State Coastal Conservancy (January 2005)

Santa Clara River

Riparian Revegetation and Monitoring Handbook

Prepared for:

Santa Clara River Trustee Council

Prepared by:

Gretchen C. Coffman, PhD

Richard F. Ambrose, PhD

UCLA

July 15, 2011

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***FWS Agreement #*: 81440-5-G005**

Submitted to: Santa Clara River Trustee Council
Submitted by: UCLA, Department of Environmental Health Sciences

Acknowledgements:

Our sincere thanks go to members of The Trustee Council from the U.S. Fish and Wildlife Service and California Department of Fish and Game who guided preparation of this document, including: Denise Steurer (USFWS, trustee), Jenny Marek (USFWS, alternate), and representatives from CDFG are Dan Blankenship (CDFG, trustee) and Ken Wilson (CDFG, alternate). We would like to thank the following individuals who provided valuable background information on conservation planning and restoration efforts related to *Arundo donax* removal, other invasive plants, riparian revegetation, and monitoring: Peter Brand, Sandy Hedrick, Dave Hubbard, Tom Dudley, Adam Lambert, Bruce Orr, Ron Bottorff, Jackie Worden, Noreen Murano, EJ Remson, Jim Greaves, Dane Williams, Peter Downs, Zooey Diggory, Mark Newhouser, Rick Austin, Richard Atmore, and Chris Solek.

***Cover Photograph*:**

Oblique air photo looking east upstream along the Santa Clara River after a large flood event in January 2005 showing riparian vegetation along the floodplain. Photo taken for the California State Coastal Conservancy.

Preferred Citation:

Coffman, G. C. and R. F. Ambrose. 2011. Santa Clara River Riparian Revegetation and Monitoring Handbook. Prepared for the Santa Clara River Trustee Council, Ventura, California. July 2011.

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EXECUTIVE SUMMARY

The Santa Clara River Riparian Revegetation and Monitoring handbook was developed as a guide to provide science-based strategies for organizations involved with riparian ecosystem restoration on the river. The primary goals of this handbook was to: (1) provide guidelines which will assist the Trustee Council, agencies, and non-governmental organizations (NGOs) in selecting restoration sites, monitoring invasive plant removal, evaluating the success of riparian revegetation projects after *Arundo donax* (*Arundo*) removal along the Santa Clara River, and integrating such efforts into an appropriate adaptive management program; and (2) create conceptual strategies for riparian restoration monitoring based on ecological data.

We attempted to apply results of our research on riparian plant species survivorship and growth at the UCLA Riparian Field Experiment to develop various aspects of this handbook. In particular, we developed four strategies for prioritization of *Arundo* removal and revegetation after removal (Chapter 4) and discuss development of success criteria using data collected on heights of four native riparian plant species sampled at the end of the first and second growing seasons after planted (Chapter 3). We recommend that other success criteria and trajectories for associated performance metrics be refined by studying an array of reference sites, establishing a field experiment, and/or sampling riparian plant species on the Santa Clara River for at least ten years.

It is our hope that this handbook will be a starting point for a unified approach to scientifically driven riparian restoration on the Santa Clara River, led by the newly developing UC Research Station and Conservation Center. One of the main objectives of the UC Research Station and Conservation Center, which is being funded by the Trustee Council, is to provide assistance in planning and monitoring restoration projects. A Strategic Plan for *Arundo* control and restoration is currently under development for the Santa Clara River (Stillwater Science and UCSB in preparation). Information from this handbook is being used in developing the Strategic Plan.

The scope of this handbook entails conceptual prioritization of *Arundo* removal strategies and monitoring of revegetation after *Arundo* removal. Several other restoration actions have been proposed for the river, although the activities we concentrated on should generally be implemented first and may possibly be the largest components of restoration of this braided sand-bed river. We present a conceptual monitoring program, and emphasize the need for development of a more detailed monitoring plan for the entire watershed.

We acknowledge that information in this handbook is not complete and advise that no portion of the conceptual monitoring program presented should be used as a final detailed monitoring plan. The proposed success criteria were not all developed based on scientific data, but should eventually be informed and refined using local or regional scientific data. If you would like to use portions of the conceptual monitoring plan for your restoration efforts, please contact the authors or the UC Research Station and Conservation Center staff for advice on developing a detailed monitoring plan suitable for your project.

Chapter 1 introduces the roles and projects of the main organizations conducting restoration on the Santa Clara River, including the Trustee Council, State Coastal Conservancy, The Nature Conservancy, and Friends of the Santa Clara River. The goals and objectives of this handbook development are stated at the end of the first Chapter. In Chapter 2, we present opportunities and constraints for riparian ecosystem restoration along the Santa Clara River, focusing on non-native invasive species removal and both active and passive revegetation after removal.

Results of our UCLA Riparian Field Experiment are presented in Chapter 3, followed by a discussion of how our results can inform success criteria targets (i.e., California Department of Fish and Game's performance criteria for riparian tree and shrub height after 3 and 5 years). Our research on riparian plant species survivorship shows that native trees and shrubs need not be artificially irrigated if planted during the appropriate time of year, under high-moderate soil moisture conditions, and using the appropriate plant installation specifications. Out of the 1,152 individuals planted in November of 2002, total riparian plant cutting survivorship in spring 2003 was 97.7%. Total plant survivorship at the end of 2003 and 2004 was 98.4% and 97.8%, respectively. Also, our first two years of growth data indicate that average height of all four riparian tree and shrub species varies significantly under varying soil moisture and light treatments. Based on these results, we suggest that success and performance criteria must be multifactorial in nature. Targets for success criteria and metric trajectories must be developed for the Santa Clara River based on long-term ecological data from this experiment and sampling at a suite of reference sites throughout the river.

Chapter 4 outlines conceptual timing and duration of each task involved in invasive plant removal and revegetation actions. Strategies and a conceptual framework for monitoring these restoration actions are presented in Chapter 5. Finally, Chapter 6 lists the next steps in planning and implementation of these restoration actions. Three appendices include: photos of the UCLA Riparian Field Experiment, Long-term photo monitoring points established around HRNA (comparing 2003 pre-restoration to 2008 five years during restoration), and an Annotated Bibliography for the Santa Clara River we developed (August 11, 2009).

CHAPTER 1
INTRODUCTION

This Santa Clara River Riparian Revegetation and Monitoring Handbook is an attempt to link research on ecology of invasive species, mainly *Arundo*, and native riparian species revegetation with management activities to help guide future riparian restoration efforts along the Santa Clara River. We met with the Trustee Council several times during the course of conducting this research and writing this handbook to more carefully guide its development and align it with the goals of the Trustee Council. Most data in the handbook were collected (Chapter 3) at the UCLA Riparian Field Experiment located immediately adjacent to Hedrick Ranch Nature Area (HRNA) on the Valley View Ranch (**Error! Reference source not found.**).

The following is a brief background of riparian restoration planning, studies and implementation along the Santa Clara River supported by the Trustee Council and conducted by other major stakeholders to date.

History of the Trustee Council

In 1994, a pipeline ruptured during the Northridge earthquake spilling 190,000 gallons of oil into the Santa Clara River, one of the last free-flowing rivers in Southern California. The 187 km long Santa Clara River and its tributaries drain a 4,185 km^2 watershed, the second largest coastal watershed in southern California. To mitigate for impacts to the river ecosystem, a settlement was reached between ARCO and regulatory authorities in 1997.

The Santa Clara River Trustee Council (Trustee Council) was formed to manage and distribute funds from the settlement of claims for natural resource damages resulting from an ARCO pipeline oil spill into the Santa Clara River which occurred in January 1994. The overall goal of the Trustee Council is to restore riparian habitat along the Santa Clara River for use by migratory bird species, provide shade and passage for native fish, control erosion, encourage recovery of native plant communities following removal of invasive plants, and improve habitat for other riparian dependent wildlife species. Wildlife species affected by the ARCO oil spill, such as the least Bell's vireo and the unarmoured three-spine stickleback, are the focus of the riparian habitat restoration. The Trustee Council consists of representatives from the U.S. Fish and Wildlife Service USFWS and the California Department of Fish and Game - Office of Spill Prevention and Response (CDFG). Representatives from the USFWS currently include: Denise Steurer (trustee) and Jenny Marek (alternate) Representatives from CDFG are Dan Blankenship (trustee) and Ken Wilson (alternate).

The Santa Clara River Trustee Council developed the Restoration Plan and Environmental Assessment (RPEA) for the Santa Clara River ARCO Oil Spill which was finalized in October 2002 (The Santa Clara River Trustee Council 2002). This document provided a framework to examine and present restoration alternatives to restore, rehabilitate and replace or acquire the equivalent of the natural resources impacted by the ARCO oil spill. The Trustee Council has the responsibility and legal authority to plan, develop, and implement restoration projects within the entire 1,600 square-mile Santa Clara River watershed. Restoration projects that have been funded by the spill settlement include land acquisition, invasive plant control, habitat enhancement, education, and watershed monitoring and research projects. Development of this Santa Clara River Riparian Revegetation and Monitoring Handbook was funded by the ARCO settlement.

In 2000, the California State Coastal Conservancy proposed the establishment of the Santa Clara River Parkway after discussions with river corridor landowners and local governments. As currently envisioned, the Parkway project will result in the acquisition and restoration of a 40 mile-long (6,000-acre) corridor from the mouth of the Santa Clara River to the Los Angeles County Boundary. Governor Gray Davis provided initial funding of $9.2 million, as appropriated by the legislature, to the Coastal Conservancy for land acquisition and planning. Land acquisition is being conducted on a willing seller basis, with the initial focus of the project on the lower river.

Early in restoration planning, the Trustee Council was approached by California State Coastal Conservancy (Coastal Conservancy) to gain funding for a planned Santa Clara River Parkway project. At the same time, the Nature Conservancy (TNC) selected the Santa Clara River as one of its priorities for land protection and conservation. A partnership was formed between the Trustee Council, the Coastal Conservancy, and TNC to restore wetland and riparian ecosystem processes and functions along the Santa Clara River, and protect these ecosystems for future generations. The Trustee Council has funded acquisition of several properties along the Parkway, totalling more than $4 million. The acquisition of land was an important step in protecting and restoring the natural riparian corridor along the Santa Clara River and in providing habitat for a multitude of wildlife and aquatic species, including a number of Threatened/ Endangered species and species of special concern. In particular, healthy riparian ecosystems along the Santa Clara River will provide vital habitat for two federally endangered species that were impacted by the oil spill, the unarmoured three-spine stickleback and Least Bell's Vireo.

The Trustee Council has funded several other grants to TNC and Coastal Conservancy including a steelhead assessment study, the development of an upper and lower watershed habitat protection plan, a vegetation classification and mapping study of the river, and a series of Watershed U science workshops (UC Cooperative Extension) to promote stakeholder understanding of the Santa Clara River Watershed. The Coastal Conservancy sponsored a science workshop on February 16, 2007 and developed a Santa Clara River Parkway website (http://www.santaclarariverparkway.org/) that facilitates the sharing of information among various stakeholders and the public.

The Trustee Council, Coastal Conservancy and TNC have been supporting the establishment of a University of California Reserve along the Santa Clara River that will serve as the headquarters of research and study, along with providing educational opportunities and support for on-the-ground habitat restoration. Also, the Trustee Council is involved with Coastal Conservancy, TNC and other stakeholders in the development of an upper Santa Clara River watershed land trust, in order for a local conservancy to take on the responsibilities and stewardship of lands acquired for restoration and long-term protection. Finally, there will be future acquisitions using Council funds that remain from the existing grant agreement with TNC.

The Trustee Council has funded many studies and pilot projects related to riparian habitat restoration on the Santa Clara River since their EA and Management Plan was finalized in 2004. Studies and project focused on riparian habitat improvement and restoration, educational efforts that focus on riparian habitat restoration, planning and watershed evaluation and assessment.

Organizations Conducting Riparian Restoration

Several organizations other than the Coastal Conservancy and TNC have been working on planning, permitting, and implementing of invasive plant removal and riparian habitat restoration projects throughout the Santa Clara River watershed. These organizations include Friends of the Santa Clara River, Natural Resources Conservation Service (NRCS), Ventura County Resource Conservation District, County of Ventura - Planning Department, Caltrans, Los Angeles and Ventura County Agricultural Commissioners, Ventura County Weed Management Area, City of Santa Clarita, UC Davis Cooperation Extension, and others.

Santa Clara River Parkway

As envisioned by the Coastal Conservancy, the Santa Clara River Parkway Project will consist of a continuous protected corridor of coastal river, riparian habitat and estuary along 40 miles of the River from the Pacific Ocean inland to the Los Angeles County line (http://www.santaclarariverparkway.org/parkwayplanning). This Santa Clara River Parkway will serve as a park and wildlife preserve; allow for ecosystem restoration along the River; provide for better flood management along the River; promote public enjoyment and environmental education; and allow for restoration of natural river processes which will in turn help prevent losses of habitat, farmland and public facilities due to flooding. The Coastal Conservancy has partnered with The Nature Conservancy's LA-Ventura Project to acquire, manage, and restore Parkway lands. Currently, a number of parcels of river corridor within the Parkway have already been acquired, totalling 3,060 acres over 14.7 miles along the river. Future management of Parkway lands is expected to be carried out under a joint powers agreement between the Coastal Conservancy, Ventura County and the cities of Oxnard and Ventura.

Friends of the Santa Clara River

In September 2001, the Coastal Conservancy purchased a 223.11-acre property, consisting of two parcels once part of the Valley View Ranch (**Error! Reference source ot found.** and **Error! Reference source not found.**). This property was one of the first properties acquired by the Coastal Conservancy as part of their Santa Clara River Parkway project. On October 9, 2001, the Coastal Conservancy granted Friends of the Santa Clara River (FSCR) this property and they officially named it the Hedrick Ranch Nature Area (HRNA). As part of the grant agreement with the Coastal Conservancy, FSCR developed a management plan for the HRNA property (URS Corporation 2003). The HRNA property is located along the Santa Clara River between Santa Paula and Fillmore, in Ventura County, California. The property contains both wetlands and riparian habitat along the southern side of the Santa Clara River that the FSCR is managing and restoring over time. As of September 2010, the riparian and wetland ecosystems on the HRNA property have been fully restored by both passive and active habitat restoration efforts over the past ten years. Lessons learned from habitat restoration actions on HRAN are discussed in Chapter 3 of this handbook.

UCLA Riparian Field Experiment

The UCLA riparian field experiment is located on a parcel of land adjacent to HRNA formerly owned by Mr. Sanger Hedrick (Valley View Ranch) and now owned by Underwood Family Farms (http://www.underwoodfamilyfarms.com/) (**Error! eference source not found.** and **Error! Reference source not found.**). This 0.5-hectare field experiment was established in October 2002 in a riparian ecosystem of a floodplain terrace along the south side of the Santa Clara River formerly infested with a monoculture of *Arundo*. The main research goal was to investigate survivorship and growth of three native riparian plant species in competition with the invasive non-native *Arundo* grown under various soil moisture, nutrient and light treatments and levels. We planted 288 groups of 4 plants in a square configuration consisting of three competition groupings (four-species, two-species and one-species groupings) in the study to compare interspecific versus intraspecific competitive interactions between *Arundo*, *S. laevigata*, *P. balsamifera* ssp*. trichocarpa*, and *B. salicifolia.* The field experiment was conducted through two growing seasons, from December 2002 to December 2004. Results of this study related to management/control of *Arundo* and revegetation of removal areas with native riparian plants is presented in Chapter 3 of this handbook.

Handbook Goals and Objectives

The primary goals of this Riparian Revegetation and Monitoring Handbook are to:

1. Provide guidelines which will assist the Trustee Council, agencies, and non-governmental organizations (NGOs) in selecting restoration sites, monitoring invasive plant removal, evaluating the success of riparian revegetation projects after *Arundo* removal along the Santa Clara River, and integrating such efforts into an appropriate adaptive management program; and
2. Create conceptual strategies for riparian restoration monitoring based on ecological data.

Objectives of this Handbook are:

1. Present results of the UCLA riparian field experiment related to revegetation and monitoring
2. Summarize the most effective techniques and timing for invasive plant removal and riparian revegetation
3. Review and comment upon the DFG's standardized protocols for monitoring the success of riparian revegetation projects along the Santa Clara River, consistent with Southern CA efforts (SCCWRP, http://www.sccwrp.org)
4. Integrate riparian ecosystem monitoring protocols, techniques, and methods used statewide that are relevant to southern California into development of this handbook

CHAPTER 2
RIPARIAN ECOSYSTEM RESTORATION OPPORTUNITIES AND CONSTRAINTS ON THE SANTA CLARA RIVER

Introduction

The Santa Clara River is a large, ecologically diverse, and regionally important river system for many plant and animal species due to a combination of the regions' characteristic Mediterranean-type climate and its dynamic hydrology and geomorphology. The 187km long Santa Clara River and its tributaries drain a 4,185 km^2 watershed, the second largest coastal watershed in southern California. The River supports a diversity of riparian vegetation types from its arid headwaters in Los Angeles County to the estuary where the river joins the Pacific Ocean just south of Ventura, CA. Many natural vegetation types have been identified within the 500-year floodplain of the Santa Clara River including: herbaceous, mixed riparian forest, mixed riparian scrub, freshwater wetland, desert riparian scrub, sand dune/beach, coastal sage scrub, and tidal marsh (Ventura County Resource Conservation District 2006, Stillwater Sciences and URS Corporation 2007). Although much of the vegetation within the 500-year floodplain of the Santa Clara River is dominated by native plants, five non-native invasive plant species were found to be widespread along the river and threaten the quality and extent of native riparian vegetation (Table 1)(Stillwater Sciences and URS Corporation 2007). Many riparian ecosystem restoration opportunities have been identified along the Santa Clara River as it is one of the largest and least regulated and human altered river systems in southern California (The Nature Conservancy 2006, Ventura County Resource Conservation District 2006, Coffman 2007, Stillwater Sciences 2008). Chapter 2 of this handbook describes the opportunities and constraints associated with non-native invasive plant removal and revegetation of these removal areas.

Riparian Vegetation Extent, Dynamics, and Condition

Vegetation types, extent and distribution along the Santa Clara River are shaped by their position in the landscape and physical habitat conditions associated with their location. Elevation relative to flooding and time since the last flood were two strong factors found to contribute to distribution of vegetation types located along the Santa Clara River (Stillwater Sciences 2008). Also, wildfire occurrence and intensity were found to affect the age, distribution, and quantity of native riparian vegetation and non-native *Arundo* (Coffman 2007, Coffman et al. 2010). Riparian vegetation and wildlife habitat types located along the Santa Clara River are described in detail in several recent reports (Stillwater Sciences and URS Corporation 2007, Stillwater Sciences 2008, Orr et al. 2011). In 2005, 7,214 acres (2,919 hectares) of riparian vegetation were mapped along the 500-year floodplain of the Lower Santa Clara River within Ventura County. The most extensive vegetation types found on the river included: herbaceous floodplain (27%), mixed riparian forest (23%), mixed riparian scrub (15%), and riparian vegetation dominated by non-native, invasive *Arundo* (12%). Only four riparian vegetation types found on the river were dominated by non-native, invasive plants: herbaceous floodplain (27%), *Arundo donax* (12%), mixed non-native trees (2%), and disturbed (1%)(percentages indicate relative extent of each type found along the river).

Opportunities for Riparian Ecosystem Restoration

Six restoration strategies were recommended for riparian ecosystem restoration along the Santa Clara River in 2008, including: (1) parcel acquisition from willing sellers of threatened and/or high value habitat that is currently prone to regular flooding; (2) levee setback and removal, floodplain recontouring, and floodplain infrastructure modification; (3) non-native invasive species removal; (4) active and passive revegetation; (5) creation of a network of water quality treatment wetlands, and (6) aquatic habitat enhancements (Stillwater Sciences 2008). This handbook focuses on two of the six restoration strategies recommended for riparian ecosystems of the Santa Clara River, non-native invasive species removal and both active and passive revegetation. These two restoration activities are high priority strategies due to the urgency of several invasive plant species threats to the riparian ecosystem functioning, condition, and associated wildlife use; relatively low level of effort and cost involved; and resulting cost compared to ecological benefit associated with these activities.

Removal of non-native invasive plant species would greatly improve riparian vegetation quality for native plant recolonization, wildlife habitat, and some riparian dependent special status species (i.e. Least Bell's Vireo). Currently, *Arundo* is by far the most abundant and invasive of the non-native plant species distributed throughout the 500-year floodplain of the Santa Clara River. It may be found as a component within almost all vegetation types as well as growing by itself in monoculture. Although widely distributed within the river, *Arundo* is commonly found at low to moderate densities throughout the river (1-50% cover)(Stillwater Sciences and URS Corporation 2007, Orr et al. 2011). Several other common but less widespread invasive, non-native plants were found to be associated with riparian vegetation in the 500-year floodplain of the Santa Clara River including: tamarisk (*Tamarix ramosissima*), iceplant (*Carpobrotus edulis*, *C. chilensis* and *Mesembryanthemum crystallinum*), eucalyptus (*Eucalyptus* spp.), Peruvian peppertree (*Schinus molle*), castor bean (*Ricinus communis*), myoporum (*Myoporum laetum*), shortpod mustard (*Hirschfeldia incana*), tocolote (*Centaurea melitensis*), white sweetclover (*Melilotus alba*), and non-native bromes (*Bromus* spp.) (Table 1) (Stillwater Sciences 2008). Active revegetation after removal of non-native plants will accelerate recovery of native riparian vegetation in targeted areas where invasive non-native plants are abundant and where native seed sources or propagules are distant.

Prioritization of Invasive and Non-native Plant Species Removal

This handbook focuses on selection of target invasive and non-native plant species for prioritized removal, control, and revegetation. The California Invasive Pest Council's (CalIPC) Invasive Plant Inventory rates non-native invasive plants that threaten the State's wildlands (http://www.cal-ipc.org/ip/inventory/weedlist.php?region=SW). Categories of high, moderate and limited ratings are based on an assessment of the ecological impacts of each species on wildlands. The Inventory represents the best available knowledge of invasive plant experts in the state of California. We categorized target invasive non-native plant species in this handbook into: (1) priority removal and (2) watch list.

The priority removal list we developed consists of five species that have both 'high' ratings on the CalIPC Invasive Plant Inventory and are known to occur throughout the Santa Clara River watershed. The most widespread of these species, *Arundo* is emphasized in this handbook because of its serious known impacts to riparian ecosystems (see section below on The *Arundo* Problem)(Giessow et al. 2011). *Arundo* removal along the Santa Clara River is thought to be the highest priority restoration action due to its widespread distribution, known impacts, and relatively minimal permit requirements for removal (if removal is non-mechanized). Also, the large effect of *Arundo* removal and short amount of time required for ecosystem recovery relative to other restoration actions (i.e., levee setbacks) is a strong incentive for prioritizing this action. Removal and revegetation strategies for these five species are discussed briefly in this handbook, including: *Arundo* (*Arundo donax)* perennial pepperweed (*Lepidium latifolium*), creeping water primrose (*Ludwigia peploides* ssp. *montevidensis*), smallflower tamarisk (*Tamarix parviflora*), and salt cedar (*Tamarix ramosissima*).

Other non-native invasive species with CalIPC high ratings were found in more limited distribution within the Santa Clara River 500-year floodplain (Table 1). Thirteen other high rated non-native invasive species have not been found along the Santa Clara River but have the potential to invade riparian and/or aquatic vegetation on the river due to their known occurrence in other semi-arid systems of California. These species are presented on the Watch List (Table 1)(Vaghti and Greco 2007). We recommend that their presence/distribution on the River be surveyed every 5 years (Table 1). Occurrences and distribution of eighteen non-native invasive species with moderate and limited ratings were included on the Watch List and should be surveyed every 5 years as well. Identification and immediate eradication of all species on the Watch List is critical to riparian vegetation quality and river ecosystem health.

