Goals – Primary reason for restoration	Remove *A. donax* (and other invasive weeds) to allow native vegetation the chance to re-establish and support targeted wildlife species including the Least Bell's Vireo.
Long term goals and considerations	Permanently eradicate A. donax from treated areas with initial removal and follow with long term monitoring.
Partnerships	Marine Corps Base Camp Pendelton, The Nature Conservancy, Mission Resource Conservation District, private land owners

Restoration Planning Process (Steps in Flow Chart)

Here, a few of the steps in the flow chart that were a major part of this restoration are discussed, for more specific details see above link to the complete eradication methods.

1. *Designation of Site as Riparian*

There are two dams on the upper watershed of the Santa Margarita River, but they release flows that roughly mimic the undammed hydrograph, allowing the river to retain a relatively natural flow regime. Therefore, flooding and sediment deposition still connect the floodplains to the river.

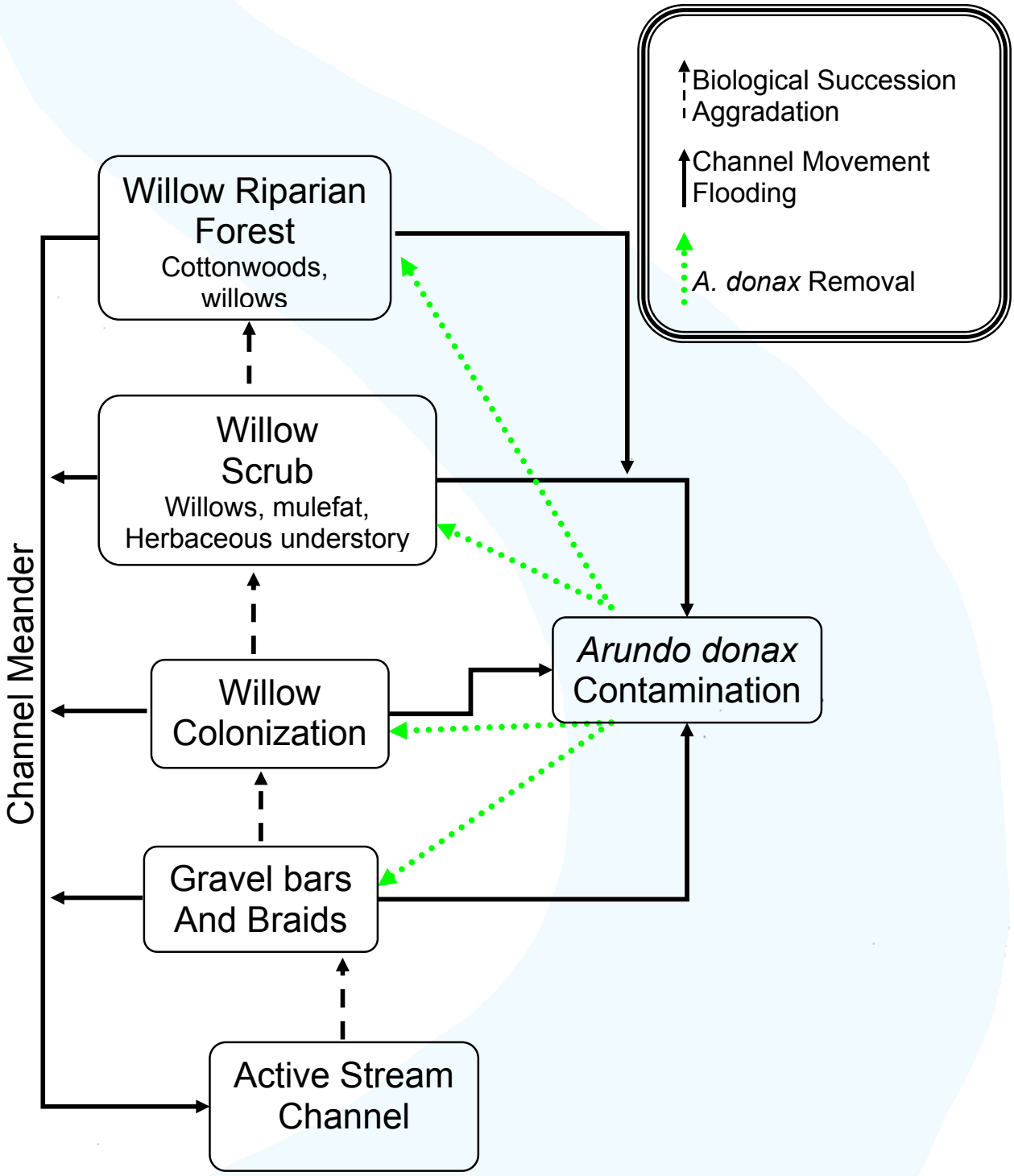
2. *Evaluation of Site Conditions: How river processes operate on the site*