The *Arundo* Problem

Infestations of *Arundo* have created serious physical and biological impacts along rivers in southern California. Where it grows extensively along floodplains, *Arundo* acts as a transformer species; it causes physical obstructions to natural water flow, thereby increasing the risk of flooding to adjacent lands. During large floods *Arundo* increases stream roughness, creates debris dams at bridge crossings, and causes bank erosion and instability (DiTomaso 1998). As the aboveground biomass dries in the hot, dry summer months that characterize Mediterranean-type climates, *Arundo* creates an unnatural fire hazard where moisture-rich riparian corridors used to form natural barriers to fire (Scott 1994, Rundel and Gustafson 2005, Giessow et al. 2011). Water loss due to high evapotranspiration (ET) of *A. donax* reduces already scarce water resources in Mediterranean-type climate regions. Based on transpiration rates of rice (another C3 species thought to have similar transpiration rates), Iverson (1994) estimated that *Arundo* uses three times more water than native riparian species. Studies using a variety of methods indicate that ET of *Arundo* (1.2–7.5 m/year) may be much higher than that of native riparian vegetation such as *Salix* spp., *Populus* spp. (1.0–3.3 m/year) and mixed riparian communities of arid and Mediterranean-type climates (0.11–1.6 m/year) (Zimmerman 1999, Hendrickson and McGaugh 2005, Shafroth et al. 2005, Abichandani 2007). Abichandani (2007) showed that *Arundo* infestations may transpire 6 to 110 times more (up to 18,206 kg m^{-2} $year^{-1}$) than native vegetation.

Arundo has very little known habitat value for wildlife in California (Bell 1997, Kisner 2004) compared to the dominant native vegetation (Bell 1994, Herrera and Dudley 2003). Its stems and leaves contain an array of inorganic noxious chemicals (Jackson and Nunez 1964) that reduce herbivory by most native insects and grazers.

Due to its dense clonal growth form, it physically restricts indigenous wildlife passage, yet many animals depend on the riparian corridor and river floodplain for foraging, nesting, and cover (Kisner 2004). Like other invasive plants, *Arundo* appears to have negative impacts on indigenous plant and animal biodiversity through the loss of suitable habitat and competition with indigenous species (Czech and Krausman 1997). In addition, *Arundo* threatens river ecosystem sustainability via its impacts on natural river processes, such as lowering of the groundwater table, decreased surface water levels in streams, creating the potential for unnatural and extremely hot fires, and loss of plant and animal biodiversity.

Passive and Active Revegetation of Removal Areas

A combination of passive and active revegetation strategies should be used when restoring the native riparian vegetation after invasive plant removal along the Santa Clara River (The Federal Interagency Stream Restoration Working Group 1998, Coffman 2007). Passive revegetation or process-based revegetation focuses on restoring rates and magnitudes of biological processes that recreate sustainable habitat quality, productivity, and a diverse assemblage of native species (Stillwater Sciences 2008). Passive riparian revegetation occurs naturally during flooding along streams and rivers, but is not predictable and typically not frequent except when adjacent to the low flow channels. Levee removal and setbacks are proposed to increase the area of potential passive revegetation on the lower Santa Clara River; their removal will increasing the available floodplain area and facilitate inundation of floodplains by slow-moving floodwaters during high flow events. Physical processes and constraints may limit full recovery of natural riparian vegetation and must be considered carefully when relying solely on passive revegetation.

Active revegetation entails planting species by hand as either containerized plants grown in a nursery, direct installation of pole cuttings, or seeding/hydroseeding. In some areas, active revegetation may involve installing and maintaining an irrigation system to ensure adequate soil moisture in areas that do not exhibit a high groundwater table throughout the growing season. Hydrology, substrate, human activities, reference conditions within a watershed, and local and seed source location and composition (upstream native and non-native plant species) must be considered when developing revegetation plans for any particular site.

In general, using passive revegetation is most appropriate when (Katagi et al. 2002 , Team Arundo del Norte 2004):

- A diverse composition of native riparian plants are well established either on-site or in close upstream proximity of the site that provide seeds and/or vegetative propagules,
- Very small areas of invasive, non-native plants are removed,
- The site contains low density of any other non-native plant species population onsite or upstream of the site,
- The site contains little disturbed, unvegetated, open ground,
- The soils are stable and at low risk of erosion, and/or
- The site floods at least once a year, allowing for nearby native plant seeds or vegetative propagules to reach the site.

The passive revegetation method requires the least effort, cost, and expertise to restore native riparian vegetation. We recommend relying primarily on passive revegetation in the channel bed (flood reset zone) of the Santa Clara River. Wind, rain, and high flows carry seeds, plants, and sediment downstream, where they will settle on the floodplains and grow. This process is periodic and may take several to many years for native plant species to become successfully established. Passive revegetation requires a lower level of soil disturbance after invasive plant removal, resulting in potentially lower soil compaction and less erosion. In addition, this revegetation method ensures the introduction of local genetic plant material. However, if non-native invasive plants dominate adjacent areas, the removal site is at risk of being repopulated by such plants if not revegetated actively with native plant species.

Using active revegetation methods is more appropriate than passive revegetation when:

- The site is located downstream from or near a population of the non-native invasive plant species that was removed or in close proximity to any other non-native invasive species population that may rapidly invade this site (Table 1). Immediate revegetation with native plant species may be necessary to prevent invasion of the removal site.
- The soil or stream bank is unstable and at high risk of erosion. Immediate revegetation will help to reduce the threat of erosion by providing bioengineered bank stabilization.
- A landowner strongly desires a privacy screen or is concerned about erosion of their property following invasive plant removal, and/or

- The site is being restored to replace habitat removed by human activities and is required by special status wildlife species known to have occurred in the area and when timely restoration of vegetation structure is important for replacement habitat.
- Many times pioneer species (initial volunteers) in passive revegetation are restricted to common species such as willows and/or mulefat. Active revegetation would enhance species diversity and vegetation structure of a site and should be used where appropriate.

Restoration of native riparian vegetation types within invasive species removal areas on the higher terraces not frequently flooded will often require active revegetation of diverse array of desirable native species. In general, active revegetation should not be initiated until most target non-native invasive plant removal is under control, since it may be difficult to avoid harming desirable plants during follow-up herbicide treatments. However, it can often take more than one season to adequately remove a well-established invasive plant population. When a removal site is located in a vulnerable area such as a steep bank, passive and/or active revegetation will likely not provide adequate soil or bank stabilization. If this is the case, bioengineered bank stabilization efforts (consult with a professional engineer or the NRCS) should be incorporated into the revegetation plan. A combination of erosion control fabric, willow wattles, deeply planted live cuttings, large logs, and engineered (man-made) stabilizing structures may be needed to adequately prevent erosion and bank failure.

Hedrick Ranch Nature Area (HRNA) – Example of both Passive and Active Revegetation

The Hedrick Ranch Nature Area provides two of the best examples of successful passive revegetation, as well as several examples of active revegetation conducted after *Arundo* removal in the Santa Clara River Watershed. The wildfire on October 25-26, 2003 burned a small portion of the grassland area in the southwest corner of the HRNA property and was stopped by a bulldozer firebreak (see Appendix A). Some of the dominant native riparian plant species that colonized passively after the wildfire included: yerba mansa (*Anemopsis californica*), creeping wild rye (*Leymus triticoides*), and Western ragweed (*Ambrosia psilostachya*). The second example of passive revegetation occurred during the extensive flooding in January and February 2005. The northern pasture (area E) of HRNA was completely transformed within a year from non-native grasslands infested with thistles and annual non-native Mediterranean grasses to mixed willow forest and scrub (mulefat alliance) vegetation (Figure 3).

Dominant plants that colonized the restored mixed willow forest included willow species (*Salix* spp.) in the tree and shrub layer and mugwort (*Artemisia douglasiana*) and stinging nettle (*Urtica dioica*) in the herbaceous layer.

The Trustee Council and State Water Resource Control Board funded several large active restoration activities described in the HRNA Management Plan. The Friends of the Santa Clara River removed many non-native invasive plants and began to actively revegetated the eastern side of the northern pasture of the HRNA (area E) with a diversity of native riparian plants prior the winter floods of 2004-2005. These initial efforts entailed broad-scale invasive non-native plant removal, including mowing and herbicide application and planting of a diversity of native riparian plants. However, not all areas needed to be actively restored, because of passive recovery of native riparian plant communities after winter 2004-2005 flooding. Work crews opportunistically removed *Arundo* by hand immediately after 2005 flooding on the northern portion of HRNA in the active floodway (flood reset zone) scoured by the floods (see Appendix A). Removing *Arundo* reduced the likelihood that this invasive plant could successfully reinvade the active floodplain on HRNA. In 2008, follow-up maintenance was performed by several contractors to remove all *Arundo* from this area using the cut stump method. Due to high soil moisture in the removal area, treatments were applied from October-November when *Arundo* culms were senescing.

After the success of the passive revegetation of the northern pasture (area E), only minimal supplemental native plantings to enhance species diversity and structure and weed control continued on these sites to increase diversity and enhance wildlife use of these riparian ecosystems. Riparian tree and shrub species were planted using 3 foot (3/4 inch – 1inch in diameter) pole cuttings. In harder soil, a battery powered drill with an auger bit was used to drill holes 2 feet deep to plant pole cuttings.

An on-site native plant nursery (solar powered) was established on HRNA to grow riparian plants from seeds and cuttings collected around HRNA. Plants grown at this nursery were installed throughout HRNA, primarily on the northern and southern pastures (areas E and F) (Figure 3 and Appendix A). Two types of planting effort occurred: intense work where non-natives originally covered 100% of the area, and invasive species control in areas dominated by natives. Active weed removal and revegetation was conducted on the south side of area F where non-native tall fescue (*Festuca arundinacea*) dominated the area. Less than five years after restoration activities, an herbaceous wetland plant community was established including:

California blackberry (*Rubus ursinus*), salt grass (*Disticlus spicata*), creeping wild rye (*Leymus triticoides*), and spike rush (*Eleocharis machrostachya*).

On-going removal of non-native plants continues to date, using both restoration professionals and volunteers. However, active revegetation of native riparian plant communities has stopped in 2011 now that riparian vegetation appears to have been successfully reestablished (Sanger Hedrick, Jackie Worden, and David Hubbard, pers. comm.).

Wildlife surveys conducted periodically on HRNA by specialists and volunteers for over ten years during restoration activities have resulted in increasing trends in abundance and diversity of riparian bird species and special status bird species (FSCR in preparation – funded by the Trustee Council). Bird surveys were completed in 2010 to evaluate the quality and extent of riparian revegetation efforts on HRNA (Western Foundation of Vertebrate Zoology 2010). Seventy bird species were observed on the HRNA between 25 April, 25 and June 24, 2010. The Western Foundation of Vertebrate Zoology (WFVF) conducted a 10 point count around the HRNA property during the breeding season and found 20 pairs of the Federally endangered Least Bell's Vireo (*Vireo bellii pusillus*). A focused survey conducted during the 2010 breeding season found 70 pairs of Least Bell's Vireo on HRNA and surrounding areas (Sandy Hedrick, pers. comm.). Bird, butterfly and other wildlife were surveyed in 2011 by the Western Foundation of Vertebrate Zoology and others. Preliminary results of 2011 surveys report that on two occasions during the 2011 breading season, the Federally Endangered Southwestern Willow Flycatchers (*Empidonax traillii extimus*) were observed. Occurrences during the breading season are a good indication that these species are nesting in or near HRNA. The first occurrence on HRNA of a Yellow-billed Cuckoo (*Coccyzus americanus*), a Federal Candidate Species, was observed early July 2011 by the Western Foundation of Vertebrate Zoology.

Trends in bird species composition and special status bird species observations indicate over time restoration activities have encouraged a healthy mix of riparian and wetland habitats on HRNA. Bird species composition, diversity, and densities are dynamic and will change with vegetation succession due to varying plant species and structural composition. Restoration activities have created a mix of vegetation types with differing age classes depending on location relative to the low-flow channel and channel bed. The restoration of natural, dynamic physical and biological processes should provide more opportunities for birds and other wildlife to benefit, if not directly, at least indirectly from restoration projects.

Other factors in combination with habitat restoration may contribute to recovery and expansion of some bird species. For example, the main reason for recovery of Least Bell's Vireo (*Vireo bellii pusillus*) on Santa Clara River (among several rivers) is thought to be the continual removal of the brood parasitic Brown-headed Cowbirds (*Molothrus ater*) (Jim Greaves, pers. comm.). Actions of Brown-headed Cowbirds (tossing eggs and/or chicks of hosts, and laying their own eggs in host nests) have contributed over many decades to low productivity among dozens of riparian and other bird species, resulting in significant population declines. Since instituting control of these bird species in 1990, seems to have reversed some of those declines. This reversal due to cowbird control, combined with restoration of riparian habitats conducive to sensitive and common species, has led to incremental increases of varying amounts for a couple dozen cowbird host species. Managers are gradually reducing period of trapping each year and carefully monitoring populations (i.e., this year only 2 months of trapping on HRNA). Only time will tell if habitat restoration alone (i.e., without active management of Brown-headed Cowbirds) can maintain sustainable populations of special status bird species like the Least Bell's Vireo.

Planting techniques for herbaceous plants and grasses installed around HRNA included the following (David Hubbard pers. comm. - http://coastalrestorationconsultants.com/):

- **Propagation of sedges, rushes and rhizomatous grasses:** Plastic kiddie pools (4 foot diameter x 1 foot deep) were filled with weed-free potting soil and rhizomes of the following species were collected on HRNA and planted in these (i.e., *Juncus mexicanus*, *Carex praegracilis*, *Distichlis spicata*, *Leymus triticoides*, etc...). These rhizomes were harvested from kiddie pools after a few months and transplanted to plug trays (50 or 72 plugs per tray). Plugs were ready to plant in 3 to 8 weeks depending on species and season.
- **Propagation of herbaceous plants and grasses from seed:** Seeds were sown in sterile soil in flats (18 inches x 18 inches). Seedlings (typically with four or more leaves) were transplanted into plug trays after 2 or 3 months. Plant plugs were ready to plant in 8 to 12 weeks depending on the species and season.
- **Planting techniques:** Careful weed control was done before planting any area. In moist soil, holes were created using a 6-foot bar with a conical end for before planting the native plant plugs. Plant plugs were installed by pushing them firmly into the planting holes and refilling the remainder of the

holes. Spacing between plants was approximately 18 to 24 inches. Two workers could plant 1,000 plants in a morning. All plants were planted in the morning when temperatures were coolest.

- **Irrigation:** Irrigation was not used for most of the wetland plantings.
- **Timing of planting:**
  - Non-native tall fescue and Bermuda grass (*Cynodon dactylon*) were left in place after herbicide treatment was completed. Native plants installed appeared to benefit from the dead organic matter creating a thatch to reduce weed recruitment and maintain higher soil moisture.
  - Planting occurred year-round in areas with good soil moisture. The driest areas were planted in winter and the wettest areas in the fall.

Riparian Revegetation Constraints

There are several physical and biological constraints that must be considered when planning and siting riparian revegetation efforts. Although revegetation of natural riparian habitat will improve ecological conditions, we must recognize that watershed-wide impacts (such as infrastructure, surface and groundwater regulation for urban and agricultural uses, in-stream mining, and grazing) will preclude a complete return to pre-European conditions. Both geomorphology landform location and hydrology of a site may limit the possible invasive plant species removal and associated revegetation activities. Location relative to the food reset zone (channel bed and low-flow channel) should be considered. Due to large flood events that occur on the Santa Clara River every 5-10 years that are known to transport invasive non-native riparian plant species such as *Arundo*, a watershed removal approach is highly recommended. Local access to an infested site is another important criterion to assess in removal of invasive non-native plant populations. Site access by equipment and work crews as well as distance to water source for irrigation of planted native species may limit the type of removal and or revegetation that may be performed. In general, sites that are easier to access should be targeted first unless invasive non-native plant infestations are small and revegetation is either not necessary or can be implemented successfully without additional irrigation.

Regulatory Constraints

If the proposed restoration action (removal of invasive weeds and/or revegetation project) involves any mechanized earthwork or is part of a larger project, you must first apply for permits through the USACE, RWQCB, and CDFG. Compensatory mitigation (and 5 years of monitoring) is required to offset any impacts to USACE jurisdictional wetland and/or CDFG riparian habitat due to the proposed project. Refer to the following documents for information on regulatory permits and CEQA compliance required on a project by project basis (Ventura County Planning Division 2006b, Ventura County Resource Conservation District 2006, Stillwater Sciences 2008). Programmatic permits for these activities are not available yet. However, it is the intent of the Trustee Council to support efforts to develop these.

CHAPTER 3
RESULTS OF UCLA RIPARIAN FIELD EXPERIMENT
AND
HRNA REVEGETATION

Introduction

We established a field experiment in a riparian ecosystem of a floodplain terrace along the Santa Clara River to investigate survivorship, growth, and competition of three common native riparian plant species and the invasive non-native *Arundo*. Native riparian tree species studied included two trees, red willow (*Salix laevigata* - Bebb) and black cottonwood (*Populus* (L.) *balsamifera* ssp*. trichocarpa* - Torrey & A. Gray) and the shrub coyote brush (*Baccharis salicifolia* - Ruiz Lopez & Pavon). Data were collected on survivorship and growth metrics under various soil moisture, nutrient and light conditions of three native plant species commonly used for revegetation of riparian habitat in southern California. Chapter 3 presents experimental methods, results, discussion related to development of criteria for monitoring success of riparian revegetation projects along this River and other similar systems throughout southern California. The California Department of Fish and Game's standard Stream Alteration Agreement Conditions were reviewed and recommendations made for updating success criteria for growth (height) of these three species after 1 and 2 years under various environmental conditions. Additionally, this chapter reviews methods and results of sampling riparian tree seedling cohorts from the 2005 flood events conducted by restoration staff on the adjacent HRNA property.

Study Site Description

The UCLA Riparian Field Experiment was located on a private ranch on the south side of the Santa Clara River between Santa Paula and Fillmore, Ventura County, California (34.363635, -118.991171) (Figure 2)(Appendix A). Large riparian trees such as black cottonwood (*Populus balsamifera* ssp*. trichocarpa*) and red willow (*Salix laevigata*) once dominated the terrace in which the field experiment was established prior to its clearing for agriculture. A mixture of smaller trees and shrubs likely comprised the understory layer, including arroyo willow (*Salix lasiolepis* Benth.), mulefat (*Baccharis salicifolia*) and blue elderberry (*Sambucus mexicana* C. Presl.).

We collected data from the field experiment for two growing seasons, from December 2002 to December 2004. In October 2002, we began construction of the 0.5-hectare field experiment on a riparian terrace between agricultural fields and the river. Based on measurements of groundwater depth taken from a grid of borings throughout the experimental area, we found that shallow groundwater flowed in a southeast to northwest direction from the agricultural fields through the experiment toward the river. Rows (or blocks) of plant groupings within the field experiment were located roughly perpendicular to the direction of shallow groundwater flow to accommodate variance due to differing hydrology throughout the area (Figure 4).

Baseline soil grain size (soil texture) and nutrient status were determined in summer 2002, before construction of the experiment began, to help in final placement of experimental groupings and treatments. The western side of the experimental area was primarily composed of two horizons: a shallow horizon of sandy loam, silt loam, and loam (soil surface to 26–66 cm) and a deep horizon of fine sand and coarser sand below the top horizon (to 171–199 cm and deeper). The eastern side of the experiment contained mostly loam (and silt loam) in the top horizon (soil surface to 44–102 cm), loam and silt loam in a middle horizon (between 44–216 cm), and sand in the lowest horizon (below 138–216 cm). Soil moisture was consistently higher on the eastern versus the western side of the experiment due to soil grain size composition and microtopography (Figure 5).

We conducted baseline soil nutrient analyses on 18 soil samples collected systematically throughout the experiment from average plant rooting depth (0–30 cm). In spring 2003, pre-fertilization soil nutrient levels in the experimental study area [mean soil nitrate (5.2 ± 1.7 ppm) and phosphate (11.1 ± 1.1 ppm) levels] were comparable to concentrations found in soil along similar terrace landforms along the Santa Clara River. Average soil pH (7.69 ± 0.02) did not differ markedly throughout the experimental site and was similar to other terrace landforms along the River.

Study Species

We selected three native riparian plant species commonly found on terraces of rivers in southern California to use in the experiment: *Salix laevigata* (red willow) *Populus balsamifera* (black cottonwood) ssp*. trichocarpa*, and *Baccharis salicifolia* (mulefat). Additionally, three individuals of *Salix lasiolepis* (arroyo willow) were planted in the experiment accidentally and we opportunistically followed these as well. *Salix laevigata* is a riparian tree that can grow as tall as 15 m and is a member of the

Salicaceae. Dominant in both floodplains and terraces along rivers in southern California, *S. laevigata* can be identified by its dark, deeply furrowed bark on mature trees and lanceolate leaves, which are shiny on the top and glaucous beneath. Also a member of Salicaceae, *P. balsamifera* ssp. *trichocarpa* grows to a height of 30 m in alluvial plains along rivers in southern California. *Populus balsamifera* ssp. *trichocarpa* trees can be identified by their broad crown and bicolored ovate leaves with acute tips, which are dark green on the top and glaucous underneath (Faber and Holland 1992, Hickman 1993). *Baccharis salicifolia* is the dominant shrub found throughout floodplains and terraces of streams and rivers in southern California. A member of the Asteraceae, *B. salicifolia* usually grows to a height of less than 4 m. Its long linear to lanceolate leaves resemble willow leaves, but they typically have three principal veins that extend the entire length of the leaf and are coarsely serrated (Faber and Holland 1992, Hickman 1993). In addition, *B. salicifolia* shrubs produce a rounded panicle of white simple compound dioecious flowers.

Arundo donax is a robust, perennial, bamboo-like member of the Poaceae (grass) family that was introduced and is now widespread throughout the floodplains and terraces of rivers in California and other warm, temperate climates worldwide (Perdue 1958, Crampton 1974). It has erect stout (yet hollow) culms that are 1–4 cm thick and 2–8 m in height. Culms branch to form ramets, typically at the end of the first year of growth or after a culm is damaged. Leaf blades are broad (2–6 cm wide), less than 1 m long, flat, clasping at the base, strongly scabrous along their margins, and evenly spaced along the culm (Crampton 1974, Hickman 1993). *Arundo* reproduces vegetatively through a network of large, thick rhizomes that grow horizontally just below the ground surface. Under some conditions it produces a large (3–6 dm) terminal plume-like inflorescence (panicles) at the end of the growing season (Faber et al. 1989, Faber and Holland 1992, Hickman 1993).

Field Experiment Design

This field experiment was organized as a full factorial randomized block design to minimize variation due to heterogeneous soil and shallow groundwater conditions found within the site. A total of 288 plant groupings (four plants per square grouping) were organized in 12 blocks (rows) of 24 groupings each perpendicular to the general flow of shallow groundwater hydrology (Figure 4). Blocks of plant groupings were placed 4 m apart and plant groupings within blocks were placed 3 m apart. A total of 756 cuttings of riparian trees/shrub species (1 m long by approximately 2–3 cm in diameter) and 396 rhizomes of *Arundo* (200–400 g) were planted approximately 0.75 m apart in square configured groupings. Native riparian species cuttings were planted throughout the experimental area in December 2002, and *Arundo* rhizomes were planted in March 2003. Both native riparian plant cuttings and *Arundo* rhizomes were installed directly into the ground in designated groupings. Multiple levels of three resource treatments (and a competition treatment grouping) were applied randomly to plant groupings along rows before planting, including soil moisture (high and low), light (high and low), and nutrient additions (high, low, and none).

Cuttings of two native riparian tree species (red willow, *S. laevigata* and black cottonwood, *P. balsamifera* ssp*. trichocarpa*) and one native riparian shrub (mulefat, *Baccharis salicifolia*) were collected from riparian habitat adjacent to the field experiment. 1 m long cuttings were taken from only young branches or from younger trees/shrubs with buds to create poles approximately 1 m long by approximately 2–3 cm in diameter. All branches and leaves were clipped from the pole plant cuttings. Pole cuttings were soaked in water and rooting hormone for overnight. We created small holes for each riparian pole cutting at each of the experimental groupings using a T-bar. Before installation at experimental groupings, we removed buds from the top 1/3 of the pole cutting and left buds from the bottom 2/3 on the cutting to form roots in the ground. Removing buds from the above ground portion of the cutting was thought to encourage growth of a root system during the wet winter months and not expend energy on aboveground biomass production. Specifications for riparian plant cuttings described above were developed based on interviews with several native plant nurseries in southern California.