Because of the semi-natural hydrograph, high flows inundate portions of the flood plain, recharging groundwater, depositing nutrient rich sediment and distributing native seeds. The frequency and extent of flooding has been altered, and in general, base flows are reduced and peak flows are increased. Many portions of the Santa Margarita River are protected, so there is riparian floodplain available to be restored. The biggest factor limiting native vegetation is the widespread invasive *A. donax*. Removal of this weed has been the major focus of restoration, therefore site evaluation has largely consisted of mapping *A. donax*, and deciding the best locations for removal. To prevent *A. donax* from spreading downstream, efforts were made to begin removal upstream and progress downstream, and a coordination of removal efforts was also implemented to limit the spread of *A. donax* into areas as a result of removal techniques. Several experimental horticultural restoration techniques were tested in plots throughout the project area. At these plots, soil texture and stratification was examined, and distance to the main channel was recorded as a substitute for relative elevation to the water table. Survival of restoration plantings was measured and related to measured variables. Through these experiments, preferred soil conditions and position on the floodplain preferences for specific native riparian plants were revealed; such plant preferences could then be applied to future restoration plantings.

3. *Conceptual Model of Physical and Biological Successional Trajectory*

Conceptual models used in horticultural restoration can help the restorationist decide which species to plant, at what densities, and at which locations. The model can then allow a guess to be made about how site conditions and plant succession will affect the future composition and plant community structure over time. They are also beneficial for process restoration will be implemented at a site.Process restoration was implemented on the Santa Margarita River; by removing the invasive weed *A. donax*, it was assumed that natural river processes would allow native plants to re-vegetate areas cleared of the exotic species. A conceptual model for the Santa Margarita River shows how *A. donax* prevents natural succession of plant communities from taking place, and helps substantiate goals that can be evaluated during vegetation monitoring after removal (Figure 1, next page).

Figure 1: Conceptual Model of Plant Succession Influence of A. donax on the Santa Margarita River



Case Study #3: Restoration on the Trinity River: Berm Removal

Project Summary

Prior to the Central Valley Project's creation of the Trinity River Diversion (TRD) in the early 1960's, the Trinity River supported abundant populations of salmon and steelhead (Trinity River EIR). With the loss of 109 miles of critical fish habitat above the Lewiston Dam on the Trinity River, and up to 90% of the water diverted to the Central Valley, fish populations declined rapidly (Trinity River EIR). The Trinity River Restoration Program is an ongoing project to restore the Trinity River Basin fish and wildlife populations.

Historically, flows through the Trinity River were extremely variable, with high floods exceeding 70,000 cfs, but after the TRD, for almost two decades a constant low flow of 100 to 150 cfs flowed through the Trinity River (Trinity River Biological Monitoring 2007). Without variable flows, fast growing willows established close to the river channel. Overtime, the willows accumulated sediment and additional shrubby species established, until narrow but often high banks of vegetation were formed that would normally have been scoured away by occasional high flow events. These berms act as natural levees to isolate the floodplain from the channel, preventing bank overflow onto the floodplain, groundwater recharge and sediment deposition. Isolated floodplains are no longer able to recruit young trees and shrubs and eventually the mature forests decline. Eventually the berms grew so large that hydraulic modeling revealed that even intentionally released high flows would not be able to remove them (Trinity River Flow Evaluation 1999).