We planted species in three competition groupings (four-species, two-species and one-species monoculture groupings) in the experiment to compare interspecific versus intraspecific competitive interactions between *Arundo*, red willow, black cottonwood, and mulefat (Table 2). Four-species groupings consisted of one individual of each species placed at random within the square configuration. The two-species groupings consisted of two *Arundo* plants and two plants of a single native species. Like species were planted diagonally across from each other in the two-species groupings. One species-groupings, or monocultures, contained four plants of only one species per grouping.

In this experiment, the criterion for existence of an interspecific competitive interaction was evidence of significantly different biomass or height in four-species or two-species plant groupings compared to monocultures. If mean biomass or height of a species was lower when grown with another species compared to when grown in monoculture, an interspecific competitive interaction was considered present. An interspecific interaction was deemed positive (facilitation) when the mean biomass or height of a species was higher in either mixed species groupings compared to its biomass when grown in monoculture. A comparison of mean height between species and groupings is briefly presented in the results section below. Competition results for biomass are presented in Coffman (2007).

Two soil moisture treatments occurred naturally (Figure 5). The western half of the experiment had soils that contained more coarse grain soil and were better drained (referred to as low soil moisture). The eastern half of the experiment retained higher soil moisture throughout the year (high soil moisture). To simulate natural establishment conditions, we did not apply artificial irrigation and analysed data according to the two soil moisture treatments.

In spring 2003, we built shade structures over half of the experiment to simulate shading by a mature riparian canopy and test the effects of light availability. The two light treatments consisted of 80% shade (referred to as low light) and full sun with no shade structures (referred to as high light). We used 80% black shade cloth on six shade structures (total dimensions were 200 feet x 10 feet x 15 feet high) that were erected along rows in two large sections of the experiment to minimize the shade effect onto non-shaded rows. One section (three rows) was placed over the high soil moisture portion (northeast quadrant) and one section (three rows) was placed over the low soil moisture portion (southwest quadrant) (Figure 4).

We applied nutrient treatments to designated plant groupings twice a year: fertilized "high N" and "low N" treatments "no N" treatment control in which only water was added. Granular ammonium-nitrate fertilizer (N-P-K, 34-0-0) was used as the source of added nitrogen and was mixed with 2 gallons of water before application. High nitrogen treatments (100 g N/m^2/year or 56 g N/plant/year or 2 oz. N/plant/year) were added to one-third of the plant groupings to simulate row crop fertilization levels adjacent to riparian areas. Low nitrogen treatments (40 g N/m^2/year or 23 g N/plant/year or 0.8 oz. N/plant/year) were added to one-third of the plant groupings to simulate orchard fertilization levels adjacent to riparian areas. We applied half of the nutrient treatments at the beginning of the growing season and the remainder at the peak of the growing season. According to interviews with local ranchers, quantities and timing of fertilization application was similar to that used in agricultural practices in the area. Each plant in the no fertilizer treatment received 2 gallons of water at each of the two application periods.

Sampling Methods

We monitored soil moisture to characterize the soil water content throughout the experimental site using 14 soil moisture probes (20 cm ECH_2O Dielectric Aquameter sensors by Decagon Devices, Inc.), which were installed systematically throughout the experiment in the summer of 2004 (Figure 4). We placed 10 soil moisture probes in a soil horizon approximately 60–80 cm from the soil surface, a depth which is roughly in the middle of the root system for most plants. The other four probes were placed in a shallower soil horizon (from 30–50 cm) to measure soil moisture in the area in which the cuttings were initially planted. We measured soil moisture content of these probes weekly from July 2004 to September 2005 to understand variability within the experiment and establish the two soil moisture treatments.

Annual mean soil moisture content at 60–80 cm below ground surface on the eastern side (mean ± SE = 38.5% ± 0.5) of the experiment was significantly higher than on the western side (33.2% ± 1.0) during the 2004–2005 water year (one-way analysis of variance results: $F_{(1,383)} = 23.583$; $P < 0.001$). The shallower soil horizon (30–50 cm below the ground surface), in which cuttings were established, exhibited a similar trend; soil moisture was 42.1% ± 0.4 on the eastern side and 37.8% ± 0.5 on the western side (one-way analysis of variance results: $F_{(1,166)} = 47.686$; $P < 0.001$). Mean soil moisture content fluctuated throughout the year but was consistently higher on the eastern side than the western side (Figure 5). Although soil moisture probes were not installed until the end of the second growing season (Summer 2004), trends observed during 2004-2005 were likely similar or more pronounced in 2003-2004 due to lower total annual precipitation in this water year. Thus, the eastern side was designated as the high soil moisture treatment and the western side as the low soil moisture treatment.

Survivorship

We measured plant survivorship at three time periods: 1) survivorship of planted cuttings in March 2003, 2) plant survivorship at the end of 2003 growing season (September-November), and 3) plant survivorship at the end of 2004 (September-November). A few cuttings (14) and rhizomes (9) that did not emerge initially during March 2003 surveys were replanted in April 2003. Percent survivorship results reported for end of growing season 2003 and 2004 represent the establishment success for all initial and replacement cuttings.

Growth

Growth characteristics were measured for all four species during both the 2003 and 2004 growing seasons (beginning and end of each growing season – March and September-November). Growth metrics included: maximum height of plant, average width of aboveground biomass of individual plants (based on two measurements), marked branch elongation (3 marked branches per individual plant), number of branches/*Arundo* culms, riparian plant cutting height, and average riparian plant cutting diameter (based on 3 measurements). Cutting diameters were measured at 10cm from the ground surface, middle of the cutting and 3cm from the top of the cutting. In addition, the basal area of *Arundo* at each planting was measured by taking an average of two perpendicular widths. We present only the total height metric in this chapter since it compares directly with success criteria established by the CDFG.

Biomass

The aboveground biomass of all plants in the field experiment was estimated over the two-year study period (2003 to 2004). We used non-destructive dimensional analyses to estimate aboveground biomass dry weight of plants in the experiment so that we would interfere as little as possible with plant growth and other measurements taken throughout the course of the study period (Whittaker 1961, 1965, Whittaker and Marks 1975, Sharifi et al. 1982, Spencer et al. 2006).
Refer to Coffman (2007) for detailed methods for biomass sampling and analyses.

Statistical Analyses

Descriptive statistics (mean ± SE) were performed on soil moisture, plant survivorship, and height measurements (Systat Statistical Program [Version 15]). We conducted one-way ANOVAs on soil moisture content to validate high and low soil moisture treatments and establishment of plant species between the first and second growing season, with Tukey's post-hoc test for pair-wise comparisons of means.

The experiment was organized in a full multifactorial design in which combinations of four fixed factors (Model 1) were crossed with each other. Four-way analysis of variance (ANOVA) tests were used to analyze effects of various combinations of four factors (independent variables) on height data collected in March 2003 and at the end of the each growing season (dependent or response variables) (Systat Statistical Program [Version 13]). The four independent variables analysed were plant species, soil moisture, light, and nutrient addition treatments. Data were analyzed for main effects of individual factors and interactions between factors. ANOVA F-tests were performed to evaluate a priori contrasts between means of grouping variables and levels in multifactor ANOVA results. Probability plots were examined to test for normality of data and to identify any data that required transformation. Because soil moisture, percent survivorship, and height data were normally distributed, data transformation was unnecessary.

Percent survivorship measured at the end of 2003 and 2004 was compared in a two-way ANOVA (year x plant species) since this was the only significant effect found in the four-way ANOVA performed. In addition, we conducted a two-way ANOVA (year x plant species) on mean heights of three native riparian plants and *Arundo* for both year 1 (2003) and year 2 (2004) to understand general differences in height among species and between years after planting. Three-way ANOVAs (year x soil moisture x light) were performed on plant height data for all individuals grown in the experiment to determine treatment effects of each factor over time. A three-way ANOVA (year x competition grouping x species) was performed on plant height data to analyze treatment effects of the three competition treatments for between species and between the end of the first (year 1 = 2003) and second (year 2 = 2004) growing seasons. Graphs were created of the most significant findings for ease of interpretation. Tables are included to present statistical findings of ANOVAs.

UCLA Riparian Field Experiment Results

Survivorship by species grown under various environmental conditions

Plant establishment success between installation in winter 2002–2003 and the end of the growing season in 2004 was very high for all species. Cutting survivorship in spring 2003 was 97.7% for all individuals planted. Total plant survivorship at the end of 2003 and 2004 was 98.4% and 97.8%, respectively.

The four-way ANOVA (species x soil moisture x nutrients x light) for percent survivorship yielded no significant main effects or interactions for cuttings and plants at the end of the 2004 growing season (Table 3). Only one significant interaction was found between species and soil moisture for plant survivorship at the end of 2003 growing season. Soil moisture, nutrient, and light treatments had no significant effect by themselves on *Arundo*, *S. laevigata*, or *B. salicifolia* survivorship (Table 3). However, establishment success of *P. balsamifera* ssp. *trichocarpa* at the end of the first growing season (2003) was significantly lower within the high soil moisture treatment than in any other species and soil moisture treatment combination (Figure 6).

Percent survivorship did not decrease significantly during the two-year establishment period ($F_{(1,158)} = 0.485$; $P = 0.487$). Therefore, we considered plants fully established by the end of the first growing season (2003). Only five plants (0.8% of plants in groupings analyzed) did not survive the second growing season.

<u>Growth metrics by species grown under various environmental conditions</u>

Mean height was the only growth metric analysed and presented in this handbook due to timing and funding limitations. We recommend analysing mean cutting diameter and volume for all three riparian plant species in the experiment in the same manner to inform development of success criteria. Results of the three-way ANOVA (year x competition grouping x species) performed on plant height data were not significant for the three way interaction. Therefore, we did not use competition as a factor in our presentation of data.

The two-way ANOVA (species x year) for plant height resulted in very highly significant main effects (species - $F_{(3,2250)} = 379.709$); $P \leq 0.001$; year - $F_{(1,2250)} = 917.356$; $P < 0.001$) and two-way interaction ($F_{(3,2250)} = 16.839$; $P \leq 0.001$). Mean height of all species was significantly greater after the second growing season than the first for black cottonwood (45%), red willow (46%), mulefat (32%), and *Arundo* (43%) (Figure 7 and Table 5). After the first growing season, mean height of mulefat was significantly greater than both black cottonwood and red willow (the height of the latter two did not differ significantly). At the end of the second growing season, riparian plant species did not differ significantly in mean height. However, *Arundo* was significantly taller than all native plant species at the end of year 1 and 2.

The three-way ANOVAs (light x soil moisture x year) for cottonwood ($F_{(1,472)} = 20.135$; $P \leq 0.001$) and willow ($F_{(1,489)} = 15.672$; $P \leq 0.001$) were significant. Four bar graphs (Figures 8 – 11) present a comparison of mean heights of each species (1 graph per species) grown in various combinations of soil moisture and light levels at the end of year 1 and 2 growing seasons. Letters above bars indicated results of post-hoc comparison of means tests between all treatments (with significance recognized at $\alpha < 0.05$).

HRNA Passive Riparian Revegetation Monitoring Methods & Results

In January and February 2005, floods overtopped the banks of the Santa Clara River and nearby Balcom Canyon Ditch and deposited soil on top of HRNA areas E and F. When floodwaters receded they left not only soil but seeds and vegetative propagules in these areas. HRNA restoration staff measured height and dbh of riparian tree and shrub seedling cohorts in March 2007 (2 years later) and November 2010 (5 ½ years later) (Coastal Restoration Consultants 2010). Height was recorded to the nearest meter and dbh to the nearest mm. Five line intercept transects were laid from north to south across the Area E and F to sampling vegetation throughout the area. The closest riparian tree or shrub found within the nearest meter was sampled at each five meter point along all transects.

Total number of individuals measured included: 17 black cottonwood, 4 sandbar willow (*Salix exigua*), 155 arroyo willow (*Salix lasiolepis*), 5 red willow, and 11 shining willow (*Salix lucida*) in March 2007; and 141 arroyo willow, 38 red willow, and 17 shining willow in November 2011. All species had a similar mean height after 2 years, but shining willow mean height was greater than either arroyo willow or red willow (Figure 12a). Mean height ranged between 10.8 – 13.8 feet in year 2 and 19.4 and 24.9 feet in year 5 ½. Diameter breast height was similar for all five species after 2 years (0.6 – 0.9 inch) (Figure 12b). However, shining willow (5.3 inches) had a much larger dbh than arroyo willow (3.1 inches) or red willow (4.7 inches) after 5 ½ years.

Discussion

Results of these our field experiment and monitoring of HRNA riparian tree seedling cohorts can provide valuable ecological data on riparian species survivorship and growth related to revegetation. Observations of revegetation techniques and monitoring of passive and active restoration activities on HRNA (Chapter 3) can provide valuable insight into future restoration actions on the Santa Clara River. The following are our recommendations for use of these data and observations:

<u>UCLA Riparian Field Experiment – Survivorship and Growth</u>

- Year 1 and 2 data collected at the UCLA Riparian Field Experiment can be used to improving success criteria for growth metrics for riparian plant species used in revegetation (Success Criterion D presented in Chapter 5). Also, these data can help inform minimum height requirements for the CDFG Stream Alteration Agreements for the Santa Clara River and similar rivers in southern California (Table 4). Figure 7 presents mean height (in feet) data for black cottonwood, red willow, and mulefat after the first and second growing seasons. Mean heights were pretty similar for all species within years and do not reflect the true variability found when grown in differing soil moisture and light conditions. Mean heights ranged from 7.26 to 8.32 ft after the first growing season and from 10.54 to 10.97 after the second growing season.

- Environmental site conditions, especially soil moisture and light availability greatly affect height of native riparian species and likely other growth metrics. A more detailed analysis of each native riparian species shows that a wide range of heights is attained under varying soil moisture and light conditions at the field experiment, especially after the second growing season (Figures 7 – 10 and Table 5). For example, black cottonwood mean height is significantly lower (6.0 ft ± 0.2) in low light and low soil moisture than the average (7.26 ft ± 0.12) after one year, yet significantly higher when grown under high light and soil moisture conditions (13.7 ft ± 0.5) than the average (10.54 ft ± 0.21) after two years. If black cottonwood cuttings are planted on a terrace landform within an already established forest along the Santa Clara River with low soil moisture, they will most likely not attain the minimum mean height success criteria if set using an average. We suggest that minimum heights for riparian tree and shrub success criteria must be set for all four conditions, not just an overall average. Creating detailed success criteria for many conditions can be done by establishing and sampling a field experiment like the UCLA Riparian Field Experiment and/or reference sites throughout the Santa Clara River exhibiting the variety of soil moisture and light conditions found.
- Data collection in summer 2012 at the UCLA Riparian Field Experiment could be used to set 10 year monitoring targets. In summer 2012, the riparian trees and shrubs in the experiment will be 10 years old. We recommend that this experiment be resampled to provide data to improve success criteria and performance metrics presented in Chapter 5, especially for Success Criteria D (Survivorship, Health and Growth of Riparian Plantings).

<u>HRNA Riparian Tree and Shrub Seedling Cohort Monitoring</u>

- Measuring height and dbh of riparian tree and seedling cohorts over time (year 2 and 5.5) created a mean (and range) target for success criteria based on known ages of 5 common riparian trees/shrubs found along the Santa Clara River. The current CDFG success criteria (in the Stream Alteration Agreement that we reviewed) for minimum height of arroyo willow and red willow are both 15 ft. Mean height of arroyo willow on HRNA was 19.4 ft (± 5.9 SD) and red willow was 23 ft (± 5.2 SD). These data suggests that minimum height requirement after 5 years growth for an area with similar soil moisture on a terrace landform could be 13.4 ft (mean – 1 standard deviation) for arroyo willow and 17.8 ft (mean – 1 standard deviation) for red willow.

- The CDFG success criteria for minimum height targets do not include shining willow which was found to have a mean height of 24.9 ft (± 4.8 SD) after growing 5.5 years on HRNA. 20.1 ft (mean - 1 standard deviation) could be used as a minimum height target for shining willow.
- We could not find a success criterion for dbh in the CDFG Stream Alteration Agreement we reviewed. We recommend using the average diameter of cutting (like the measurements we collected at the field experiment) for developing year 1 and 2 success criteria. For years 5 and 10 success criteria, we recommend using dbh of the tree or shrub.
- Areas E and F on HRNA should be used as a reference site to create a restoration trajectory for these height and dbh metrics and others (Success Criterion D: Survivorship, Health and Growth of Riparian Plantings). Height and dbh should be measured at 10 years to inform these metrics. Caution must be taken when using these data to develop targets for success criteria and performance metrics – these measurements can only be compared to plants grown from seed (container plants).

<u>HRNA Lessons Learned</u>

The following recommendations or lessons learned were compiled from our restoration work on HRNA since 1997 and interviews with FSCR and HRNA restoration staff (Sanger Hedrick, Dave Hubbard, and Jackie Worden, pers. comm.).

- **Non-native plant removal and riparian revegetation lessons learned:**
    - Clear goals and objectives must be established at the beginning of the restoration project.
    - Restoration approaches must be adapted if site conditions change.
    - Experiment with methods.
    - Methods and techniques can be optimized by learning about what works on your site and altering the approach accordingly.
    - Invasive plants and non-native weeds should be controlled if possible before planting for optimal revegetation success.

- Long project timelines (5-10 years) allows for greater efficiency and effectiveness of implementing restoration actions.
- Irrigation is not needed for establishment of riparian and wetland species in native soils with good relatively high moisture.
- Plants should be installed only in the winter after rains have thoroughly soaked the soil if irrigation is not used.
- Fertilizer is not needed to establish native plants. In fact, fertilizing encourages invasive plant and non-native weed growth.
- Battery operated drills with 1 inch auger heads can be very effective at creating holes for cutting placement in clay soils.

➢ **Photo monitoring lessons learned:**

- Photo monitoring points should be taken before and after both passive/active revegetation (see Appendix B for photo monitoring example at HRNA).
- Photo monitoring station descriptions must be very detailed and clear for relocation of these stations. Including landmarks in photos is helpful for relocation of stations.
- GPS locations and compass direction of photo must be recorded for each photo monitoring station.
- The biggest challenge in photo monitoring at HRNA was that the background views became blocked by vegetation in the foreground. Siting photo monitoring station at vantage points above the site or across water/sand/road is helpful in positioning stations.

➢ **Vegetation monitoring protocol lessons learned:**

- Randomly placed line intercept transects can be sampled throughout systematic zones of a restoration area to get a broad understanding of success of restoration actions over an entire site (i.e., percent cover of native vs. non-native plants).
- More specific vegetation monitoring protocol must be developed to evaluate the success of each project objective (see Chapter 5).

- Permanent plots must be established to track individual plant survivorship. It was estimated from anywhere between 50-95% (90% on average) for HRNA. But without sampling permanent plots, we cannot evaluate survivorship of plants installed during active revegetation relative to this success criterion.
- Opportunistically measuring riparian tree and shrub seedling cohorts after a flood event can provide valuable data for improving success criteria and establishing reference sites for the Santa Clara River.

CHAPTER 4
SITING AND TIMING OF INVASIVE PLANT REMOVAL, REVEGETATION, MONITORING, AND MAINTENANCE

Both locating priority sites for *Arundo* removal and riparian revegetation after removal as well as implementation timing of both these restoration actions are crucial to their success. Results of competition between *Arundo* and three native riparian plants measured in the UCLA Riparian Field Experiment, fire studies, and observation while working on the Santa Clara River from 1997-present have been used to formulate five conceptual siting and timing strategies for *Arundo* removal (Coffman 2007, Coffman et al. 2010). In addition, preferred methods for removal of *Arundo* and other CalIPC high ranking species removal are summarized. Timing of *Arundo* removal, revegetation, monitoring and maintenance is presented on Table 6.

Prioritization of *Arundo donax* Removal and Riparian Revegetation after Removal

Millions of dollars have been spent to remove *Arundo* infestations of riparian ecosystems throughout California (Katagi et al. 2002). Due to the lack of understanding of *Arundo* ecology, however, decisions regarding prioritization of removal areas and removal techniques often have to be made in the absence of sufficient scientific information. After analyzing research results (Coffman 2007) and the current body of literature available on *Arundo*, we propose the following management strategies, which incorporate the most current understanding of the *Arundo* invasion process, to most effectively and efficiently address this problem. We recommend that *Arundo* control efforts should be placed where ecological benefits are the greatest and associated removal effort the lowest (see priorities for the Santa Clara River below).

Currently, the preferred methods of *Arundo* removal in Southern California are called the bend-and-spray or hook methods, both which imitate nature. Alternatively, the cut-stump method can be used in areas where *Arundo* stems cannot be bent. Where *Arundo* is removed near the edge of streams, caution must be used so as not to allow any pieces of *Arundo* to fall in or near intermittent or perennial streams. Timing of *Arundo* stem spraying and removal is extremely important. Late summer through early fall (August to October) is the most effective time of year to treat *Arundo*. However, follow up spraying of resprouts must be done on an annual basis once resprouts are approximately three feet tall.

Due to the height of *Arundo* (up to 20 feet tall) and typical interspersion with surrounding native vegetation, sensitive species, and/or water, the bend-and-spray or hook methods have proven effective for remotely located small to moderately sized infestations (Newhouser 2008). The bend-and-spray or hook method maximizes coverage of herbicide on *Arundo* stems, allows for sufficient translocation of the herbicide to the rhizomes by bending and spraying the *Arundo* stems, and minimizes residual spraying of non-target native species. Using the bend-and-spray method, a worker bends the *Arundo* stems away from the native vegetation and the applicator sprays the culm (or stems) with an approved herbicide. The person preparing the *Arundo* for herbicide spraying grasps the stems between stem nodes with two hands and bends or snaps the stem so that it splits longitudinally without breaking off. If done properly, over 90% of the bent stems will remain intact. *Arundo donax* stems must be living to translocate herbicide to their rhizomes and kill the plant. Thus, the nodes should not be bent as they tend to break off completely. Next, a fan shape should be created with the bent canes on the ground. With a crew of two or three workers to bend the *Arundo* stems and one applicator, the removal team can rotate between three or four clumps of *Arundo* at a time. This should kill most of the biomass within approximately 2 months. Then all dead *Arundo* biomass must be mulched on-site and/or carried off site to ensure that it does not spread during flood events or create a fire hazard.

The hook method allows the applicator to work solo, working the hook with left hand (between pumping) and spraying with the right hand. Using a hook, the worker gathers up to 10 *Arundo* stems to concentrate them for quicker application. This method uses the least amount of herbicide and has the least potential to overspray and risk of non-target plant species damage. The hook resembles a swimming pool rescue hook (8 foot wooden pole with an 18 inch PVC hook with and an additional side hook on top). It was designed to reach up and pull *Arundo* stems down away from desirable vegetation to spray them. The hook is very useful in reaching the center of small patches of *Arundo*. When employing the hook technique, the worker inserts the hook vertically into the upright canes and then turns the hook horizontally to grab approximately 10 canes. The next step is to pull the stems towards you while stepping back and sliding the hook up the canes. As you slide the hook up the stems, the *Arundo* stems will bend toward you and you will be able to spray the full length of the cluster of stems in the hook.

Planning a bending route is recommended so that it is easier to work your way methodically through the clump. Neither the ben-and-spray nor the cut-stump methods are recommended for large infestations of *Arundo*.