A major component of restoration along the Trinity River is mechanical removal of berms, and physical reconstruction of the damaged floodplain. A second necessary component of restoration on the Trinity has been an incorporation of variable annual instream flows that can prevent future berm formations, encourage native riparian vegetation establishment, and improve fish habitat. Restoration efforts include introduction of coarse sediment to increase gravel storage, improve channel dynamics, and increase salmon spawning and rearing habitat. Revegetation of rebuilt floodplains is expected to occur naturally with increased flows, but native riparian vegetation is planted on some floodplains to quickly stabilize banks and decrease sediment loads into the river. Restoration along the Trinity River requires applying new techniques and learning about the system throughout the process. To ensure scientific monitoring and evaluation could influence restoration decisions throughout implementation, an Adaptive Environmental Assessment and Management Program was formed.

Project Name	Trinity River Restoration Program
County, River, Bioregion	Trinity County, Trinity River, Klamath Bioregion
Project Goals – Primary reason for restoration	Restore fish and wildlife habitat by allowing the river to function more naturally – remove berms, rebuild floodplains, restore variable flow regime, stabilize river banks with native vegetation.
Long term goals and considerations	Through physical removal of berms, rebuilding of the floodplain, and allowing a more variable flow regime through the river, the trinity river should be able to maintain fish and wildlife habitats naturally, but continued monitoring may reveal that altered flows are needed.
Partnerships	Bureau of Reclamation, U.S. Fish and Wildlife Service, Forest Service, National Marine Fisheries Service, California Resources Agency (including the Departments of Water Resources and Fish and Game), Trinity County, the Hoopa Valley Tribe, and the Yurok Tribe

Restoration Planning Process (Steps in Flow Chart)

Here, a few of the steps in the flow chart that were a major part of this restoration are discussed, for more specific details see above link to the Trinity River Restoration Program.

1. *Designation of Site as Riparian*

Lewiston Dam regulates releases into the Trinity River. Historic streamflows were highly variable, and this kept the channel actively creating floodplains, sloughs, and scoured away opportunistic woody vegetation in low flow reaches. With low flow releases after creation of Lewiston Dam, riparian berm formation acted as natural levees and isolated floodplains from the river channel in several reaches of the river. Removal of berms and release of higher base flows and annual variability in flows will reconnect the floodplains with the active channel, designating the floodplains as riparian areas.