Alternatively, the cut-stump method may be used in remote areas where *Arundo* stems cannot be bent or in situations where a foliar spray application poses a significant risk to aquatic species, desirable vegetation, and other non-target species. In addition, use of this method may be desirable where standing dead *Arundo* poses a significant fire hazard or when conducting a follow-up treatment on a small amount of regrowth. Using cut-stump method, *Arundo* stems are cut approximately one foot from the ground with a chainsaw, lopper, or machete. The stem stump is then immediately painted with herbicide (must be painted with herbicide within 1 minute of cutting to be effective). Dye should be added to the herbicide to mark treated stumps and ensure full coverage. All cut *Arundo* biomass must be mulched on-site and/or carried off site to ensure that it does not spread in a flood.

The following five priorities were developed upon analysis of *Arundo* studies that looked at contribution of wildfire, soil moisture, nutrients and light as well as other literature on *Arundo* ecology (Coffman 2007). We recommend that *Arundo* control efforts be placed where ecological benefits are the greatest and associated removal effort the lowest as follows.

Priority 1. Remove Arundo under mature riparian forests, especially adjacent to fire-prone shrublands

The highest priority location for *Arundo* removal is within mature riparian forests adjacent to coastal Southern California shrublands (chaparral and coastal sage scrub) and grassland. Recent research conducted throughout the Santa Clara River (Coffman 2007) suggests that *Arundo* removal in mature riparian forests would create the greatest environmental benefit, because these areas have the highest risk of further damage if removal is not conducted (i.e., increased fire hazard) and threat of reinfestation is lowest (i.e., where removal effort is long-lasting). *Arundo donax* may reinfest areas that are flooded occasionally but not completely scoured (e.g., higher terraces), especially where water and nutrient levels are high. In these locations, mature riparian forests may facilitate invasion by physically trapping propagules stranded by flooding (Dudley pers. comm.). Coffman (2007) showed that *Arundo* grows more rapidly under high light conditions than under low light conditions when high water and nutrient levels are present. Also, field observations reveal that the understory of mature riparian forests can be invaded by *Arundo* after large floods, however the invasion trajectory may be protracted due to the effect of canopy shading. When these mature riparian forests become heavily invaded, areas near fire-prone shrublands are highly susceptible to fire. The large, dry biomass produced by *Arundo* in these areas carries fires (i.e., ladder effect) through canopies of these once-natural firebreaks, burning across and along river systems. *Arundo* in mature riparian forests should be targeted for high priority removal due to the threat of an invasive plant-fire cycle and the lasting damage caused – risk of the complete loss of mature riparian forests on the Santa Clara River.

Priority 2. Remove the largest Arundo propagule source

Another high priority for *Arundo* removal high we recommend is to target areas containing the largest source of propagules. Removing these should help to curtail the distribution of *Arundo*, thereby working to control it in the initial phase of the invasion process. Due to its clonal growth form, dominant asexual reproduction, and flood-driven dispersal mechanisms, the largest *Arundo* infestations will produce the highest quantity of vegetative propagules (all pieces of stalk or rhizome regardless of size). Coffman (2007) suggested that the largest infestations are most prevalent in riparian ecosystems found within highly urbanized watersheds, located adjacent to agricultural and residential land uses, and in areas that have burned in southern California, the Western Cape region of South Africa, and other Mediterranean climate regions. Furthermore, large infestations in areas most frequently scoured by winter flooding contain the largest potential source of propagules.

Prioritization of removal in riparian ecosystems with the lowest likelihood of reinfestation has been suggested (i.e., areas outside the flood zone) (Coffman et al. 2004). In general, their findings suggest that *Arundo* is least likely to invade open substrates or recently scoured areas in which resources levels are low (i.e., low soil moisture and nutrient availability) and where native plants have established at the same time. Further investigation of the relationship between frequency of rhizome establishment and *Arundo* abundance in various locations, after flood events, is necessary to validate this recommendation. Riparian ecosystems downstream of large propagule sources along active floodplains are most likely to be reinfested and removal in these areas should be given lowest priority. Results of Coffman's studies (2007) suggest that *Arundo* is most likely to invade open (i.e., very low native vegetation cover) or recently scoured areas in which resources levels are high (i.e., high soil moisture and nutrient availability). These areas often are found next to agricultural land uses and areas exposed to wastewater treatment discharge from residential land use (Neely and Baker 1989).

Many *Arundo* removal projects to date have focused on large infestations. However, removing large propagule sources with active floodplains with high resource levels should not be prioritized because ecological benefits are low and associated removal efforts are high. Natural biological and physical processes in riparian ecosystems that are heavily invaded by *Arundo* are usually already degraded. Although removal efforts may slightly reduce propagule abundance, net ecological benefits from removing *Arundo* from heavily invaded riparian areas may be much lower than from areas less invaded. Coffman (2007) suggests that removal of *Arundo* in locations within riparian forests adjacent to fire-prone shrublands, watersheds with low nutrient inputs, and watersheds with little *Arundo* abundance will result in the greatest ecological benefit. Furthermore, a considerable amount of money and effort is involved in removal of large infestations.

<u>Priority 3. Control Arundo on a watershed scale</u>

We suggest several watershed scale *Arundo* control strategies, given the natural dynamic flood regime in streams of Mediterranean-type climate regions and the widespread anthropogenic resource inputs that are not easily corrected. *Arundo donax* should be removed from low nutrient input watersheds where infestations are small or area of infestation is localized; the highest probability of eradication success at the lowest cost is possible in these locations. However, watershed-scale long-term control of *Arundo* in natural riparian ecosystems may require management of resource levels that promote invasion to reduce growth and competition. Manipulation of resource availability in favor of a given native (desired) species has been proposed to create a competitive advantage and a barrier to reinvasion (Blumenthal et al. 2003, Corbin and D'Antonio 2004, Suding et al. 2004, Prober et al. 2005, Perry and Galatowitsch 2006). Results of Coffman's studies (2007) suggest that reduction of nutrient inputs in urbanized watersheds may slow invasion of *Arundo* but likely will not, alone, prevent its eventual spread. Several researchers suggest that *Arundo* should be removed from the most frequently inundated floodplains only using a top-down directional approach, beginning in the upper reaches of the watershed and moving downstream (Bell 1997, Coffman et al. 2004). Removal of *Arundo* on higher terraces may not necessarily need to proceed in this downstream manner because reinfestation is much less likely. However, one study suggests that layering (i.e., rooting from nodes) is an important *Arundo* invasion mechanism in streams of southern California and, thus, an inside-out approach is required (Boland 2006). An inside-out approach means removing *Arundo* from the low flow channel to the banks of rivers and streams.

Both approaches are necessary depending on the flood dynamics of the reach of the river reach or stream, infestation size and distribution, and fluvial geomorphic location of the infestation. In the flood reset zone (or floodplain) of the main stem of the Santa Clara River where resource levels and flood frequencies are high, *Arundo* should be removed in a top-down manner.

<u>Priority 4. Removal of Arundo immediately after fires or floods</u>

Because removal of large areas of *Arundo* is very costly, the ideal time to remove it from a heavily infested watershed is immediately after a very large flood (i.e., 100-year flood) or wildfire event that removes most of the vegetation, resulting in much easier access to much reduced quantities of *Arundo* biomass. During this time, the impacts to special status species (i.e., Least Bell's Vireo, Southwestern Willow

Flycatcher) are low or absent. Removal of the rhizome is necessary to completely kill *Arundo* after floods, but is relatively easy to dig out in the first few weeks after flooding when biomass is low (Sanger Hedrick, pers. comm.). We found that after wildfires burned through large *Arundo* infestations (i.e., on the Santa Clara River), one herbicide treatments increased *Arundo* density less than one year after treatment (Coffman unpublished data). Therefore, we recommend that either multiple herbicide treatments (during the first 3 or until completely killed) be applied *Arundo* resprouts after burned or that the rhizomes are removed completely if feasible.

In order to prepare adequately for *Arundo* removal opportunities immediately after floods or fires, a contingency fund should be set up for this work. The timing of these events are unpredictable and do not easily fit into typical funding schedules. In lieu fee programs in California in which mitigation funds are accumulated have been set up in other watersheds and may be an effective strategy.

Priority 5. Revegetation after removal may not help resist or suppress Arundo

The management literature recommends revegetation of riparian systems with native species after removal of invasive species, including *Arundo*, to resist further invasion (Sonoma Ecology Center 1999, Ventura County Planning Division 2006a). Resistance to invasion may be achieved if natives obtain a much higher biomass than *Arundo* and suppress it when competing for resources. However, results of our two-year competition field experiment suggest that this is rarely the case; *Arundo* had a significantly higher biomass than almost all native plant species under all resource levels (Coffman 2007). Only minimal suppression by native plants was documented under a few conditions tested. Results of this competition field experiment indicate that *B. salicifolia* may increase in biomass when grown with *Arundo*, although it never obtained a significantly higher biomass than Arundo under any conditions. Longer studies are needed to validate these findings, although it appears that revegetation will not resist reinvasion without implementation of appropriate *Arundo* removal and maintenance. However, active revegetation after *Arundo* removal should help initiate restoration of riparian ecosystem functioning if *Arundo* removal is conducted in the appropriate location (see Priorities 1-4) and diligent maintenance is implemented for the first 3 years or until the *Arundo* is completely removed from the site.

Selection of active versus passive revegetation treatments for invasive plant removal sites depends on several factors: invasive plant species life history/invasion process; location relative to floodplain and terrace landforms; location in landscape/watershed; quantity of soil moisture, nutrients, shade; and wildfire potential. In the initial planning stages, the life history of each non-native, invasive species located on the removal site and each native riparian species used in revegetation must be understood thoroughly to insure success and sustainability of removal and revegetation.

Removal Strategies for other CalIPC High Ranking Species

Four non-native invasive species with CalIPC high ratings were found in more limited distribution than *Arundo* within the Santa Clara River 500-year floodplain, including: perennial pepperweed (*Lepidium latifolium*), creeping water- primrose (*Ludwigia peploides* ssp. *montevidensis*), smallflower tamarisk (*Tamarix parviflora*), and salt cedar (*Tamarix ramosissima*). The locations, approximate distribution and extent, life history, invasion process and removal strategies are summarized for each below (see http://www.calflora.org/ and http://calphotos.berkeley.edu/for photos of these plants).

Perennial pepperweed (Lepidium latifolium)

During the 2005 vegetation mapping surveys, only one population of perennial pepperweed (*Lepidium latifolium*) was found within the 500-year floodplain (Stillwater Sciences and URS Corporation 2007). This population occurs on an upper floodplain terrace of the Hedrick Ranch Nature Area (HRNA) at approximately 34.362163, -118.999187 (Stillwater Sciences and URS Corporation 2007). The Friends of the Santa Clara River have been actively controlling this *L. latifolium* population since its identification during vegetation surveys conducted in 2002 on the property (URS Corporation 2003). The population remains small (approximately < 0.05 acres) but has not yet been completely eradicated. Other small populations such as this may exist along the Santa Clara River.

Perennial pepperweed is an herbaceous member of the Mustard Family (Brassicaceae) that reproduces by many small seeds it produces and vegetatively via a rhizome (http://www.cal-ipc.org/ip/management/ipcw/pages/detailreport.cfm@usernumber=58&surveynumber=182.php). It reaches heights of 4-8 feet at maturity. Leathery, ovate to oblong leaves are both basal and cauline. Many small, white flowers (and seeds 0.8-1.2mm) are produced on a panicle inflorescence in late May through early July. Seedlings have small, bright green cotyledons typical of annual mustards and are difficult to differentiate from other invasive members of the mustard family.

Native to southeastern Europe and western Asia, it invades many disturbed areas near water courses throughout California below 2,500m including: wet pastures, fields, grassland, saline meadows, canals, agricultural ditches, streambanks, and the edge of marshes. The mechanisms of its successful invasion include reproduction via seed and root propagules and its ability to withstand flooding for long periods and saline conditions once established. The plants form large spreading clones under most moist conditions. Perennial pepperweed appears to successfully compete with other plant species for moisture, nutrients, and light.

Mechanical control and mowing of this species has been unsuccessful, since it can resprout from very small fragments (smaller than 3cm). Perennial pepperweed does not appear to survive lengthy periods of flooding during the growing season or high salinity levels (Young et al. 1997). Control of perennial pepperweed by grazing is not recommended since herbivores will only feed on the young leaves and, furthermore it is poisonous to many herbivores (Young et al. 1997). Biological Control methods are not an option due to safety considerations for host-specificity; there are too many valuable crop species in this family. Many herbicide treatments have been document to effectively kill the aerial portions of perennial pepperweed plants. The most effective herbicide control found is called chlorsulfuron, which works both in soil and on foliage. Hutchinson and Viers (2011) found that tarping *L. latifolium* infestations applied in combination with a mow and till treatment before tarping (Mow–Till–Tarp) had similar effects on control as herbicide treatments with Mow–glyphosate and with Mow–chlorsulfuron. However, they found the Mow–Till–Tarp treatment used extremely time consuming and may have the potential to limit native plant community recovery unless the area is actively revegetated.

<u>Creeping water-primrose (Ludwigia peploides ssp. montevidensis)</u>

During the 2005 vegetation mapping surveys, *Ludwigia peploides* (Kunth) Raven ssp. *montevidensis* (Spreng.) Raven (floating primrose-willow) was documented to occur within the 500-year floodplain (Stillwater Sciences and URS 2007). However, there are currently five species of water-primrose (*Ludwigia*) and two subspecies of *Ludwigia peploides* found in California, only two of which are native (Jepson Interchange - http://ucjeps.berkeley.edu/interchange.html) (Burkhart and Kelly 2005). These species are very difficult to differentiate based on plant morphology. Due to difficulties in distinguishing between species and subspecies of *Ludwigia*, researchers from UC Davis are conducting genetic testing of members of this genus and are creating a morphological key based on their findings (Brenda Grewell, pers. comm.). They have collected specimen from the Santa Clara River to positively identify and help in development of the key.

The non-native, invasive creeping water-primrose, *Ludwigia peploides* ssp. *montevidensis*, is a perennial aquatic plant member of the evening primrose family (Onagraceae) native to South America. *L. peploides* ssp. *montevidensis* can be found throughout California in rice fields, ditches, ponds, slow moving streams, and along edges of lakes and reservoirs. At maturity it grows to 60-140cm in height. Stems are floating or creeping. Leaves are plants spreading-hairy and have glandular leaf tips. Fruit range from 25–40 mm in length. *L. peploides* ssp. *montevidensis* flowers in May through October with 5 bright yellow petals. This subspecies outcompetes native aquatic plants by forming dense, nearly impenetrable floating mats, rooting at the nodes, displacing native vegetation and open water habitat, and restricting fishing and boat access. Recent hydrologic changes in invaded wetlands may be the cause of its invasive spread throughout California.

Many control methods have been used with various levels of success to control *Ludwigia* species throughout California, including application of aquatic herbicide treatments (using air boats and track rigs), harvesting of dead biomass, and removal of dead biomass. Although these treatments appear to be successful initially, they have not proven to control *Ludwigia* species over time. Continual application of these control techniques and maintenance is required. Information regarding *L. peploides* ssp. *montevidensis* tolerance and response to a range of environmental conditions was researched by Grewell et al. (2006) to help inform water managers of most effective control. They found that as water depth increased shoot length, number of rooting nodes and branches, leaf area, relative growth rate and total plant biomass decreased. Plants growing at one meter in depth had the highest leaf mass ratio. At one meter depth, plants were not able to develop significant aerenchyma tissue as an adaptation to anoxia. Results of their study indicate that restoration of deep water habitat may help to suppress the spread of invasive *L. peploides* ssp. *montevidensis* in California.

<u>Smallflower tamarisk (Tamarix parviflora)/salt cedar (Tamarix ramosissima)</u>

Both *Tamarix parviflora* and *Tamarix ramosissima* were found growing along the Santa Clara River in small populations. Both species are members of the Tamaricaceae family and are known to invade river systems in throughout the arid southwest, inhabiting moist, saline soils. *Tamarix* species were introduced to the southwestern US in mid 1800s and have become naturalized as they spread westward due to their use as windbreaks, shade cover, erosion control, and as ornamental plants (Shafroth et al. 2005). Native to southeastern Europe, *Tamarix parviflora* is tree or shrub reaching between 1.5-5 meters tall. The branching twigs are covered in tiny linear leaves only 2 or 3 mm in length. The inflorescence consists of a dense spike flowers approximately 1-4 cm long that flower from March through April. Each small flower has four pink petals. Plants generally have four sepals, petals, and stamens.

Tamarix ramosissima is native to eastern Asia and may grow in the form of a tree or shrub up to 8 m tall. Leaves are small and linear (1.5-3.5mm long) with an acute to acuminate tip. Its inflorescence grows in a spike from 1.5-7cm in length. Petals are 1–2 mm and elliptic to oblanceolate. *Tamarix ramosissima* flowers from April through August. Plants generally have five sepals, petals, and stamens.

Both *Tamarix* species spread rapidly throughout streams and rivers via wind-dispersed seeds (Graf 1978). Their seeds are short-lived (only a few months in summer), have no dormancy requirements, and germinate in less than 24 hr. *Tamarix* species seeds require a moist, fine-grained (silt or smaller particle size) substrate to germinate, readily found in arid southwestern riparian habitats after flood waters subside. *Tamarix* species appear to be more tolerant of harsh environmental extremes (especially high salinity levels) than are native species. Graf (1978)describes *Tamarix* as an effective geomorphic agent due to its rapid colonization of moist sand surfaces, high growth rate, and ability to stabilize sediment. Like *Arundo, Tamarix* species form dense stands, often excluding other native species.

Tamarix spp. can be removed by hand, using herbicide application, cut-stump, or basal bark methods. When plants are small, hand pulling or using a weed wrench to uproot and remove individuals is most effective, insuring that plants do not resprout. If these removal methods are used, all biomass must be removed from the site. On smaller sites the cut-stump method (similar to that described for *Arundo*) has been found successful when triclopyr herbicides are used. Aerial application of imazapyr herbicide, alone or in combination with glyphosate, has been found effective at controlling *T. ramosissima* in dense stands where little or no native vegetation is present. On plants with a basal diameter of less than 4 inches, basal bark applications of Garlon4 have proven effective. Other herbicides and combinations of herbicides have been found effective on small infestations. A tamarisk biocontrol program was initiated in the 1960's, due to the difficulties and limitations found with mechanical and chemical control methods. After many years of testing, the leaf beetle *Diorhabda elongata* was released in the wild in 2001. By 2004, the beetles successfully defoliated vast stands (i.e., over 10,000 ha damaged at one site) at sites in northern Nevada (http://rivrlab.msi.ucsb.edu/tamarisk.php).

CHAPTER 5
EVALUATING SUCCESS OF INVASIVE PLANT REMOVAL AND REVEGETATION

Introduction

Evaluation of the success of restoration actions is an essential component of river ecosystem restoration (Jordan et al. 1987, Kondolf 1995a, Kondolf and Micheli 1995, The Federal Interagency Stream Restoration Working Group 1998, Downs and Kondolf 2002, Downs et al. 2002, Newhouser et al. 2005, Lennox et al. 2007, Stillwater Sciences 2008, Lewis et al. 2009). However, most invasive plant removal projects focus on monitoring the removal of the weed population from a site for only a short period based on funding availability or the minimum timeframe associated with mitigation requirements (1-5 years). Ecosystem recovery is the primary goal of invasive plant removal in river systems, not simply removal of the weed populations over the short term (Zavaleta et al. 2001). Riparian revegetation of invasive plant removal areas is an important component of recovery under many conditions (Coffman et al. 2004, Coffman 2007, Stillwater Sciences 2008). Therefore, evaluating success of invasive plant removal not only includes monitoring of removal of invasive plants, but riparian vegetation and riparian ecosystem recovery metrics as well. Also, many of these metrics should be measured over a much longer timeframe to insure that long-term sustainability of the riparian ecosystems is attained.

Millions of dollars are spent on *Arundo* removal throughout streams and rivers in California each year, utilizing limited funding and expending immense effort. To protect these investments and assure the most successful riparian ecosystem recovery, removal efforts must be located thoughtfully (see Chapter 4) and monitored carefully over the long-term both at the site-specific and watershed scale. Chapter 5 of the handbook focuses on monitoring strategies and conceptual techniques of both invasive weed removal as well as riparian vegetation recovery after invasive weed removal on the Santa Clara River.

Invasive weed removal and revegetation of riparian ecosystems on the Santa Clara River may be implemented for a variety of goals, including: habitat for migratory bird species, shade and passage for native fish, improved habitat for other riparian dependent wildlife species, recovery of a diversity of native plant communities after invasive plant removal, erosion control, fuel reduction for fire hazard, and/or wetland/riparian mitigation. Regardless of the restoration project goals, carefully planned monitoring is essential to evaluating performance or success of each project action relative to target trajectories and attainment of project goals and objectives. Success criteria or standards must be developed for each parameter of interest monitored to evaluate the success of weed removal, planting, and long-term sustainability of the riparian ecosystem relative to restoration trajectories. A restoration action is deemed successful if parameters monitored fall along this trajectory. Kondolf (1995) stresses that all stream restoration projects constitute potential experiments, so we must adequately measure the relevant variables related to our restoration actions both before and for ten years after implementation.

Collection of baseline vegetation data for both current pre-restoration and historical conditions is essential for a meaningful comparison to post-project monitoring of riparian habitat revegetation success (Kondolf 1995b). We must carefully select monitoring variables related to riparian restoration project objectives, and adequately measure these relevant variables for a sufficient length of time (at least ten years) to understand riparian ecosystem recovery. Monitoring regrowth of invasive plants after removal is needed to properly retreat areas and insure long-term invasive weed eradication at each removal site. Revegetation monitoring will help to assure that riparian habitat is being restored to or maintained in areas in which invasive plants are removed. Also, monitoring assesses the need to implement contingency measures in the event that success or performance criteria are inadequately met.

Three types of monitoring are important to a complete restoration project assessment: implementation, effectiveness and validation monitoring (Kersher 1997). Detailed monitoring plans should include success criteria and metrics that evaluate each restoration action relative to all three types of monitoring. Implementation monitoring helps evaluate if the project implemented as planned. Effectiveness monitoring assesses if the restoration actions were effective at meeting the project goals and objectives. Finally, validation monitoring help answer the question: Are the basic assumptions behind the conceptual model developed for the project valid? We have integrated all three types of monitoring in our proposed set of success criteria and metrics for monitoring invasive plant removal and revegetation on the Santa Clara River.

Adaptive Management Framework

An adaptive management framework should be developed for the overall ecosystem restoration of the Santa Clara River to more effectively coordinate and implement restoration actions at the watershed scale. Adaptive management is a systematic process for continually improving environmental management (i.e., restoration recovery of various metrics) by learning from the outcomes of previously employed practices. In other words, if restoration actions are treated as experiments, monitoring will provide a scientific basis for changing management or restoration actions to reset performance trajectories (Holling 1978). Monitoring strategies presented in this Chapter should be integrated into a larger adaptive management framework developed for the entire river system. An excellent example of a monitoring program for riparian restoration within an adaptive management framework is presented in the Lower Redwood Creek Restoration at Muir Beach: Geomorphic and Habitat Assessment Framework (Stillwater Sciences 2009).

We recommend forming a Santa Clara River technical advisory committee (TAC) to develop and help implement the river wide adaptive management framework. This framework should include TAC peer-review all restoration monitoring reports to continuously inform management decisions. Review of monitoring reports by TAC will help identify metrics that are not on an anticipated trajectory and identify appropriate change in management actions. In this way, analysis of the monitoring data will help to inform and assist in the efficacy of long-term management and recovery of each restoration area and the entire Santa Clara River. TAC should produce brief recommendation reports at the end of their evaluation period. The TAC should consist of a combination of botanists, plant ecologists, wildlife ecologists, and ecological managers working on the Santa Clara River and in similar coastal systems in California.

Monitoring Strategy for the Santa Clara River

The two main restoration actions discussed in this report are removal of target invasive plant species and revegetation of riparian habitat after removal. Monitoring must be conducted before and after both of these restoration actions in order to evaluate their success relative to targets established in the form of success criteria. California statewide monitoring frameworks for both of these restoration actions have been developed in the past few years. In this handbook, we propose various monitoring parameters for each of these actions and performance standards for each based on these statewide monitoring standards and results discussed in chapters 2 and 3 of this handbook.