2. *Evaluation of Site Conditions: How river processes operate on the site*

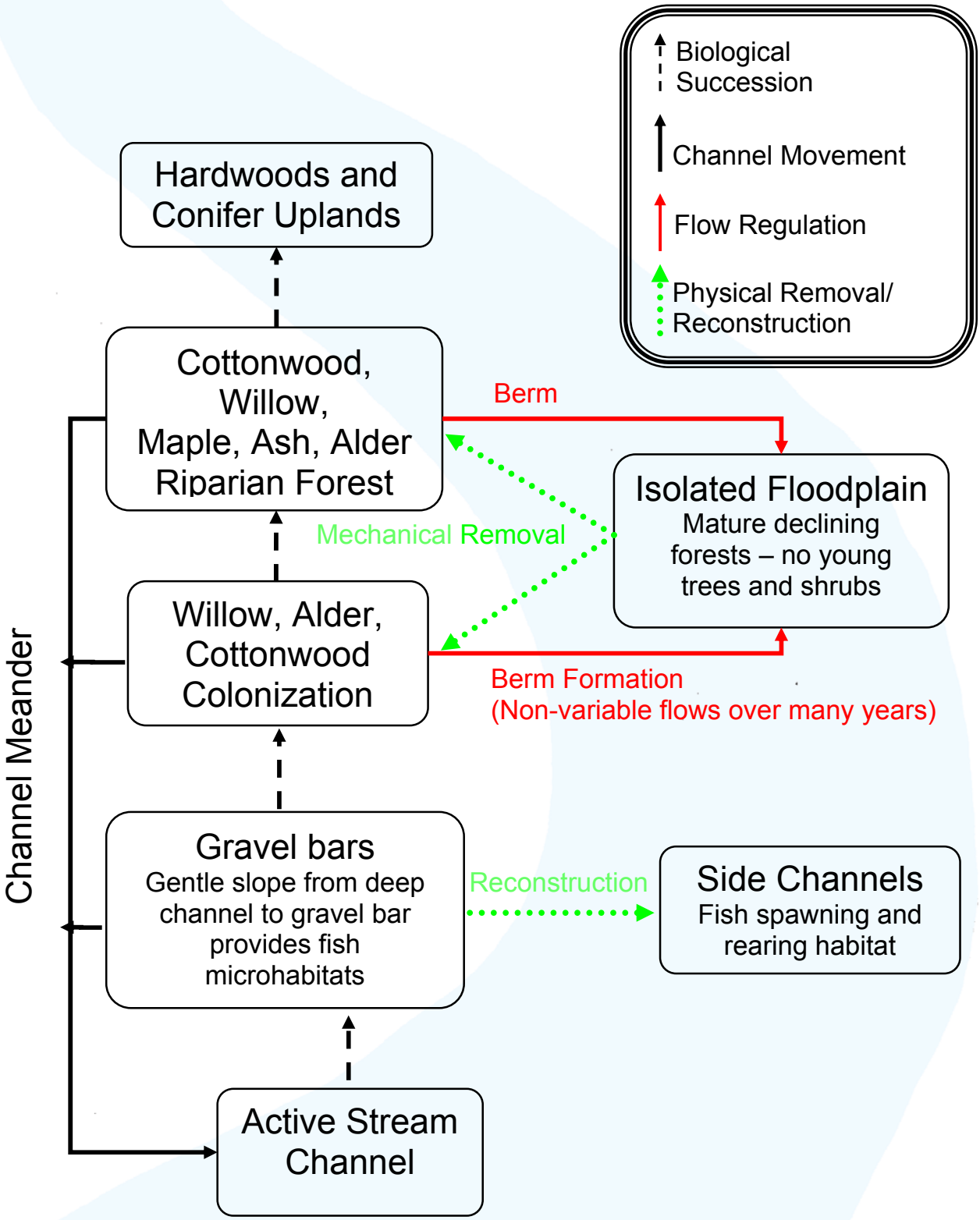
Hydraulic Modeling: In 1984, the Trinity River Basin Fish and Wildlife Act was signed, with the goal of restoring fish and wildlife populations to pre-regulation levels. It was recognized that riparian berms had formed along the river and were altering the morphology of the river channel. Naturally, the channel gently sloped from the deepest part of the mainstream channel up to the lower floodplain terrace, providing microhabitats for fish. On this gentle slope, during low flows, riparian vegetation established and continued low flows were not strong enough to scour the vegetation away. As sediment gathered among the vegetation and the berms formed, the channel became narrow with steep sides as the river was confined. The fish habitat created by the gentle slopes was lost with the formation of berms. Isolated floodplains also suffered with the lack of connection to the river channel. Young trees and shrubs were unable to recruit without overflow onto the floodplains, and mature vegetation no longer received nutrients from sediment input or groundwater recharge. Overtime the riparian vegetation on floodplains declined. The first phase of restoration on the Trinity River called for hydraulic monitoring to evaluate whether the berms could be removed by releasing high flows. Hydraulic modeling revealed that even the highest controlled flood releases would not be powerful enough to remove all of the berms. This modeling informed restorationists that mechanical berm removal would be necessary. Modeling did show that once removed, variable high flow releases would be sufficient to prevent new berm formation.

Sediments: Enhancing fish populations are a primary goal of the Trinity River Restoration Program. In addition to isolation from 109 miles of spawning habitat above the dam and altered morphology of the river below the dam, fish populations suffered due to loss of coarse spawning gravel below the dam. Studies of spawning gravel availability showed that directly below the dam, most of the coarse sediment – cobbles and gravel, had been trapped by the dam. Therefore, after berm removal, floodplain reconstruction and side channel creations, fish habitat close to the dam was enhanced by the addition of spawning gravel sized sediment. Isolation of floodplains from the river channel by riparian berms eliminated much of the riparian shrubs and trees along the channel, which causes additional fine sediment load into the river from bank erosion. Stabilization of the banks with native vegetation helps reduce the sediment load.

3. *Conceptual Model of Physical and Biological Successional Trajectory*

A conceptual model of the processes of the river channel and plant succession on the Trinity River can illustrate how over-regulated flows and riparian berm formation can alter the natural course. The model can also help plan which native plants to use to revegetate side channels and newly created floodplains (Figure 1, next page).

Figure 1: Conceptual Model for Plant Succession on the Trinity River - Influence of Riparian Berms



Case Study #4: Restoration on the Upper Truckee River Bank Stabilization

Project Summary

The Upper Truckee River flows into Lake Tahoe, and has been identified as the largest contributor of sediment into the lake from eroding stream banks (Simon et al. 2006). In compliance with the Total Maximum Daily Load developed for Lake Tahoe, and as a priority of the Lake Tahoe Environmental Improvement Program, the Sunset Reach of the Upper Truckee River is a site of process restoration that will physically rebuild the channel and contour the surrounding meadows and riparian floodplains with the goal of reducing sediment loads into the lake.

A history of urban development, flow regulation (decreased flows and channel straightening) gravel mining, grazing, infrastructure development, and logging has increased the sediment load into the river. The river has adjusted through bank failures, channel widening and incising. The combination of a larger channel and a lower volume of water released through the river rarely allow overbank flow and the ground water table is lowered. The riparian floodplains are therefore rarely inundated, and in many locations the water table is too low for meadow vegetation to reach. Under natural conditions, water flows through sinuous channels with banks stabilized by native meadow or riparian plants, and there is little bank erosion. During high flows (and natural conditions) much of the sediment is distributed onto the floodplain where it is trapped, reducing the load carried by the channel to Lake Tahoe. Under current conditions – straightened, incised channels and lower released flows – the vegetation adapted to drier conditions that establishes along the banks has shallower roots and cannot prevent bank erosion. The widened channels are mostly filled with sand. High quality fish habitat – pools and coarse gravel riffles – has declined along with the primary aquatic production that sustains fish populations.

Restoration on this reach of the Truckee River is focused on reducing sediment load due to channel erosion and improving fish habitat. The proposed method for restoration is to create new channels of the appropriate width and depth to accommodate the sediment loads and current flows. Old channels will be filled in and revegetated. The new channels will be stabilized to prevent future erosion with riparian vegetation and structural supports such as sod blocks, large woody materials and rocks. The channels will be constructed to include deeper pools and gentle gravel lined slopes for fish spawning and rearing habitats. The floodplains will also be reconstructed to include seasonally wet depressions. Riparian and meadow vegetation will be planted along the river channels. Additionally, where conifers have encroached into the riparian zone, they will be removed.

Project Name	Sunset Reach of the Upper Truckee River
County, River, Bioregion	El Dorado County, Truckee River, Sierra Bioregion
Project Goals – Primary reason for restoration	Improve clarity of Lake Tahoe by reducing sediment load from the Upper Truckee River due to streambank erosion. Restore fish and wildlife habitat through channel construction and planting riparian vegetation.
Long term goals and considerations	The channel will be rebuilt to accommodate current flow and sediment regimes, and will be strengthened by riparian vegetation and structural supports. Models predict these modifications will prevent future erosion.
Partnerships	National Forest Service Lake Tahoe Basin Management Unit, California Tahoe Conservancy

Restoration Planning Process (Steps in Flow Chart)

Here, a few of the steps in the flow chart that were a major part of this restoration are discussed, for more specific details see above link to the Proposed Action for the Upper Truckee River (Sunset Reach).