The California Invasive Plant Council (CalIPC) developed the California Weed Mapping Handbook as a training resource for groups (i.e., Weed Management Areas) involved in wildland weed mapping (http://cain.ice.ucdavis.edu/weedhandbook). The primary goal of this handbook is to guide organizations working on weed issues to develop mapping systems that will support project goals on both a local and state level. The handbook provides two types of information, including: shared data mapping standards for State-wide comparison of data, and instructional information on mapping techniques.

The Southern California Coastal Water Research Project (SCCWRP) is developing the *Integrated Wetlands Regional Assessment Program (IWRAP)* that uses a three-level (tiered) approach to wetland assessment based on U.S. Environmental Protection Agency's (USEPA) Level 1-2-3 framework (USEPA 2006). This framework enables the USEPA and the State governments to determine whether their programs meet the prerequisites of Section 305b of the Clean Water Act (CWA). We recommend using a combination of these 3 levels of monitoring to evaluate success of removal of target invasive plant species and revegetation of riparian habitat after removal.

- Level 1 Assessment – Riverine wetlands inventory
- Level 2 Assessment - California Rapid Assessment Method (CRAM)
- Level 3 Assessment - Intensive site assessment/monitoring

Mapping the extent of riverine wetlands and riparian habitat on a revegetation area in GIS is an example of a Level 1 Assessment. We recommend using a combination of the US Army Corps of Engineers (USACE) wetland delineation protocol, California Department of Fish and Game riparian habitat delineation protocol, and US Fish and Wildlife Service protocol to map wetland types within the revegetation area (Environmental Laboratory 1987).

The California Rapid Assessment Method (CRAM) for evaluating the conditions of wetland ecosystems is an example of a Level 2 Assessment (Collins 2008). The primary goal of CRAM is to provide rapid, scientifically defensible, standardized, cost-effective assessments of the status and trends in the condition of wetlands and related policies, programs and projects throughout California (http://www.cramwetlands.org)(Collins 2008, 2009). It has been tested on various wetland types throughout California by the Southern California Coastal Water Research Project, San Francisco Estuary Institute, Moss Landing Marine Lab and Humboldt State University (Stein et al. 2009). Rapid assessments are used to evaluate the general condition of wetlands using field indicators. These methods provide standardized, cost-effective tools for land use planning and project evaluation. A rapid assessment method is especially helpful when full funding is not available for intensive monitoring or more frequent monitoring of a site.

CRAM was developed specifically for the wetland types of California, including riverine wetlands (and associated riparian habitats) associated with rivers like the Santa Clara River, as a tool to assess the status of and trends in the condition of wetlands throughout the state. It is designed to enable standardized ambient assessments at multiple scales: projects, watersheds, regions, and statewide. In addition, the Los

Angeles District of the USACE is in the process of adopting this rapid assessment method as part of their regulatory requirements for assessments of wetland impacts and for mitigation.

The goal of Level 3 monitoring is to generate more detailed information about the *condition* of *specific riverine wetland sites and their adjacent riparian habitat.* Level-3 monitoring facilitates an assessment of trends in the condition of sites over time, providing information about the success of specific restoration efforts or the success of wetland regulatory efforts. It can also yield insight into the spatial heterogeneity of certain indicators (such as faunal populations and plant community composition) within a given riverine wetland site, as well as facilitate studies on the relationships between specific stressors and the condition of wetland ecosystems. The minimum core indicators or variables for use in Level 3 monitoring that are recommended by the IWRAP are: CRAM, benthic macroinvertebrates, benthic algae, plant community composition, and amphibian species richness. Monitoring associated with restoration actions described in this handbook will focus on evaluation of extent and distribution of target invasive species; survivorship and growth of native riparian plantings; and plant community composition along transects perpendicular to the stream or river.

The Science Advisory Panel of IWRAP suggests that some of the same indicators recommended for Level 2 monitoring (CRAM) should be incorporated in Level 3, *but the primary indicators chosen should be those that answer project-specific questions.* Such questions may address causative factors for wetland/riparian habitat condition, or examine stressor response relationships (*e.g.*, as they relate to performance standards), in contrast to the kinds of indicators that are of interest for ambient monitoring.

Site-specific assessment of wetland/riparian habitat condition (Level 3 monitoring) is currently the most commonly practiced form of assessment in Southern California. These assessments are used in restoration and mitigation monitoring and for site-condition assessments conducted as part of the environmental review process when impacts to wetlands could occur. However, the State has not yet adopted standardized, detailed monitoring protocols developed for use in evaluating success of invasive plant removal or revegetation of riverine wetlands or riparian habitat. Site specific monitoring protocols for these restoration activities have typically been developed on a project by project basis. The California Department of Fish and Game (CDFG) have developed standardized conditions per their streambed alteration agreement that include performance standards. However, monitoring protocol and report format have not been standardized.

It is the intent of this Chapter of the Handbook to present monitoring strategies and an array of protocols for invasive species removal and revegetation of riverine wetlands and riparian habitat on the Santa Clara River (Level 3) that integrate into the IWRAP framework. A conceptual monitoring program for evaluation of invasive plant removal and riparian restoration success along the Santa Clara River was developed. This chapter includes proposed success criteria, metrics and monitoring protocols to meet the restoration goals and objectives of the Trustee Council, its parent agencies, and others (see Chapter 1). A more detailed and comprehensive monitoring program must be developed by a team of interdisciplinary scientists and managers familiar with the Santa Clara River, such as the proposed TAC. Success criteria targets should be continuously improved with results of reference sites studies and restoration project data analyses. Proposed monitoring designs should be refined by the TAC as well after further testing of various designs proposed under differing conditions is completed.

Monitoring Parameters

IWRAP recommends monitoring efforts should be focused on evaluating indicators of riverine wetland extent (area of riverine wetland/riparian habitat within a watershed or site), distribution, habitat condition (value to wildlife and riparian species), physical structure, and biotic structure (i.e. community abundance and composition).

The following is an array of recommended parameters that can help measure success of invasive plant species removal and riparian revegetation:

- Extent and location of invasive plant species
- Extent and location of riverine wetlands and riparian habitat (areal coverage)
- Riverine wetlands and riparian habitat quality
- Survivorship and growth of riparian plants installed
- Plant community composition (native and non-native)
- Plant species diversity
- Biomass of invasive species
- Wildlife species surveys

Setting Success Criteria

Success criteria describe measurable attributes that can be used to evaluate success in meeting the goals and objectives of a restoration project or activity. Success criteria (also called performance criteria or standards) and associated metrics describe a desired state, threshold value, amount of change, or trend to be achieved for a particular population or habitat characteristic over time after a restoration action is implemented. Performance metrics are used to guide site management activities (adaptive management) during the post project monitoring period and may be used as benchmarks measured during the final monitoring to evaluate success of habitat, population, and/or ecosystem recovery.

Proposed success criteria were developed to measure success of riverine wetland and riparian habitat restoration associated with removal of invasive plant species and native plant revegetation. The eight success criteria developed were based on the parameters recommended by the Science Advisory Panel of IWRAP for Level 3 monitoring of invasive plant species removal and riparian revegetation. Success criteria and associated metrics were developed for this handbook to evaluate the success of the following restoration objectives: invasive plant species eradication (see Success Criteria A and C); riparian plant establishment, health, and growth (see Success Criteria D, E and F); extent of riverine wetlands and riparian habitat restored (see Success Criteria B and C); and wildlife use of restored habitat (see Success Criterion G). Also, long-term sustainability of riverine wetlands and riparian habitat restored should be monitored and evaluated relative to established success criteria over a 30 year period (see Success Criteria C and H).

The California Department of Fish and Game's standard Stream Alteration Agreement (SAA) conditions for riparian restoration actions in Southern California and several project specific SAA conditions were reviewed in the process of writing this handbook. We made recommendations for updating survivorship and growth (mean height) metrics of three riparian tree species and one shrub species after 1 and 2 years under various soil moisture and light conditions based on our research (see Chapter 3). However, all other metrics were developed based on professional restoration experience and other ecological studies in which we have been involved throughout Southern California. Success criteria and metric targets should be updated as new ecological data become available related to invasive plant removal and revegetation with native riparian plant species. These success criteria targets were developed primarily for reaches of the Santa Clara River with high soil moisture and groundwater tables similar to HRNA. In drier reaches of the Santa Clara River, success criteria should be evaluated and modified by TAC on a case by case basis until data is available from reference sites to understand plant performance and natural vegetation in these areas (such as the alluvial scrub vegetation type).

We recommend including as many of the eight success criteria and associated 24 metrics as possible when developing a Monitoring Plan for an invasive species removal and riparian revegetation project on the Santa Clara River. We recognize that time and budget constraints might prevent use of all of these. The Santa Clara River TAC should be involved in guiding organizations proposing restoration activities as to the most important success criteria and metrics for their project. Measures D4 and G3 should only be used if site conditions meet the descriptions below. Details of each of these success criteria are as follows:

NOTE: If any of these performance metrics are not met after the stated monitoring timeframes, a contingency plan must be implemented and replacement plantings installed between years 1-10 of monitoring. If you must replant some of the riparian cuttings or take some other remedial action to reset the restoration trajectory, the monitoring period for those replacement plants or invasive plant removal must be reset to time 0. Year 1 monitoring will start at the end of the growing season of the following year and continue for the next 10 years.

Success Criterion A: Extent of Invasive Plant Species

Metric A1 (Monitor in Years 1-10)
The following target invasive plant species shall be completely removed from the weed removal/riparian planting areas: *Arundo donax*, *Lepidium latifolium*, *Ludwigia peploides* ssp. *montevidensis*, *Tamarix parviflora*, or *Tamarix ramosissima*) by the end of the 10 year monitoring period. During the first 3 years, less than 5% of the originally mapped acreage of each of these species is acceptable while control and maintenance measures are ongoing. From year 4 – 9, extent of these 5 invasive plant species should be < 1% cover or better of the entire site.

Success Criterion B: Extent of Riverine Wetlands and Riparian Habitat

Metric B1 (Monitor in Years 1, 2, 5 and 10)
The extent of riverine wetlands and riparian habitat as defined by the USACE/USEPA, USFWS, and CDFG must meet minimum mitigation goals (target ratio or acreage cited in the permit) 1 year after planting riparian and/or wetland plants. For non-mitigation restoration projects, the extent of riverine wetlands and riparian habitats should measure within 10% of the target extent (below or above) 1 year after riparian planting and remain within 10% for the 10 year monitoring period.

Success Criterion C: Quality of Riverine Wetland and Riparian Habitat

Metric C1 (Monitor in Years 1-10, 15, 20, 25, and 30)
Using the California Rapid Assessment Method (CRAM), the revegetation area must attain a score within 10% of the CRAM score for Riverine Non-confined reference sites along the Santa Clara River by the next growing season after both invasive species have been removed and native riparian and wetland plants installed (or by year 5 at the latest).

Success Criterion D: Survivorship, Health and Growth of Riparian Plantings

Metric D1 (Monitor in Years 1, 2, and 5)
Riparian tree and shrub species planted in the revegetation area must achieve at least 80% survivorship one year after the site is revegetated. Note each species must attain 80% survivorship (not a combined 80%). Of the year 1 survivors, 95% must survive after 2 and 5 years.

Metric D2 (Monitor in Years 1, 2 and 5)
80% of all planted riparian species (individual species analyzed separately) that survive in riparian area must achieve a health (vigor) rating of 3 or higher one year after the site is planted. 95% of the planted riparian species (individual species analyzed separately) must have a health rating of 3 or 4 during monitoring in Years 2 and 5.

Metric D3 (Monitor in Years 1 and 2)
Native riparian trees and shrub species planted should have a mean cutting diameter 10% larger than the year before or found within the range of each species of similar age at the reference site(s) chosen.

Metric D4 (Monitor in Years 1 and 2)
If the following 3 native tree species and 1 shrub species are used in revegetation actions, their mean heights must be within 10% of the mean heights of each species shown in Table 4 per the revegetation area's soil moisture and light availability.

Metric D5 (Monitor in Year 5)
Native riparian species must achieve at least a combined aerial cover of 50% in the planting area 5 years after planting.

Metric D6 (Monitor in Years 5 and 10)
All riparian species must achieve a health rating of 3 or higher 5 years and 10 years after planting.

Metric D7 (Monitor in Years 5 and 10)
Native riparian trees and shrub species planted should have a diameter breast height (dbh) within the range of each species of similar age at the reference site(s) chosen.

Metric D8 (Monitor in Year 10)
Native riparian species must achieve at least 70% aerial cover in the planting area.

Metric D9 (Monitor in Year 1, 2, 5 and 10)
Biomass of each native tree and shrub species (estimated based on a volume calculation) must be within 10% of the same species found in the reference site.

Success Criterion E: Plant Species Diversity

MetricE1 (Monitor in Years 1-10)
The Shannon-Weiner Diversity Index for all native trees, saplings and shrubs (both planted and naturally recruited) in the revegetation site must measure within 10% of the reference site(s) chosen.

Metric E2 (Monitor in Years 1-10)
Species richness for all native plants (both planted and naturally recruited) in the revegetation site must measure within 10% of the reference site(s) chosen.

Success Criterion F: Plant Community Structure and Composition

Metric F1 (Monitor in Years 1, 2, 5 and 10)
The restored native riparian plant community must be composed of a diversity of life forms (also called growth forms). The riparian restoration area must have at least the following number of species and absolute % aerial cover in each of 5 strata as defined in the monitoring protocol section of this chapter (see Table 7).

Metric F2 (Monitor in Years 1-10)
Non-native plant species (other than the 5 target invasive species) should consist of less than 10% total absolute cover in years 1 – 3, less than 5% in years 4-10.

Metric F3 (Monitor in Years 5 and 10)
The restored native riparian plant community must be composed of a diversity of life forms, with varied heights occupying at all strata. The restored riparian habitat must have at least 10% of each life form in one or more of the height classes. (More study of reference sites is needed to better define the targets for this metric.)

<u>Success Criterion G: Wildlife Activity in and near Restored Riverine Wetlands and/or Riparian Habitat</u>

<u>Metric G1</u> (Monitor in Years 1-10)
Used as an indicator of revegetation success, bird species diversity and abundance relative to reference site(s) with the same soil moisture and light levels chosen will measure the following: Year 1 (50%), Year 2 (40%), Year 3 (30%), Year 4 (20%), and Years 5-10 within 10% or greater than.

<u>Metric G2</u> (Monitor in Years 1-10)
A diversity of common and rare native wildlife species use of the revegetation areas shall be recorded (tracks, faeces, visual observation, or sound) in and around the riparian revegetation area while annual bird surveys are being conducted. Diversity and abundance of common wildlife species relative to reference site(s) chosen will measure the following: Year 1 (50%), Year 2 (40%), Year 3 (30%), Year 4 (20%), and Years 5-10 within 10% or greater than.

<u>Metric G3</u> (Monitor in Years 1-10)
If a portion of the Santa Clara River or its tributary runs within the revegetation area, native fish use adjacent to the revegetation area shall have a species diversity and abundance measuring the following relative to that of the reference site(s) chosen: Year 1 (70%), Year 2 (60%), Year 3 (50%), Year 4 (40%), and Years 5-10 within 30% or greater than.

<u>Success Criterion H: Long-term Sustainability of Ecosystem</u>

<u>Metric H1</u> (Monitor in Years 15, 20, 25, and 30)
Non-native plant species (other than the 5 target invasive species) should consist of less than 5% absolute cover.

<u>Metric H2</u> (Monitor in Years 15, 20, 25, and 30)
The 5 target invasive species should not be present on the revegetation site.

<u>Metric H3</u> (Monitor in Years 15, 20, 25, and 30)
The riverine wetland and/or riparian habitat revegetated must have 60% total absolute aerial cover or greater of native riparian plant species (in the absence of flooding or wildfire).

<u>Metric H4</u> (Monitor in Years 15, 20, 25, and 30)
The riverine wetland and/or riparian habitat revegetated must measure within 5% of the area attained in Year 10 of monitoring or greater (if Performance Measure B1 is met in Year 10) (in the absence of flooding or wildfire).

Developing the Monitoring Approach and Sampling Design

The approach chosen for monitoring a restoration area depends on the success criteria and metrics selected. The size (area), configuration, and fluvial geomorphic location of the restoration area relative to the active floodplain and low flow channel of the Santa Clara River will determine the sampling design. We recommend the following approaches and sampling design strategies for revegetation areas along the Santa Clara River.

Monitoring Approach

Table 8 lists recommended approaches for monitoring of each metric associated with the specific success criteria.

Sampling Design

Permanent long-term monitoring plots, transects (permanent or randomly selected), or the combination of the two may be used to monitor success criteria, depending on the size (area), configuration, and fluvial geomorphic location of the restoration site relative to the active floodplain and low flow channel of the Santa Clara River. Sampling designs for each restoration area should be consistent among sites with similar conditions. Since many physical conditions (i.e., depth to groundwater, soil moisture availability, geomorphic location etc…) exist along the Santa Clara River, the TAC should be involved in sampling design for all revegetation efforts.

Plot-based Sampling

Permanent, long-term monitoring plots may be established in revegetation sites that are both small (generally less than 1 acre or less than 100 riparian plantings) and situated entirely in one geomorphic location (i.e., the active floodplain or floodplain terrace); and those sites located far from the influence of the Santa Clara river hydrology (floodplain terrace). Also, riparian plant survivorship, health and growth metrics are best measured in permanent long-term monitoring plots (but may be located along transects for efficiency of access).

We recommend using the following plot sizes (Coffman 2000):

- Herbaceous plant stratum ($1m^2$; 3.28ft x 3.28ft square quadrat)
- Shrub and vine strata ($25m^2$; 16.4ft x 16.4ft square)
- Trees stratum ($100m^2$; 32.8ft x 32.8ft square)

All plots of the same vegetation type to be analyzed in a study must be the same size (area not necessarily exact configuration). Plot shapes are dependent on the vegetation type. If the riparian revegetation area or plant strata are linear, the plot should be configured to this area. Plot dimensions should not go beyond the community's natural ecological boundaries.

At least 5 permanent, long-term monitoring plots should be randomly located within the revegetation area using a grid overlaid on the sampling area. For each long-term monitoring plot, the center of the tree, shrub and herbaceous strata sampling area should be nested according to Figure 13 (Ponce-Hernandez 2004). The center of each permanent plot should be GPSed and permanently marked with rebar.

Transect-based Sampling

The transect-based monitoring design presented was based on a protocol developed for the USEPA in Calleguas Creek watershed for sampling riparian vegetation in southern California (Coffman 2000). We amended this riparian vegetation sampling protocol for use in monitoring performance of riparian revegetation projects (Lennox et al. 2007). Success of invasive plant removal and riparian revegetation may be monitored quantitatively and efficiently along transects placed perpendicular to the river across various restoration treatments or geomorphic landforms along the Santa Clara River.

Transect-based sampling is recommended for planting areas that extend across the river or cover multiple landforms – both active floodplain and floodplain terrace or those located along smaller tributaries to the Santa Clara River. Vegetation transects are typically placed along permanent cross-sections surveyed in fluvial geomorphology studies to understand vegetation dynamics over time or distribution of plant assemblages relative to physical gradients in a river system. Sampling vegetation along transects located at cross-sections helps ecologists to understand the relationship between physical factors of fluvial geomorphology (location relative to disturbance), distance to standing water/water table, and vegetation composition. Sampling along transects in revegetation areas can help with direct comparisons to reference and control sites at similar landform positions, and to evaluate reasons for success of plant species relative to varying physical conditions in each landform or treatment.

Vegetation transects should be positioned along an established cross-section if possible or perpendicular to stream or river flow if permanent cross-sections are not present in the revegetation area. At each revegetation area along a river or stream reach, at least three transects should be randomly chosen, perpendicular to the flow of water and at least 50 meters from one another. Landforms and/or restoration treatment areas (i.e., each revegetation area with a differing plant planting palette or plant composition) should be visually delineated along the length of each transect and 20 meters perpendicular to each transect. The linear distance of each restoration treatment or landform along the transect should be measured and recorded..

Geomorphological landforms on the Santa Clara River were defined using a combination of sources. The main landforms consist of: low flow channel(s) (wetted width during the summer months), channel bed (from wetted width of low-flow channel to terrace bank), and/or floodplain/terrace (from terrace bank to the valley floor) (Figure 13). We define the combination of the channel bed and the low-flow channel as the flood reset zone. The floodplain/terrace boundaries are difficult to delineate on the Santa Clara River due to channel incision. Giessow et al. (2011) further defined landforms for mapping *Arundo* in rivers of southern California based on amount of vegetation present (level of flood disturbance):

- ***Low-flow Channel*** – The part of the main channel where water is flowing at the time of aerial photos. In those cases where the riverbed is dry, the area appearing to have the most recent flows was delineated as low flow.
- ***Bar/Channel/Floodplain - unvegetated*** – Main channel or floodplain areas with less than 50% vegetation cover, usually consisting of bar surfaces, dry channel beds, or recent deposition or scour.
- ***Floodplain - vegetated*** – Areas on the river floodplain with more than 50% vegetation cover.
- ***Floodplain/Low Terrace – vegetated*** – Areas on either the river floodplain or an adjacent low terrace with more than 50% vegetation cover.
- ***Upper Terrace - vegetated –*** Areas on higher ground adjacent to the low terraces with more than 50% vegetation cover. The mapping did not go beyond levees or roads in most cases.

According to the belt grid transect method, vegetation will be sampled in five plots located randomly within each landform or restoration treatment according to a grid system (x coordinate along the survey tape and y coordinate 20m perpendicular to the transect) (Figure 13). A survey tape should be laid out along the transect length. Starting at one end of the transect, five random locations should be chosen (using a random number generator) along the survey tape within the length of the highest landform. These locations may be marked with pinflags (or write on your data form) for ease of location – this will mark the x coordinates of each sampling location in this landform/treatment. Find five random numbers for your y coordinates (within the 20m width of the belt transect). The sampling locations are found by starting at each pinflag and using the 1 m^2 quadrat as a measuring device to find the y coordinate. This procedure should be used to locate plots and sample plant metrics in five quadrats in each of the remainder of the landforms/treatmenst along all transects.

Selecting Reference Sites

Carefully selected reference and control sites can provide a useful context for evaluating the trajectory of each ecosystem attribute using a suite of success criteria and eventually interpreting overall project success (Lewis et al. 2009). At least one reference site (preferably multiple sites if possible) and one control site exhibiting similar physical characteristics to the revegetation site should be identified, sampled, and used for comparison to the revegetation area. A reference site is a natural area that represents the ideal restored conditions or the least anthropogenically altered conditions found in the same watershed and subject the same physical conditions. For the purposes of this handbook, a suitable reference site consists of healthy riparian habitat or riverine wetlands – a site completely free of *Arundo* and other invasive weeds exhibiting high plant species diversity, vegetation structure, and wildlife use. The suitable reference site must have similar physical conditions to the proposed revegetation site, including: depth to groundwater, soil moisture content, soil texture, and geomorphic landform position. Whereas a control site consists of a river reach or smaller area within one morphological landform in the vicinity of the proposed restoration site that is similar in terms of human and natural disturbance, but has not received any restoration treatments. Ideally, the TAC would select these reference sites and the UC Research Station and Conservation Center scientists would monitor these over time to determine the most appropriate success criteria targets for each physical condition along the Santa Clara River.

Physical characteristics such as soil texture, soil moisture and light availability conditions, depth to groundwater, stream order, and stream gradient should be assessed throughout the restoration site in order to identify an appropriate reference site. Currently, there are only a few areas in the low gradient reaches of the Santa Clara River that may be good candidates for use as reference sites (where *Arundo* and other invasive plants are absent). These potential reference sites occur primarily on the floodplain terrace landform. We have identified ten potential reference site locations along the Santa Clara River during vegetation mapping in 2005 and assessment of the current aerial photography (Figure 14) (Stillwater Sciences and URS Corporation 2007). However, this list is not meant to be exhaustive, just a starting point in the identification of reference sites.