1. *Designation of Site as Riparian*

This reach of the Upper Truckee River is historically characterized by a lower channel gradient and broader floodplain, with large meadows within reach of the groundwater table. As a result of channel alterations, in many locations the meadows are no longer able to reach the groundwater. Currently, flows high enough to overflow the banks and connect the channel to the floodplain and recharge groundwater occur about every 2 to 5 years. Through restoration, flows through the newly constructed channels should overflow on an average of 1.4 years, and smaller, repositioned channels should sustain groundwater levels required by meadow species. Even though the meadows are primarily connected to the river channel through ground water, overflows are still necessary to their function. The meadows floodplains within this reach are considered riparian.

2. *Evaluation of Site Conditions: How river processes operate on the site*

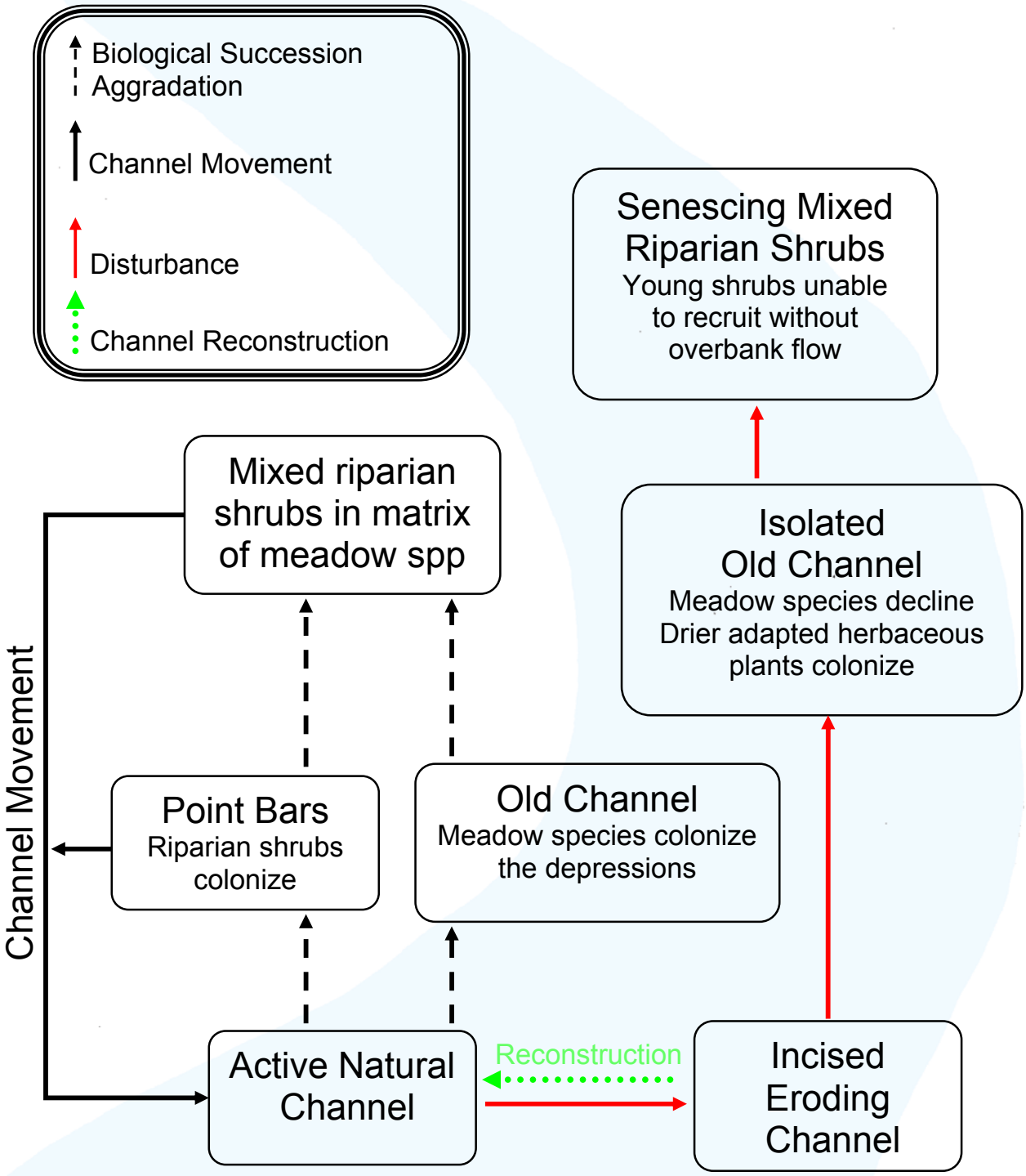
Aerial photographs of the Sunset Reach show large meander scars that describe the historic sinuosity of the channel. This reach of the Upper Truckee River is less constrained by valley walls which give the river space to meander. When the matrix of vegetation on the site is examined, it can be seen that wet meadow species are dominant in lower elevation reaches of old channels, which are closer to groundwater, while shrubby riparian species are found along recently deposited point bars or recently eroded, shallow stream banks. As the river meandered and left old depressions behind where meadow species thrive, and deposited new coarse sediments that favor riparian shrubs and trees, the matrix of vegetation grew more complicated. Aerial photographs document the changes to channel meander and shape as a result of human activities. Logging practices, grazing and agriculture in particular disrupted the system by straightening the channel and altering flows. Straightened channels tend to become deeper or wider in order to carry water and sediment loads over a shorter distance. This process creates positive feedback because the slope of the channel also increases which leads to an increase in velocity and further erosive power. The incised channels carry water lower relative to the floodplain, and the roots of wet meadow species cannot reach the groundwater. Similarly, even though eroded banks are typically colonized by shrubby species, if the channel is too deep relative to the bank, the shrubs do not get flooded frequently enough to establish. Restoration at this reach of the river will involve creation of a new channel that can meet the hydrologic needs of the riparian and meadow species. To determine the appropriate channel width and depth, stream gauges can be used to document current base flows and high flows. Restorationists determined that for the Sunset Reach, channels needed to flood an average of 1.4 years when flows reached 450 cubic feet per second (cfs).

The history of sediment distribution across the floodplain is also reflected in the matrix of vegetation. Meadow species are typically more successful in finer soils rich in organic matter. These conditions are frequent in old channels where sediments were deposited in layers overtime. Shrubs however cannot compete with the fast growing herbaceous meadow species in the finer soils, but they can grow fast through coarse soils in open areas where their roots can quickly reach the water table. Without natural meander to create cut off banks and deposit coarse sediment on point bars, shrub species lose the ability to recruit. As the deeper channel is unable to overflow its banks, meadow species do not receive nutrients attached to fine sediments. The newly constructed channels will be smaller and shallower. The banks will be reinforced by planting riparian shrub species along the channel banks. Meander into the old incised channels will be discouraged by filling the channels but maintaining a low depression to be planted with meadow species. Examination of sediment sizes in the altered channels showed high levels of sand relative to coarser grains preferred by fish. In the new channels, coarse sediments will be added to specifically contoured slopes to create fish spawning and rearing habitat.

3. *Conceptual Model of Physical and Biological Successional Trajectory*

A conceptual model of physical processes and plant succession on the Sunset Reach of the Upper Truckee River under the influence of altered channels is useful to determine the need for restoration, and to predict the outcome of constructing a new channel (Figure 1).

Figure 1: Conceptual Model for Plant Succession on the Upper Truckee River: Influence of Eroding Channel Beds