Portions of HRNA contain the largest, most natural riverine wetland and riparian habitat conditions in the low gradient portions of the Santa Clara River. Active and passive restoration actions on HRNA have created a mosaic of natural riverine wetland and riparian vegetation types in which *Arundo* has been completely removed. HRNA is not a typical reference site since much of the riverine wetland and riparian habitat on the property was actively restored, however it still represents the most natural conditions along the River. The 2011 final monitoring report for restoration at HRNA will be useful for identifying reference sites (in preparation). The most natural riparian conditions in the watershed occur in much higher gradient tributaries to the Santa Clara River (i.e., Sespe Creek) and exhibit differing riparian habitat characteristics due to differing physical conditions.

Since reference sites and conditions on the Santa Clara River may be difficult to identify and access, historical vegetation conditions of the proposed restoration site may be investigated to better understand reference conditions relative to the site. Historical information, such as aerial photographs, maps, ground photography and land and biological survey records can be used to establish prior conditions (Palmer et al. 2005). The Ventura County Historical Ecology study documents historical landscape patterns and ecological and hydrologic dynamics and trends along the main stem of the Santa Clara River in Ventura County by synthesizing an array of historical records (Beller et al. 2011). Chapter 3 of this study presents historical maps and photos as well as a narrative describing the historical distribution, abundance, and functions of the pre-European riparian habitats and riverine wetlands of the lower Santa Clara River. The Ventura County Historical Study created a geo-database containing a comprehensive dataset of historical aerial photos of the reaches of the Santa Clara River located in Ventura County (contact Erin Beller at SFEI for review of the geo-database, erin@sfei.org). In addition, interviews with current or former land owners of the proposed restoration site and adjacent properties may be helpful in understanding historical vegetation conditions of this site.

Monitoring Protocol and Methods

Extent of Invasive Plant Species

As part of the baseline conditions assessment for a proposed restoration area, the extent and location of each of the following target invasive plant species must be mapped. These species should be mapped during the growing season before the plant populations will be removed and each year of the 10 year monitoring period: *Arundo* *donax*, *Lepidium latifolium*, *Ludwigia peploides* ssp. *montevidensis*, *Tamarix parviflora*, and *Tamarix ramosissima*. Mapping should be done using a Trimble GPS XH or XT unit (and the GPS Pathfinder ProXH receiver) or similar GPS with sub-foot accuracy if at all possible to get an accurate estimate of extent of each weed. For each monoculture infestation, the extent of the population should be mapped with a GPS polygon feature. In areas where invasive weeds and native plants are mixed and cannot be easily separated to GPS individual populations, the associated percent cover of each weed species in the infested area should be estimated and its phenological stage noted (Newhouser et al. 2005). After collected, the GPS data should be uploaded to a GIS geo-database GIS data and be reported each year for the duration of the 10 year monitoring period to Calflora using the Cal Weed Mapper tool (http://www.calweedmapper.org/).

Extent of Riverine Wetlands and Riparian Habitat

The extent and location of riverine wetlands and riparian habitat as defined by the USACE/USEPA and CDFG must be determined one year before the proposed restoration actions are implemented and again in years 1, 2, 5 and 10 of monitoring. Potentially jurisdictional waters of the U.S., including wetlands (i.e. riverine wetlands), must be delineated on the proposed restoration site using the U.S. Army Corps of Engineers Wetlands Delineation Manual and the Arid West Supplement (Environmental Laboratory 1987, U.S. Army Engineer Research and Development Center 2008). In combination, these manuals provide technical guidance and procedures for identifying and delineating wetlands that may be subject to regulatory jurisdiction under Section 404 of the Clean Water Act or Section 10 of the Rivers and Harbors Act. Wakeman and Fong (1984) provide additional guidance for identifying and delineating USACE potentially jurisdictional wetlands in riparian areas. Also, the USACE Sacramento District web site contains more information related to delineations of wetlands as defined by the USACE and USEPA(http://www.spk.usace.army.mil/organizations/cespk-co/regulatory/delineations.html).

Riparian habitat must be delineated before the onset of invasive weed removal or revegetation and during the monitoring period (years 1, 2, 5 and 10). Riparian habitat should be identified and delineated according to the CDFG guidelines for stream delineation. CDFG Code 1600 regulates riparian vegetation associated with streams and lakes. These areas are often more expansive than extent of USACE jurisdictional wetlands, however much less guidance is available for delineating riparian habitats. The CDFG Environmental Services Division developed "A Field Guide to Lake and Streambed Alteration Agreements, Sections 1600-1607, California Fish and Game Code" that provides some guidance for determination of the geographical extent of those areas under state jurisdiction (California Department of Fish and Game Environmental Services 1994). The outer edge of riparian vegetation is generally used as the line of demarcation between riparian (including wetland) and upland habitats and is therefore a reasonable and identifiable boundary for the lateral extent of a stream for protection. For streams that contain riparian vegetation along their edges, the outer drip line of the riparian vegetation shall be used to determine the extent of the stream. The outer drip line shall be estimated by walking under the tree canopy and then moving outward such that a vertical line from the ground to the sky is not covered by any tree canopy associated with riparian trees or shrubs.

Quality of Riverine Wetland and Riparian Habitat

CRAM should be used to assess the condition of riverine wetlands and riparian habitat on each proposed restoration area along the Santa Clara River before the restoration actions are implemented and during post-project monitoring years 1-10, 15, 20, 25 and 30 (Collins 2008, 2009). Using the CRAM Riverine Wetlands Field Book, four attributes (buffer and landscape context, hydrology, physical structure, biotic structure) are assessed to fully understand the pre- and post-project short-term efficacy of the restoration actions and the long-term sustainability of these actions. The CRAM scores for each revegetation area will then be compared to scores for reference riverine wetlands along the Santa Clara River to evaluate the effect of restoration actions on the area. CRAM assessments were completed before (in 2010) and one year after *Arundo* removal on a 250-acre site located along the floodplain of the Santa Ana River near Corona, CA. Overall scores have increased significantly (especially for biotic and physical structure attributes) only one year after removal when reassessed in July 2011 (Lindsay Teunis pers. comm.).

A full CRAM assessment takes an average of 4 hours to complete, but may vary between 2-6 hours depending on access, size, and density of vegetation in the assessment area. The first pre-project assessment may take up to 6 hours in order to identify the assessment area. CRAM assessments completed after project implementation should take less time on average. We highly recommend that CRAM assessments are carried out by a pair of certified CRAM practitioners to insure consistency among assessments.

Survivorship, Health and Growth of Riparian Plantings

Riparian plant survivorship, health and growth metrics (implementation metrics) are best monitored in permanent plots during the middle of the growing season. At least five replicate plots should be established in each revegetation treatment area. Survivorship should be measured at years 1, 2 and 5. In each replicate permanent plot, count and record the number of each species that is alive and dead.

Health rating should be evaluated during the middle of the growing season in years 1, 2, 5, and 10. Assess the health of each plant installed in the permanent plot and record its rating on your data form.

We recommend using the following health rating system:

4 = healthy, robust, vigorous; all leaves are green

3 = robust; a couple leaves are lighter in color or some insect damage

2 = many leaves light green in color; smaller in stature due to herbivory or other stressors

1 = most leaves very light green or white; very small in stature; heavy damage from herbivory

0 = plant dead; all above ground biomass dead

Growth metrics should be used to measure each native riparian plant within permanent plots or transects. Sampling should occur in the middle of the growing season within during the following years associated with each growth metric as described below:

- **Cutting diameter (monitor years 1 and 2) –** Each cutting diameter should be measured at three locations (10cm from the ground surface, in the middle of the cutting and 2.5cm from the top of the cutting) along each native riparian tree or shrub cuttings. The average cutting diameter should be calculated.
- **Height (monitor years 1 and 2) –** The height of each riparian plant installed should be measured. Without moving the plant to measure it, the height of the tallest branch or leaf should be measured perpendicular to the ground surface.
- **Absolute total percent cover (monitoring years 5 and 10) –** The absolute percent cover of all riparian plant species should be estimated within each replicate plot along each transect or each permanent plot.

- **Diameter breast height (dbh) (monitoring years 5 and 10)** – Diameter at breast height (dbh) of each riparian tree and shrub species planted should be measured in each replicate plot along each transect or permanent plot.
- **Volume (monitoring years 1, 5 and 10)** – Biomass should be estimated based on volume calculated for each riparian tree and shrub. The following tree measurements must be made for each tree sampled: height, dbh, length of crown (branches and leaves in the tree canopy), average width of the crown (2 perpendicular widths), and height of trunk from base of the crown to the ground. Tree volumes can be calculating trunk volume and crown volume and adding them together. Trunk volume can be estimated by imputing dbh and trunk height into the formula for a cylinder: $Trunk\ Volume = h \times \pi(dbh/2)^2$. Crown volume can be estimated by using the formula for the shape of the crown and plugging in the height of the crown and average width.
    - **Volume of a cone** – $Volume = \frac{1}{3}rh$, where h = total height of tree – trunk height.
    - **Volume of a hemisphere** –$Volume = \frac{2}{3}\pi r^3$

The volume of the crown estimated by these equations is the gross total volume. However, much of this volume is empty, interstitial space. The actual proportion of the volume occupied by branches and leaves should be estimated by standing beneath the canopy, beside the trunk, and carefully estimate the % canopy structure versus interstitial space. This proportion is then used to discount the air space in the crown volume: solid volume = V (m^3) × proportion of branches and foliage in crown volume. Shrubs volume can be simply estimated by these procedures, but by leaving out the trunk estimation step.

Plant Species Diversity

Both species diversity and richness should be sampled in either permanent plots or transects annually for 10 years. The Shannon-Weiner Diversity Index should be calculated for all native trees, saplings and shrubs (both planted and naturally recruited) in each the revegetation site. The index combines two quantifiable metrics: species richness (number of species within the planting area or plant community) and species equitability (how even are the total numbers of species). To calculate the Shannon-Weiner Diversity Index, the total number of species (per unit area) and the frequency each species occurs in each plot (density/unit area) must be tallied. The formula for the Shannon-Weiner Diversity Index is:

$$H' = -\sum_{i=1}^{S}(p_i \ln p_i)$$

Where S is the total number of species and p_i is the frequency of the *i*th species.

Species richness should be calculated for all native plants (both planted and naturally recruited) in each revegetation site. Species richness is the number of native species per unit area.

Plant Community Structure and Composition

Plant community structure and composition metrics should be monitored in years 1, 2, 5, and 10 as follows. These metrics can be sampled either in permanent plots or in plots located along belt grid transects. We recommend the following protocols for each metric based on a combination of the California Native Plant Society (CNPS) guidelines and standard plant ecology sampling protocol. However, we recognize that many other protocols are available and the TAC should refine these methods in their detailed Monitoring Plan for the River.

- **Absolute percent cover** - Each plant found in permanent plots or plots along transects should be identified to species and recorded. Percent cover should be estimated to the nearest 1% within the first 10% and to the nearest 5% from 15%-100%. Percent cover is considered the proportion of the ground occupied by a perpendicular projection of the aerial parts of individuals of a species (Moore and Chapman 1986). When estimating percent cover, it is often helpful to think of coverage in terms of the following cover intervals at first:

  <1%, 1-5%, >5-15%, >15-25%, >25-50%, >50-75%, >75%.

  Keeping these classes in mind, then refine your estimate to a specific percentage. ***Note: All field staff estimating percent cover must be trained by a member of the UC Reserve staff to insure consistency in estimation of percent aerial cover.***

- **Plant growth forms** - For each plant species that absolute percent cover is recorded, plant growth forms must be recorded. Growth forms indicate functional groups within a plant community, including: trees, saplings, seedlings, shrubs, vines, graminoids, and forbs. However, the CNPS Vegetation Program classifies plants into 6 strata: tree, seedling, sapling, herbaceous, vine and nonvascular (will likely not be found on the Santa Clara River). We recommend using a combination of these two methods, by recording the following functional groups as defined by CNPS and Hickman (1993):

- **Tree** = A woody perennial plant that has a single trunk
- **Shrub** = A perennial, woody plant, that is multi-branched and doesn't die back to the ground every year
- **Seedling** = A tree species clearly of a very young age that is < 1" dbh.
- **Sapling** = 1" - <6" dbh and young in age, OR small trees that are < 1"diameter at breast height, are clearly of appreciable age, and kept short by repeated browsing, burning, or other disturbance.
- **Vine** = a trailing or climbing plant, sometimes attaching to its support by tendrils.
- **Graminoid** = grasses (family Poaceae) and grass-like plants such as sedges (family Cyperaceae) and rushes (family Juncaceae).
- **Forb** = a non-woody (herbaceous) flowering plant other than a grass, sedge, or rush.

- **Native vs. non-native status –** For each plant species identified in a permanent plot or along a belt grid transect, native or non-native status should be recorded for each.
- **Height class** - According to the California Native Plant Society (CNPS) and California Wildlife-Habitat Relationships (CWHR), the size/height class should be recorded for tree, shrub, and/or herbaceous categories (vines, graminoids and forbs combined) (http://www.cnps.org/cnps/vegetation/pdf/protocol-combined.pdf). These three categories are based on functional life forms. An estimate of height for each functional life form in a plot should be made using the height intervals listed below.
  - **Height Classes:** 01 =< 1/2m, 02=1/2-1m, 03 = 1-2 m, 04 = 2-5 m, 05 = 5-10 m, 06 = 10-15 m, 07 = 15-20 m, 08 = 20-35 m, 09 = 35-50 m, 10 => 50m.

Record an average height value per each category by estimating the mean height for each life form. An individual plant is recorded in only one layer, according to the height of the tallest point on that individual and its life-form.

- **Collection of voucher specimen** - One voucher specimen for each species should be collected, pressed and mounted to show positive identification of all species recorded for on a restoration area. We recommend that the UC Research Station and Conservation Center keep a herbarium of plants collected along the River.

<u>Wildlife Activity in and near Restored Riverine Wetlands and/or Riparian Habitat</u>

We recommend these metrics should be evaluated based on point counts (and replicates) located within each revegetation area (typically 3 during the breading season for birds) not on USFWS protocol surveys. More work is needed to better understand the most appropriate metrics and targets for the Wildlife Activity success criterion and associated metrics. These must be developed further by a team of wildlife biologists and plant ecologists familiar with the Santa Clara River birds, fish, and other wildlife and the Santa Clara River TAC. The Trustee Council supported restoration on a portion of HRNA as well as bird and other wildlife surveys associated with these activities. The final report will be completed in summer 2011 and should be used to develop this criterion and metrics. Other organizations and resources that we recommend using to develop these include: Western Foundation of Vertebrate Zoology (http://www.wfvz.org/), Riparian Habitat Joint Venture (http://www.rhjv.org/), and Point Reyes Bird Observatory (http://www.prbo.org/).

<u>Long-term Sustainability of Ecosystem</u>

Protocol for collecting metrics for long-term sustainability of riparian ecosystem restoration actions are as follows:

- **Percent cover of non-native plant species –** Percent aerial cover of non-native plant species (other than the 5 target invasive species) should be estimated. See plant community structure and composition for detailed methods.
- **Survey extent of 5 target invasive species –** Resurvey for 5 target invasive species and GPS the extent (area) of each as a polygon if present**.**
- **Percent cover of native riparian plants species –** Percent aerial cover of native riparian and wetland plant species should be estimated. See plant community structure and composition for detailed methods.
- **Survey extent of riverine wetland and/or riparian habitat –** Resurvey the extent of riverine wetlands and riparian habitat as discussed earlier.

Photo Monitoring

Photo monitoring is simple yet illustrative tool often used in long-term monitoring studies, including restoration project monitoring. The goal of long-term photo monitoring in restoration projects is to detect visual change due to the restoration action over time. Typically, photo monitoring helps in understanding of vegetation and channel form change and is used to evaluate the long-term success of restoration actions.

Location of each photo station should be strategically chosen, anticipating potential rapid growth of riparian plants over time (see photo monitoring examples from HRNA in Appendix B). We recommend placing at least one station in a location higher in elevation in order to get a landscape overview photo. At least 10 photo stations should be carefully established throughout each revegetation area (more stations if the site is larger or there are more invasive plant removal areas) to show a diversity of removal areas, planting locations, vegetation types, and invasive plant removal areas. If transects are used in the vegetation monitoring approach. One photo station should be placed at each transect. If long-term monitoring plots are the chosen approach, photo stations should be established at each of these.

When establishing each photo station, record a GPS location and compass reading for each photo point. A permanent marker such as a piece of rebar can be installed to ensure exact relocation. If possible, all photos should have a permanent landmark in the photo (i.e., mountain, large tree, transmission line etc…) so that they are easy to locate. A map of the photo monitoring plots should be created and included in the Monitoring Plan.

Photo stations must be established at least one growing season before the restoration project is implemented; immediately before and after removing invasive plants; and immediately before and after planting. Photos must be taken at each monitoring station twice a year during years 1-2 and once a year from years 4-10 and in year 15, 20, 25 and 30. In the first 3 years, photos should be taken immediately after planting in the winter (and at this same time for years 2 and 3). In all years, photos must be taken from photo stations consistently in the middle of the growing season (i.e., usually sometime in July). Ideal timing of photo monitoring is during the same timeframe as the vegetation monitoring.

Using Volunteer Labor

Adequate implementation of a restoration monitoring plan can consume more time and funding than is often available. Student interns, community volunteers, and members of non-profit environmental organizations were successfully used to help in data collection at the UCLA riparian field experiment over two year study. Trained volunteers are the backbone of several major water quality monitoring efforts along the Santa Clara River, Ventura River and Malibu Creek Watershed. Also, student and community volunteers have contributed significantly to habitat restoration efforts on HRNA since 1998. We recommend considering augmenting your revegetation monitoring team by incorporation student interns and volunteers using elements of the following as models as part of the UC Research Station and Conservation Center.

Heal the Bay's Stream Team is a citizen monitoring program developed to collect high quality useable data to help determine the environmental health of the Malibu Creek Watershed (http://sites.healthebay.org/streamteam/). The Stream Team partners citizens who want to volunteer to actively work for the environment with environmental organizations and government agencies who have environmental data needs. Data collected is intended to enhance the ecological function and improve water quality throughout the watershed while educating community members about their watershed. Since November of 1998, more than 5800 Stream Team volunteers have been trained by Heal the Bay to collect and analyze water quality in the watershed. Data collected is entered into GIS and distributed to government agencies. In addition, Stream Team data is used to track trends in water quality to assist local planning agencies in developing future water quality protection goals and land use management strategies.

In fall 2004, FSCR received funding from the State Water Resources Control Board (SWRCB) to develop a Santa Clara River Stream Team (http://www.fscr.org/html/2004-01-01.html). FSCR trained a group of citizen volunteers to regularly monitor water quality at selected sites along the Santa Clara River from Soledad Canyon to the estuary. This three-year program focused on nutrient loading, sampling at 6-10 sites along the river. Teams consisting of 3-4 volunteers were assigned to cover two or three sites per session on a one-weekend-per-month sampling schedule. All volunteers were required to complete a volunteer monitor training course. This monitoring effort was quite successful due in large part to support from University of Santa Barbara laboratory which analyzed all of the nutrient samples and trained volunteer labor.

The Ventura River Watershed Monitoring Program ("Stream Team") was established conceptually in the spring of 2000 as a joint project of Santa Barbara Channelkeeper and Surfrider, Ventura Chapter (http://www.stream-team.org/Ventura/main.html). The Stream Team is conducts volunteer-based water quality monitoring at 15 sites throughout the Ventura River Watershed, from just above the estuary at the Main Street Bridge to pristine sites above Matilija Dam. As of 2006, volunteers collected over 250 data points each month since January 2001, and logged over 850 hours in the field.

Since 1999, FSCR have developed a strong volunteer base that helped with removal of invasive and noon-native weeds and planting on HRNA. With Trustee Council funding, a Volunteer Coordinator was hired to recruit and organize volunteers and to develop a stewardship program for the HRNA. A total of 40 workdays were conducted from 2005-2010 (October – April consisting of a total of 1,739 labor hours (Friends of the Santa Clara River 2011). The Volunteer Coordinator encouraged volunteer participation in all phases of the restoration project, including weed removal, installation of native plants, and on-going monitoring. Volunteers included school groups, home school groups, scout troops, Roots & Shoots (Jane Goodall Institute's international environmental and humanitarian program for youth of all ages), and local citizens. A press release for the entire volunteer season was sent to local newspapers, radio stations, schools, service clubs and scout troops, and former volunteers.

Schedule and Timing of Monitoring Period

Most monitoring of revegetation areas will be conducted in the first 10 years, either annually, or during selected years. Performance metrics for long-term sustainability of the ecosystem restored should be implemented every 5 years from years 10-30 after implementation of the restoration action. Recommended timing of monitoring each performance measure varies and is described in the section above on Setting Success criteria.

Vegetation monitoring should be conducted once a year between the middle and end of the growing season. Depending on the weather each year and environmental site conditions, optimal monitoring should be conducted between June 1 and August 30. A combination of preliminary site inspections and professional ecological judgment must be used when determining the timing of monitoring each year.

Reporting

The Monitoring Plan for each restoration area should be finalized at least 1 year before the restoration actions are implemented so that pre-project baseline monitoring data can be collected. The plan should include at the minimum the following sections:

- Introduction and background
- Monitoring approach and design
- Schedule
- Monitoring methods and protocols
    - Invasive and non-native plants
    - Native riparian plants
    - Plant community structure
    - Bird and wildlife surveys
    - Mapping extent of invasive species and native riparian habitat
    - Riverine wetlands and riparian habitat conditions assessment (CRAM)
    - Long-term sustainability assessment
    - Other surveys based on project specific goals and objectives
- Reference and control sites
- Photo monitoring
- Literature cited

Monitoring reports should be prepared at the end of each monitoring year for the duration of the 10 year monitoring period. Reports should present results of each monitoring metric related to each success criteria target, reference sites, and control sites over time. Any changes in methods or protocols should be noted in the report and should include recommendations on any adaptive management that should be taken resulting from data analyzed during that monitoring period. A final comprehensive Monitoring Report should be conducted after the year 10 monitoring data for all performance metrics. Monitoring reports should be prepared for years 15, 20, 25 and 30 as well as 10 year monitoring reports for any supplemental plantings.

The following data should be submitted at the end of each monitoring year to each of the following organizations:

- Annual invasive and non-native species mapping and location data to Calflora using the Cal Weed Mapper tool (http://www.calweedmapper.org/).

- Annual CRAM scores online to the California Wetlands Portal located at: http://www.cramwetlands.org/cramdataentry.html
- Plant composition data to CNPS/CDFG Vegetation Program

Management and Implementation

Long-term Management and Restoration Plan

The following are recommendations for restoration management and implementation that we have compiled from experiences working on riparian restoration projects throughout California. We recommend developing a long-term management and conceptual restoration plan all properties in the Santa Clara River Parkway. The HRNA management and restoration plan may be used as a model for the larger Parkway (URS Corporation 2003).

The HRNA plan is based on the restoration element approach that prioritizes restoration activities and integrates these into long-term management programs. According to this approach, a series of 'restoration elements' and 'restoration actions,' is developed and then combined into several restoration scenarios. Restoration elements are broader categories, such as the riparian enhancement element, whereas restoration actions are various subsets of elements or tasks related to an element (i.e., restoration of a large riparian forest or riparian habitat enhancement through invasive plant removal). Selected elements and actions are combined into feasible, logical scenarios, by cost and type of funding/action. Scenarios are then evaluated to determine the preferred scenario as each funding opportunity becomes available and then incorporated into a preferred long-term ecosystem management and restoration program. Alternatively, if none of the restoration scenarios developed in this plan adequately addresses the funding opportunity sought, elements may be used individually or with other elements in various combinations.