3. Ecological and Landscape Considerations of Riparian Plants

Table 1: ECOLOGICAL TOLERANCES OF RIPARIAN PLANT SPECIES

	HYDROLOGIC TOLERANCES			
Species	**Water Table Required**	**Maximum Depth to Water Table**	**Tolerates Long Duration Flooding**	**Drought Recovery*** **
Black willow *Salix gooddingii*	Yes	3 meters	Yes	Yes
Sandbar Willow *Salix exigua*	Yes	2 meters	Yes	Yes
Arroyo willow *Salix lasiolepis*	Yes	3 meters	Moderate**	Moderate
Red willow *Salix lasiandra*	Yes	7 meters	No	No
Fremont Cottonwood *Populus fremontii*	Yes	7 meters	Yes	Yes
Buttonbush *Cephalanthus occidentalis*	Yes	3 meters	Yes	Yes
White alder *Alnus rhombifolia*	Yes	<1 meter	No	No
Western Sycamore *Platanus racemosa*	Yes	7 meters	No	Yes
Oregon Ash *Fraxinus latifolia*	No		Yes	Yes
Box-Elder *Acer negundo*	No		No	Yes
Valley Oak *Quercus lobata*	No		Yes	Yes
Blue Elderberry *Sambucus mexicana*	No		No	Yes
Coyote Brush *Baccharis pilularis*	No		No	Yes
Rose *Rosa intermontana*	No		Yes*	Yes
Blackberry *Rubus ursinus*	Yes	3 meters	Yes*	No
Creeping rye grass *Leymus triticoides*	No		Yes	Yes
Basket sedge *Carex barbarae*	No		Yes	Yes
Mugwort *Artemisia douglasiana*	No		No	Yes
Gumplant *Grindelia camporum*	No		No	Yes

*If top is above water, **many stump-sprout after top-death, ***Recovery after drought induced leaf-drop

Table 2: RIPARIAN PLANT SPECIES ON THE LANDSCAPE

Species	OPTIMAL LANDSCAPE SETTING	USES BY WILDLIFE
Black willow *Salix gooddingii*	Heavy clay soils; seasonal wetland basins; perimeter of permanent wetlands	Leaf insects
Sandbar Willow *Salix exigua*	Sandy soils; on point bars	Allows other species to colonize inside stand due to more open canopy
Arroyo willow *Salix lasiolepis*	Loamy soils; upper bankfull flow	Early spring source of leaf-insects
Red willow *Salix lasiandra*	Upper floodplain; on tributaries	Leaf insects
Fremont Cottonwood *Populus fremontii*	Sandy and Loamy soils, lower floodplain	Tall structure
Buttonbush *Cephalanthus occidentalis*	Perimeter of Permanent wetland; freshwater tidal marsh (Delta)	Nectar/pollen
White alder *Alnus rhombifolia*	Edge of channel	Source of insects to SRA
Sycamore *Platanus racemosa*	Sandy loams; well-drained	Denning/nesting cavities/heron rookery
Oregon Ash *Fraxinus latifolia*	Edge of channel; loamy soils in basins.	Leaf insects
Box-Elder *Acer negundo*	Mid to upper floodplain; loamy soils	Leaf insects
Valley Oak *Quercus lobata*	Upper Floodplain; fine textured, well-drained soild during growing season	Leaf/bark insects/acorns
Blue Elderberry *Sambucus mexicana*	Loams on upper floodplain	Host of VELB/pollen/nectar/fruit/ insects
Coyote Brush *Baccharis pilularis*	Upper floodplain	Evergreen cover/pollen/nectar in Fall
Rose *Rosa intermontana*	Thickets across floodplain	Pollen/nectar/fruit/cover/important nesting site
Blackberry *Rubus ursinus*	Thickets lower on floodplain	Pollen/nectar/fruit/cover
Creeping rye grass *Leymus triticoides*	Sun or shade across floodplain	Sod-forming
Basket sedge *Carex barbarae*	Shade/frequently flooded	Soil stabilization/"Fire cooler"*
Mugwort *Artemesia douglasiana*	Sun; mineral soil	Important for Cover/weed control
Gumplant *Grindelia camporum*	Sun	Pollen/nectar/large seeds

Individuals of all species can be found anywhere on the floodplain. This table describes conditions where the species dominates stands of vegetation and the resources they provide wildlife. All plant species provide cover and nesting sites, and contribute organic matter into rivers.

**Carex barbarae* burns at a lower temperature than dry grass, resulting in survival of tree around which it grows.