The HRNA plan presented the range of possible management and restoration elements and actions that could be implemented on HRNA. Five restoration scenarios were developed according to funding type and three were grouped according to implementation cost (high, medium and low cost). Cost estimates associated with each restoration element action were presented in this plan. Using this plan, Friends of the Santa Clara River (FSCR) HRNA Steering Committee were able to successfully make decisions as to which restoration elements to implement both in the short and long term based on the particular funding opportunities that were available. All restoration elements/actions were not necessarily implemented due to passive revegetation that occurred after the January and February 2005 floods. Restoration of natural riverine wetlands and riparian habitats were successfully restored by the FSCR from 2003 until 2011.

UC Research Station and Conservation Center and Manager

The Trustee Council, State Coastal Conservancy and TNC support the development of a UC Research Station and Conservation Center on the Santa Clara River. The vision for the Santa Clara River field station is to support and conduct environmental research, biodiversity conservation, and ecosystem restoration in the Santa Clara River watershed. The Center will serve as a base for academic research studies, teaching and outreach programs that include an interpretive center and volunteer program, and a natural resource information center to support regional floodplain management and restoration. The UC Research Station and Conservation Center staff will serve in an advisory role and assist with planning, implementation, and coordination of ecological-based monitoring and restoration projects in the watershed. The UC Research Station and Conservation Center Manager will be in charge of managing ecological monitoring and ecological restoration research projects on the Santa Clara River, and will serve as the head of the TAC that reviews all restoration monitoring reports. In partnership with TNC, the station is proposed to be based in Santa Paula, CA on a 1,000 acre property with a diversity of riparian and upland habitats.

Build a Native Plant Nursery on the UC Research Station and Conservation Center Site

A native plant nursery is planned to be constructed as part of the proposed UC Research Station and Conservation Center site. This nursery must be large enough to support multiple revegetation areas on the Santa Clara River concurrently. Currently, there are two proposed locations: (1) expansion of the native plant nursery established on HRNA for on-site restoration, or (2) development of a native plant nursery adjacent to the proposed UC Research Station and Conservation Center.

Data Management and Dissemination

We have tried to incorporate as many existing state and federal monitoring protocols into our recommended monitoring framework presented in this handbook in an attempt to share monitoring data with these agencies and organizations. Our intent is to provide consistently collected, high quality data that can be compared both throughout the Santa Clara River watershed and the State of California. These monitoring datasets may be used to for multiple purposes including: (1) insure that invasive weed removal and revegetation is implemented per project plans, (2) improve our understanding of the effectiveness of invasive weed removal and revegetation techniques of riverine wetlands and riparian habitat after removal; and (3) provide high-resolution spacial data on five invasive, non-native target species and extent of riverine wetlands, as well as CRAM scores at each restoration area for statewide use.

The UC Research Station and Conservation Center Manager will manage all monitoring data on a GIS geo-database established for the river. After collected, spatial GPS data and other monitoring data should be entered into the established Santa Clara River monitoring database by the UC Research Station and Conservation Center staff or submitted by the organization collecting the data in the proper database format. GIS data collected for the five invasive, non-native target species should be reported each year for the duration of the 10 year monitoring period to Calflora using the Cal Weed Mapper tool (http://www.calweedmapper.org/). GIS data on extent of riverine wetlands should be submitted to CDFG's Biogeographical Information and Observation System (BIOS) (http://bios.dfg.ca.gov/). CRAM data collected should be submitted to the California Wetlands Portal (http://www.cramwetlands.org/cramdataentry.html). Also, plant composition data should be sent to CNPS/CDFG Vegetation Program.

The Santa Clara River Parkway website (http://www.santaclarariver parkway.org/) was developed by the State Coastal Conservancy to facilitate the sharing of information among stakeholders and the public. Monitoring reports and GIS shapefile data should be made available on this web site for use by various stakeholders.

Bi-annual Science Symposium

The State Coastal Conservancy sponsored the first Santa Clara River science symposium on February 16, 2007 to facilitate sharing of scientific and management related study results among stakeholders involved in conservation and restoration on the Santa Clara River. This one-day workshop was held at Faulkner Farm and University of California, Hansen Agricultural Center in Santa Paula, California. Due to the success of this first science workshop and continued interest in conservation and restoration in the watershed, the State Coastal Conservancy and other organizations involved would like to continue holding a bi-annual science symposium on the State of the Santa Clara River. Results of invasive, weed removal and revegetation monitoring and lessons learned should be presented at this symposium by the UC Research Station and Conservation Center staff and restoration ecologists working on these projects.

CHAPTER 6
RECOMMENDED NEXT STEPS

Develop Detailed Strategic Plan for Invasive Species Removal and Revegetation of Priority Sites

Based on updated mapping for each target invasive plant species, a detailed plan for prioritization of removal and revegetation sites should be completed. The goal of this task is to develop a comprehensive set of watershed maps illustrating prioritization of sites for target plant removal/revegetation based on our UCLA research results and results of other removal and revegetation projects in southern California. GIS spatial analyses will be performed as part of this task.

Currently, Stillwater Sciences and the UC Research Station and Conservation Center staff are working on a Strategic Plan for *Arundo* removal for the State Coastal Conservancy. The plan summarizes: 1) cost/acre estimates for different treatment methods, 2) potential permit requirements, and 3) *Arundo* treatment priorities for parcels in the Santa Clara River Parkway. In identifying treatment priorities, they are using the historical flood mapping for the Santa Clara River (Stillwater Sciences 2007) to define a "flood reset zone". They recommend herbicide treatment is contingent upon *Arundo* being naturally scoured away by high flow events. Above this zone, we recommend different treatment types based on the level of interspersed native vegetation, ranging from mowing before herbicide application to hand removal before herbicide application. Treatment priorities for Santa Clara River Parkway parcels (i.e., what *Arundo* patches should be treated first and why) are further based on criteria such as: onsite habitat quality, adjacent habitat quality, risk of reinfestation, fire risk, special features such as nodes of unusual vegetation, and the amount of surrounding *Arundo*.

Update Current Extent of Each Invasive Plant Species along the River

Vegetation mapping was conducted on the 500-year floodplain of the Upper Santa Clara River from November 2004-March 2005 by the VCRCD (Ventura County Resource Conservation District 2006) and on the Lower Santa Clara River from July to November 2005 with Trustee Council funding (Stillwater Sciences and URS Corporation 2007). A data gaps analysis was completed as part of the Santa Clara River Watershed Invasive Plant Removal (SCIPR) Program to review both vegetation mapping efforts and prepare a single database and a complete set of maps with a consistent resolution of data for the entire watershed. Recommended actions to improve the data set and to fill in these data gaps include:

1. Utilize a single mapping protocol to consolidate the current data and additional areas for mapping.
2. Conduct surveys in areas not previously surveyed, especially along tributaries.
3. Verify vegetation classification in areas impacted by flooding and/or wildfires.
4. Review atypical vegetation classification from previous surveys

Thorough and updated mapping of *Arundo* and Tamarisk populations along the River is essential for prioritizing and planning of removal of these infestations (Stillwater Sciences 2008, Wildscape Restoration 2009). These mapping efforts only represent a "snapshot" in time. The Santa Clara River is dynamic in nature - Large flood events, periods of drought or high rainfall, and wildfires change the vegetation and invasive plant species distribution along the River. For example, flood events in January and February, 2005 on the Santa Clara River resulted in extensive vegetation scouring and essentially resetting of portions of the floodplain. Thus, mapping in 2004 before the flooding in the upper Santa Clara River is inaccurate.

Arundo and Tamarisk population distributions were mapped over 6 years ago. Since there has not been a significant flood event since winter 2005, extent and biomass of *Arundo* and Tamarisk infestations have increased significantly in the floodplain areas reset these floods (Orr et al. 2011). Thus, we recommend updating of current extent of all five priority invasive species to inform prioritization removal strategies. Priority invasive species mapping should be updated regularly (every 5 years) using the following strategies or combination of these strategies:

- Remote sensing techniques can creates cost effective mapping solutions that allow more time, money and effort to be spent on removal of invasive plant infestations with greater distribution, such as *Arundo donax* and associated revegetation. Griswold et. al. (2009) demonstrated the ability to use readily available low cost natural color band aerial imagery to accurately, efficiently, and quantitatively map select invasive species like giant reed (*Arundo donax*) over time. This mapping approach utilizes supervised segmentation software in an automated process whereby the software extracts individual vegetation groups or features and creates digital polygons to represent them. The user then assigns the features according to land use or vegetation type. They utilized ground-truth data collected by plant ecologists to "train" the image analysis software to recognize the presence or absence of *Arundo* at the site. After the editing process, the features were exported into a GIS for mapping and analysis. Using 2005 NAIP imagery (1m spatial resolution), *Arundo* was correctly classified nearly 80% of the time when compared to known *Arundo* stands. *Arundo* mapping was found to be less accurate using the 2008 QuickBird imagery with near-infrared (NIR) band but lower spatial resolution (2.4m multispectral and 0.6m panchromatic).

- If remote sensing is used, accuracy assessment must be included.
- Vegetation types should be classified to Alliance level using A Manual of California Vegetation (Sawyer et al. 2009).
- Field verification must be conducted for any remote sensed mapping effort.
- If funding for remapping all five invasive species is limited, priority should be given to *Arundo* and Tamarisk located in priority removal areas identified by the Detailed Strategic Plan for Invasive Species Removal and Revegetation of Priority Sites (Stillwater Science and UCSB in preparation).
- Timing of mapping should be carefully assessed after flood events and/or wildfire. If mapping is done immediately after a flood event or wildfire in the areas most affected, mapping can be used for removal projects. Otherwise, waiting 1-2 years may be advantageous for mapping the extent of invasive plants post-flood more accurately.
- Mapping of invasive plants should be conducted as specified in Chapter 5 for as part of monitoring and evaluation of success criteria.

Survey Invasive Plant Species on Watch List

Surveys should be conducted along the 500-year floodplain of the Santa Clara River to assess the presence and distribution of the other 40 target invasive species on the watch list (Table 1). This task could be undertaken in a number of ways including:

- Conduct thorough invasive plant surveys when vegetation mapping is updated next. This will only work for species that are widely distributed, such as *Arundo*, if vegetation mapping is conducted using remote sensing technology. If vegetation is mapped primarily by field verification as in 2004-5, this would be the most efficient time to search and document these target invasive species.
- If planned and implemented carefully, a community-based volunteer monitoring program could be the most cost-effective way to carry out on-going invasive plant species mapping. Based on a successful model program

implemented at Hedrick Ranch Nature Area and the Upper San Joaquin River, a volunteer coordination team would be developed to oversee and work closely with local college student interns and community volunteers (i.e., California Native Plant Society) to identify and map invasive species on the Watch List. The UC Research Station and Conservation Center staff would train interns and volunteers in invasive plant identification and mapping protocols. To gain community support for this approach, several public outreach training workshops should be conducted for local land owners to find out more about target invasive species on their property. An initial pilot mapping effort along the river is recommended to demonstrate viability. The extent of target riparian invasive species would be mapped during field surveys with handheld GPS as polygons and waypoints depending on extent of each. This mapping method would require development of a Watershed mapping tool on the Santa Clara River Watershed Portal similar to the one developed by David Siedband for Putah Creek (http://www.watershedportals.org/lpccc/maps).

- Mapping of each plant species either by individual waypoints when their distribution is limited or by GPSing polygons when the species population is greater than the minimum mapping unit (approximately 100ft^2). When invasive plants are mixed with native vegetation, percent cover of each invasive species found within each vegetation type mapped may be estimated in the field (Stillwater Sciences and URS Corporation 2007).

Finalize the Santa Clara River Invasive Plant Removal Plan (SCIPR), Environmental Impact Report (EIR), and Programmatic Permits for the Lower Santa Clara River

The permitting requirements to conduct non-native plant control programs are onerous and expensive, often discouraging capable applicants and increasing proposed costs. Developing programmatic permits will facilitate implementation of on the ground habitat restoration work by reducing costs and time necessary to begin work. The following activities have been initiated to streamline this process, but a comprehensive permitting and environmental compliance program needs to be finalized for the Santa Clara River. Currently, programmatic permitting, environmental documentation, and implementation efforts described below are on hold. We believe finalizing a comprehensive permitting, environmental compliance program, and implementation plan is important for implementation of cost-effective and streamlined invasive plant removal and revegetation efforts.

The planning for the upper watershed contained several major tasks: 1) development of the Upper Santa Clara River *Arundo*/Tamarisk Removal Plan (SCARP); 2) surveying and mapping 16,400 acres within the upper watershed; 3) development of the programmatic California Environmental Quality Act (CEQA) Environmental Impact Report (EIR); 4) development of a water quality monitoring plan and quality assurance project plan; and 5) initiating baseline water quality monitoring at five sites.

The Ventura County Resource Conservation District (VCRCD, Somis, CA) completed the Upper Santa Clara River Watershed *Arundo*/Tamarisk Removal Plan (SCARP), Environmental Impact Report (EIR), and Programmatic Permits for the portion of the Santa Clara River watershed that is upstream of the Ventura/Los Angeles County line (funded by Proposition 13 and the Trustee Council). A long-term *Arundo*/Tamarisk removal implementation plan was developed for the 500-year floodplain of the upper Santa Clara River watershed (approximately 16,300 acres). In addition, this project included vegetation mapping, using a modified Sawyer Keeler-Wolf classification system. The EIR for the implementation work was prepared for the long-term plan and approved in February 2006. Wildscape Restoration, Inc. obtained the associated programmatic permits for the VCRCD for SCARP.

Wildscape Restoration, Inc. began preparing the Santa Clara River Invasive Plant Removal Plan (SCIPR), Environmental Impact Report (EIR), and Programmatic Permits for the VCRCD on the lower Santa Clara River. The original plan was for SCIPR to be integrated with SCARP to facilitate the removal of species such as *Arundo* (*Arundo donax*) and tamarisk (*Tamarix* spp.) through the inception of a programmatic review and permitting process on a watershed-wide basis (both Los Angeles and Ventura Counties).

Develop a Detailed Monitoring Plan for Santa Clara River

One a Strategic Plan for *Arundo* removal is completed, the UC Research Station and Conservation Center and TAC should be developed based on recommendations in this handbook and site specific surveys.

Establish and Monitor Reference Sites along the Santa Clara River

A series of reference sites should be identified and monitored along the Santa Clara River that represents the suite of physical conditions found along the river. Data collected from these reference sites will help to further develop success criteria based on ecological data. Three types of reference sites should be established: reference reaches sampled using transects and cross sections, from field experiments like our UCLA riparian field experiment next to HRNA, and establishing permanent monitoring plots in areas reset by the next flood or fire (sampling native plant species cohorts over time). Summer 2012 will be a unique opportunity to measure native plants at the UCLA Riparian Field Experiment - 10 years after establishment – to help in development of the 10 year targets for various performance metrics for 3 dominant native riparian species found on the river.

Remove Target Invasive Species throughout Watershed and Riparian Revegetation

Using the strategies presented in this handbook and other CalIPC resources (http://www.cal-ipc.org/ip/management/index.php), site-specific removal and revegetation implementation plans should be developed for target invasive plant species including: *Arundo* (*Arundo donax*), perennial pepperweed (*Lepidium latifolium*), creeping water- primrose (*Ludwigia peploides* ssp. *montevidensis*), smallflower tamarisk (*Tamarix parviflora*), and salt cedar (*Tamarix ramosissima*) and other new arrivals with high CalIPC ratings. Also, techniques for *Arundo* and Tamarisk removal and revegetation are summarized in the Calleguas Creek Watershed *Arundo*/Tamarisk Removal Program: Arroyo Simi Pilot Project Implementation Plan prepared for Ventura County Resource Conservation District (Wildscape Restoration 2008). The Trustee Council, State Coastal Conservancy and The Nature Conservancy should work together to plan and facilitate removal at priority sites as funding is available.

We recommend implementing removal and revegetation of large infestations using local contractors. Smaller invasive species infestations could be removed and revegetated continuously and most efficiently throughout the watershed through a Community Involvement Program. On terraces and floodplain areas not prone to frequent flooding, active riparian revegetation techniques should be employed, whereas allowing flood prone areas to passively revegetate is the most cost-effective strategy. See discussion in Chapter 2 for more detailed strategies.

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TABLES

Table 1. Preliminary list of invasive non-native riparian and aquatic plant species found or that have the potential to be found on the 500-year floodplain of the Santa Clara River. This list is not comprehensive, but reflects the most notable problem species.

Plant Species		CalIPC Rating		Removal Priority		Rationale for Removal Priority
Scientific name	Common name	High	Moderate	High Priority[1]	Watch List[2]	
Ailanthus altissima	tree-of-heaven		X		X	Moderate rating. Unknown distribution in watershed.
*Arundo donax**	giant reed	X		X		High rating. Wide distribution.
*Bromus diandrus**	ripgut brome		X		X	Moderate rating. Wide distribution.
Bromus madritensis ssp. *rubens*	red brome	X			X	High rating. Unknown distribution in watershed.
*Carduus pycnocephalus**	Italian thistle		X		X	Moderate rating. Wide distribution.
*Carpobrotus chilensis**	iceplant		X		X	Moderate rating. Limited distribution.
*Carpobrotus edulis**	Hottentot-fig	X			X	High rating. Invading in limited areas.
*Centaurea melitensis**	tocalote	X			X	High rating. Unknown distribution.
*Centaurea solstitialis**	yellow starthistle	X			X	High rating. Unknown distribution.
*Cirsium vulgare**	bull thistle		X		X	Moderate rating. Wide distribution.
*Conium maculates**	poison-hemlock		X		X	Moderate rating. Wide distribution.
*Cortaderia jubata**	jubatagrass	X		X	X	High rating. Limited distribution.
Cortaderia selloana	pampasgrass	X			X	High rating. Unknown distribution.
*Delaria odorata**	cape ivy	X			X	High rating. Limited distribution.
Egeria densa	Brazilian egeria	X			X	High rating. Not recorded in watershed.
Eichhornia crassipes	water hyacinth	X			X	High rating. Not recorded in watershed.
*Eucalyptus globulus**	Tasmanian blue gum		X		X	Moderate rating. Limited distribution.
*Festuca arundinacea**	tall fescue		X		X	Moderate rating. Limited distribution.
Ficus carica	edible fig		X		X	Moderate rating. Unknown distribution.
*Foeniculum vulgare**	Fennel	X			X	High rating. Limited distribution along

[1] Removal and revegetation discussed in this handbook.
[2] The watch list includes some species not yet observed on the Santa Clara River, but have been included on this list due to their known occurrence in other semi-arid systems of California (Vaghti and Greco 2007).
* = Plants found along the Santa Clara River.

Table 1. Preliminary list of invasive non-native riparian and aquatic plant species found or that have the potential to be found on the 500-year floodplain of the Santa Clara River. This list is not comprehensive, but reflects the most notable problem species.

Plant Species		CalIPC Rating		Removal Priority		Rationale for Removal Priority
Scientific name	**Common name**	**High**	**Moderate**	**High Priority[1]**	**Watch List[2]**	
						riparian/ upland ecotone.
Hedera helix, H. canariensis	English and Algerian ivy	X			X	High rating. Unknown distribution.
*Hirschfeldia incana**	shortpod mustard		X		X	Moderate rating. Wide distribution.
Hydrilla verticillata	hydrilla	X			X	High rating. Not recorded in watershed.
*Lepidium latifolium**	perennial pepperweed	X		X		High rating. Distribution known to fluctuate. Know populations in estuary and on HRNA.
Ludwigia peploides ssp. *montevidensis**	creeping water-primrose	X		X		High rating. Subspecies not confirmed but presumed non-native.
Mentha pulegium	pennyroyal		X		X	Moderate rating. Unknown distribution.
Lythrum salicaria	purple loosestrife	X			X	High rating. Not recorded in watershed.
*Mesembryantemum crystallinum**	crystalline iceplant		X		X	Moderate rating. Limited distribution.
*Myoporum laetum**	myoporum		X		X	Moderate rating. Limited distribution.
Myriophyllum aquaticum	parrotfeather	X			X	High rating. Not recorded in watershed.
*Nicotiana glauca**	tree tobacco		X		X	Moderate rating. Wide distribution.
*Phalaris aquatica**	hardinggrass		X		X	Moderate rating. Not recorded in watershed.
*Ricinus communis**	castorbean		limited		X	Limited rating. Wide distribution.
Rubus armeniacus	Himalaya blackberry	X			X	High rating. Unknown distribution.
*Schinus molle**	Peruvian peppertree		limited		X	Limited rating. Limited distribution.
Sesbania punicea	scarlet wisteria	X			X	High rating. Not recorded in watershed.
*Spartium junceum**	Spanish broom	X				High rating. Limited distribution.
*Tamarix parviflora**	smallflower tamarisk	X		X		High rating. Limited distribution.
*Tamarix ramosissima**	salt cedar	X		X		High rating. Wide distribution.
Vinca major	big periwinkle		X		X	Moderate rating. Unknown distribution.

Table 2. Plant distribution in competition plant groupings (four plants per grouping) used in the field experiment. (Source: modified from Coffman 2007)

Competition grouping treatment	**Plant species (number of species per grouping)**			
	Arundo donax	***Baccharis salicifolia***	***Salix laevigata***	***Populus balsamifera* ssp. *trichocarpa***
1-species grouping (monoculture)	4			
		4		
			4	
				4
2-species grouping	2	2		
	2		2	
	2			2
4-species grouping	1	1	1	1

Table 3. Four-way ANOVA significance table for percent plant survivorship during establishment by factors of species from one-species and two-species groupings combined (*Arundo donax* and three native riparian species, *Salix laevigata*, *Populus balsamifera* ssp. *trichocarpa*, and *Baccharis salicifolia*), soil moisture (high and low), nutrient additions (high and none), and light (high and low). Results are for three time periods: 1) cutting survivorship (March 2003), 2) plant survivorship at end of 2003, and 3) plant survivorship at end of 2004. Significant results are in bold. (Source: Coffman 2007)

Factors and interactions	Cuttings	2003	2004
Species	$F_{(3,48)} = 1.821$, $P = 0.156$	$F_{(3,48)} = 2.352$, $P = 0.084$	$F_{(3,48)} = 2.523$, $P = 0.069$
Soil moisture	$F_{(1,48)} = 1.346$, $P = 0.252$	$F_{(1,48)} = 4.029$, $P = 0.050$	$F_{(1,48)} = 1.858$, $P = 0.179$
Nutrients	$F_{(1,48)} = 0.050$, $P = 0.824$	$F_{(1,48)} = 0.042$, $P = 0.839$	$F_{(1,48)} = 0.046$, $P = 0.831$
Light	$F_{(1,48)} = 1.625$, $P = 0.208$	$F_{(1,48)} = 0.855$, $P = 0.360$	$F_{(1,48)} = 0.170$, $P = 0.682$
Species x soil moisture	$F_{(3,48)} = 1.456$, $P = 0.238$	**$F_{(3,48)} = 3.628$, $P = 0.019$***	$F_{(3,48)} = 2.100$, $P = 0.113$
Species x nutrients	$F_{(3,48)} = 0.398$, $P = 0.755$	$F_{(3,48)} = 0.513$, $P = 0.675$	$F_{(3,48)} = 0.723$, $P = 0.543$
Species x light	$F_{(3,48)} = 0.400$, $P = 0.754$	$F_{(3,48)} = 1.197$, $P = 0.321$	$F_{(3,48)} = 0.412$, $P = 0.745$
Soil moisture x nutrients	$F_{(1,48)} = 0.361$, $P = 0.551$	$F_{(1,48)} = 0.490$, $P = 0.487$	$F_{(1,48)} = 1.018$, $P = 0.318$
Soil moisture x light	$F_{(1,48)} = 0.022$, $P = 0.884$	$F_{(1,48)} = 0.000$, $P = 0.984$	$F_{(1,48)} = 1.455$, $P = 0.234$
Nutrients x light	$F_{(1,48)} = 0.624$, $P = 0.434$	$F_{(1,48)} = 0.001$, $P = 0.980$	$F_{(1,48)} = 0.138$, $P = 0.712$
Species x soil moisture x nutrients	$F_{(3,48)} = 0.124$, $P = 0.946$	$F_{(3,48)} = 0.265$, $P = 0.850$	$F_{(3,48)} = 1.266$, $P = 0.296$
Species x soil moisture x light	$F_{(3,48)} = 2.431$, $P = 0.077$	$F_{(3,48)} = 1.253$, $P = 0.301$	$F_{(3,48)} = 1.543$, $P = 0.215$
Species x nutrients x light	$F_{(3,48)} = 1.193$, $P = 0.322$	$F_{(3,48)} = 2.046$, $P = 0.120$	$F_{(3,48)} = 0.921$, $P = 0.438$
Soil moisture x nutrients x light	$F_{(1,48)} = 0.111$, $P = 0.740$	$F_{(1,48)} = 0.772$, $P = 0.384$	$F_{(1,48)} = 1.359$, $P = 0.249$
Species x soil moisture x nutrients x light	$F_{(3,48)} = 2.212$, $P = 0.099$	$F_{(3,48)} = 2.104$, $P = 0.112$	$F_{(3,48)} = 2.431$, $P = 0.077$
r^2	0.428	0.490	0.457

* = 0.05 ≥ P > 0.01 = significant; ** = 0.01 ≥ P > 0.001 = highly significant; *** = P ≤ 0.001 = very highly significant.

Table 4. Minimum height of riparian plant species 3 and 5 years after planting. (Source: CDFG Stream Alteration Agreement reviewed).

TABLE OF MINIMUM HEIGHT AFTER 3 AND 5 YEARS				
SPECIES	SIZE AT PLANTING (GALLONS)	PLANTING CENTERS	HEIGHT	
			3 years	5 years
arroyo willow	1 gallon	8 ft	10 ft	15 ft
black willow	1 gallon	8 ft	12 ft	18 ft
sandbar willow	1 gallon	5 ft	4 ft	6 ft
red willow	1 gallon	8 ft	9 ft	15 ft
California sycamore	1 gallon	20 ft	5 ft	9 ft
California bay laurel	1 gallon	20 ft	5 ft	7 ft
Black walnut	1 gallon	20 ft	7 ft	12 ft
black and Freemont cottonwood	1 gallon	20 ft	7 ft	12 ft
white alder	1 gallon	15 ft*	6 ft	11 ft
OAKS				
coast live oak	1 gallon	20 ft	3 ft	6 ft
canyon live oak	1 gallon	20 ft	3 ft	6 ft
scrub oaks	1 gallon	20 ft	2 ft	4 ft
all shrub species	1 gallon	8 ft	2 ft	4 ft

*** 40 ft on center if used as a supplementary species.**

Table 5. Mean height [in feet (cm)] of three native riparian trees, one native shrub, and invasive, non-native *Arundo donax* at the end of the first and second growing seasons with no artificial irrigation added (± 0.1 refers to the standard error of the mean).

Plant Species	Year 1				Year 2			
	High Soil Moisture		Low Soil Moisture		High Soil Moisture		Low Soil Moisture	
	High Light	Low Light	High Light	Low Light	High Light	Low Light	High Light	Low Light
Black Cottonwood (*Populus balsamifera* ssp. *trichocarpa*)	8.4 ± 0.3 (257 ± 8)	8.2 ± 0.2 (251 ± 7)	6.5 ± 0.2 (198 ± 5)	6.0 ± 0.2 (184 ± 5)	13.7 ± 0.5 (418 ±15)	11.4 ± 0.3 (347 ± 9)	8.2 ± 0.2 (251 ± 7)	9.1 ± 0.3 (276 ± 8)
Mule Fat (*Baccharis salicifolia*)	8.7 ± 0.1 (265 ± 4)	8.8 ± 0.2 (269 ± 6)	7.4 ± 0.1 (225 ± 4)	8.4 ± 0.1 (256 ± 4)	11.6 ± 0.2 (354 ± 5)	10.8 ± 0.2 (329 ± 6)	10.3 ± 0.1 (314 ± 4)	11.1 ± 0.2 (339 ± 5)
Red Willow (*Salix laevigata*)	8.3 ± 0.3 (254 ± 11)	7.4 ± 0.3 (226 ± 8)	6.1 ± 0.2 (185 ± 6)	7.6 ± 0.2 (231 ± 5)	13.4 ± 0.6 (408 ± 19)	11.1 ± 0.4 (339 ± 12)	7.2 ± 0.3 (221 ± 8)	11.2 ± 0.2 (341 ± 7)
Arroyo Willow[3] (*Salix lasiolepis*)		8.4 ± 0.2 (255 ± 7)				11.5 ± 0.1 (349 ± 2)		
Arundo (*Arundo donax*)	11.2 ± 0.2 (343 ± 6)	11.6 ± 0.2 (354 ± 7)	8.5 ± 0.2 (260 ± 5)	12.0 ± 0.2 (365 ± 7)	17.9 ± 0.4 (546 ± 11)	16.7 ± 0.3 (510 ± 9)	11.4 ± 0.2 (346 ± 5)	16.3 ± 0.2 (497 ± 5)

[3] These averages are only based on sample size of 3 individuals from the high soil moisture shaded treatment.

Table 6. Conceptual timing of *Arundo* removal, revegetation, monitoring, and maintenance on the Santa Clara River (timing may vary slightly for some activities based on weather and site conditions).

Restoration Activity (associated tasks)	Timing											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
***Arundo* Removal**[4]												
• bend-and-spray method								X	X	X	X	
• hook method								X	X	X	X	
• cut-stump method								X	X	X	X	
Riparian Revegetation												
• cut 1m poles (cuttings) after riparian plants senesce	X										X	X
• soak in water for 1 day – 1 week immediately after cutting	X										X	X
• install riparian pole cuttings	X	X									X	X
• collect seed from native riparian plants (depends on plant species phenology and weather)						X	X	X	X	X		
• grow plants from seeds (depends on propagation method, seed treatment requirements, and irrigation type)	X	X								X	X	X
• install container plants	X	X									X	X

[4] Follow up spraying of resprouts must be done on an annual basis once resprouts are approximately three feet tall.

Table 6. Conceptual timing of *Arundo* removal, revegetation, monitoring, and maintenance on the Santa Clara River (timing may vary slightly for some activities based on weather and site conditions).

Restoration Activity (associated tasks)	Timing											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Monitoring (Success Criteria)												
• Extent of Invasive Plant Species						X	X					
• Extent of Riverine Wetlands and Riparian Habitat			X	X								
• Quality of Riverine Wetland and Riparian Habitat							X					
• Survivorship, Health and Growth of Riparian Plantings							X					
• Plant Species Diversity							X					
• Plant Community Structure and Composition							X					
• Wildlife Activity in and near Restored Riverine Wetlands and/or Riparian Habitat	• Surveys should be conducted during breading season for each bird species											
• Long-term Sustainability of Ecosystem			H4	H4			H1-3					
Maintenance												
• plant replacement cuttings and container plants	X										X	X
• respray *Arundo* (or as soon as plants reach 3 feet tall)								X	X	X		

Table 7. Minimum number of species and % cover for each riparian growth form at 1-2, 5 and 10 year monitoring periods.

Riparian Plant Growth Form	Years 1-2		Year 5		Year 10	
	No. species	% cover	No. species	% cover	No. species	% cover
trees	4	5%	4	20%	3	40%
shrubs	2	5%	2	10%	2	20%
graminoids	3	5%	2	10%	2	10%
forbs	7	5%	6	10%	5	10%
vines	2	5%	2	10%	1	10%

Note: These success criterion targets are based on understanding of the general community structure of riparian plant communities along the Santa Clara River is gaining reaches. Data on these targets should be measured at reference sites and modified based on data collected on this metric over a 10 year period.

Table 8. Recommended monitoring approaches for measuring eight success criteria and associated metrics.

Success Criteria		GPS extent (area)	CRAM conditions assessment	Permanent Plot	Transect	Measure all Plantings
A	**Extent of Invasive Plant Species**	X				
B	**Extent of Riverine Wetlands and Riparian Habitat**	X				
C	**Quality of Riverine Wetland and Riparian Habitat**		X			
D	**Survivorship, Health and Growth of Riparian Plantings**			D5-D8	D5-D8	D1-D4
E	**Plant Species Diversity**			Years 3-10	Years 3-10	Years 1-2
F	**Plant Community Structure and Composition**			F2 & F1 (Years 3-10)	F2 & F1 (Years 3-10)	F1 (Years 1-2)
G	**Wildlife Activity in and near Restored Riverine Wetlands and/or Riparian Habitat**			G1-G2	G1-G2	G3 (entire river reach next to plantings)
H	**Long-term Sustainability of Ecosystem**	H2, H4		H1, H3	H1, H3	

FIGURES

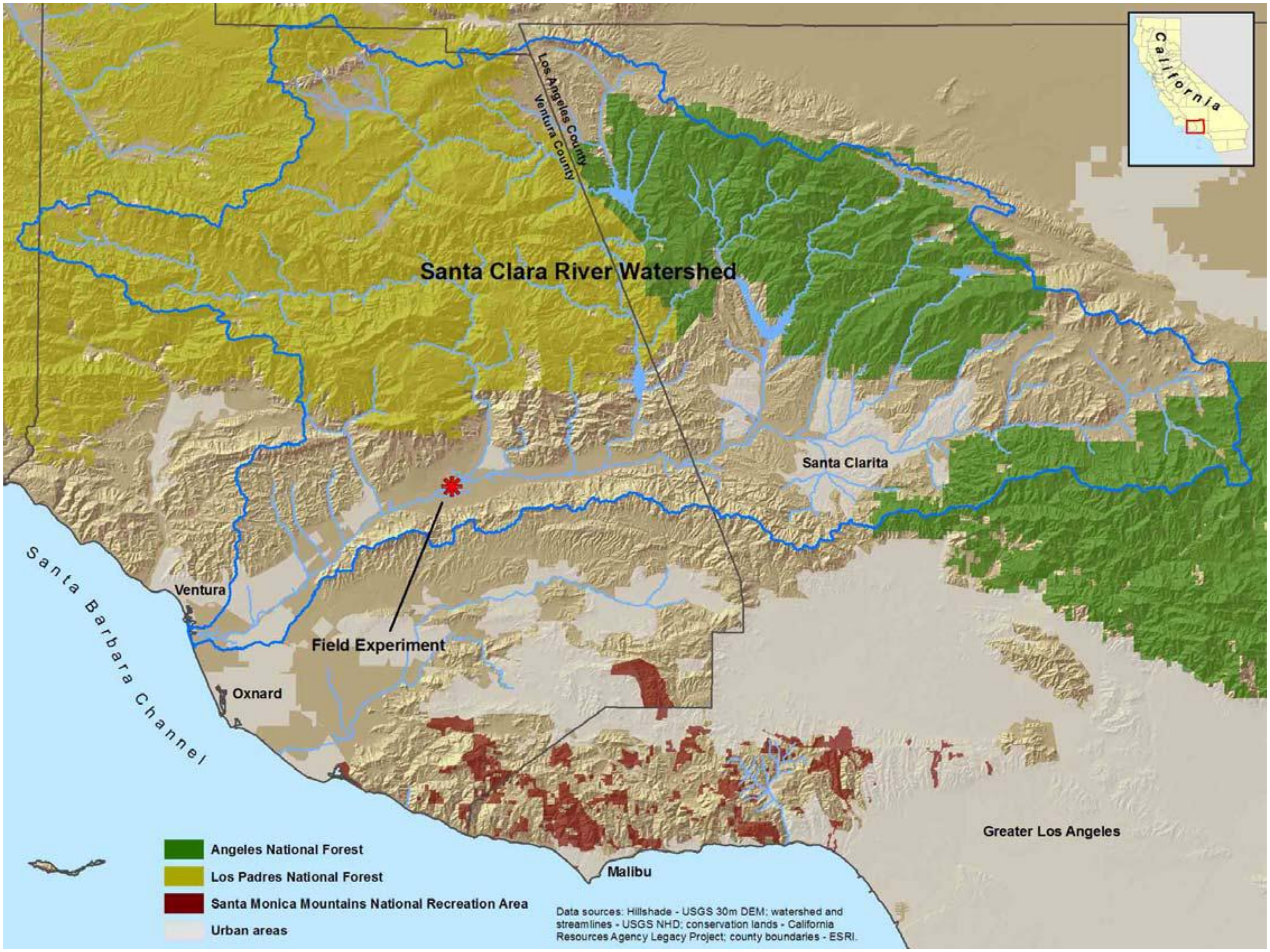


Figure 1. Location of UCLA riparian field experiment study site, Santa Clara River Watershed, Ventura County, California.

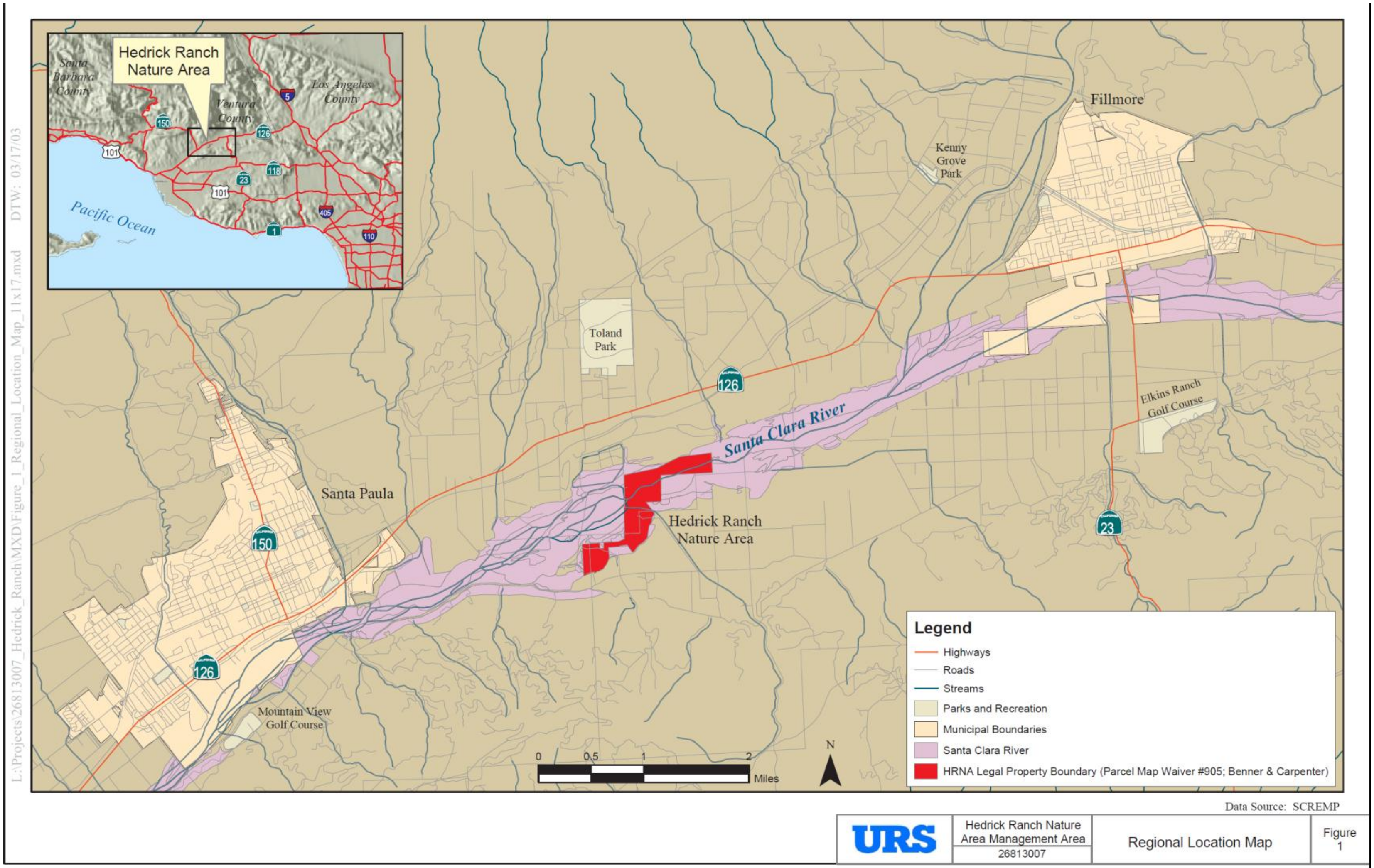


Figure 2. Location of Hedrick Ranch Nature Area, Santa Clara River Parkway property, Ventura County, California. (Source: Coffman 2007)

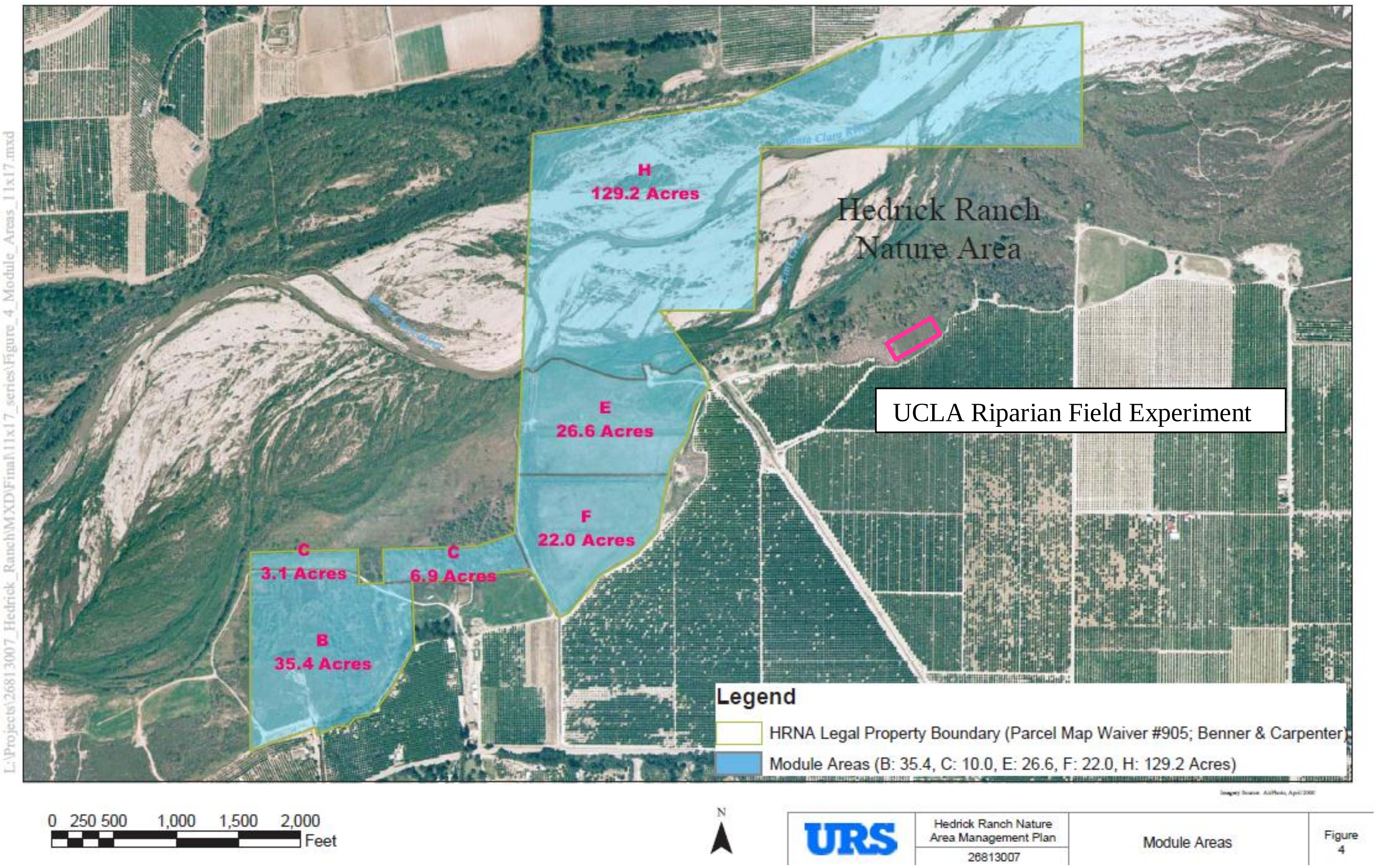


Figure 3. HRNA and UCLA Riparian Field Experiment boundaries and restoration areas. (Source: URS 2003)

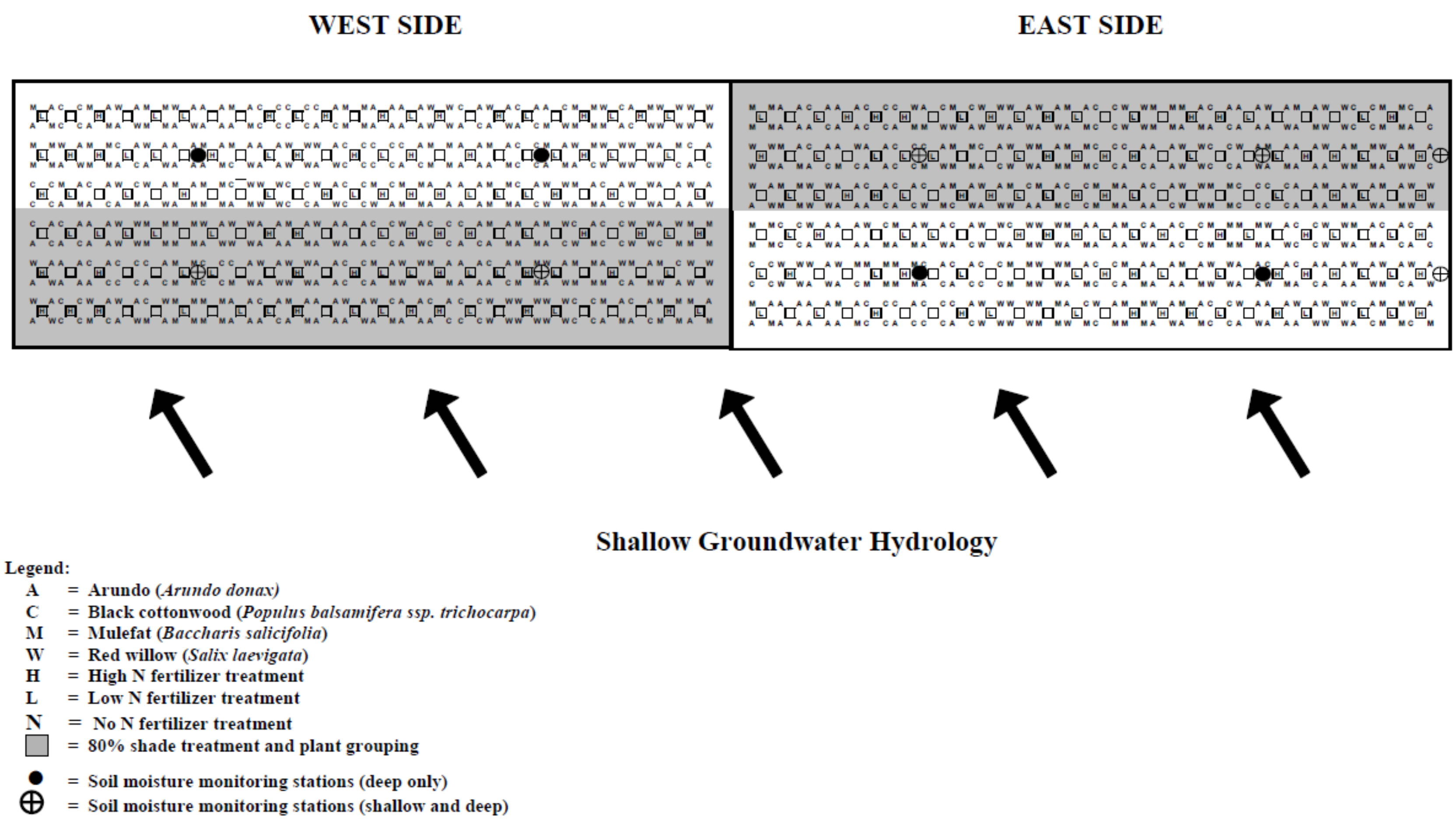


Figure 4. UCLA riparian field experiment planting and sampling layout. (Source: Coffman 2007)

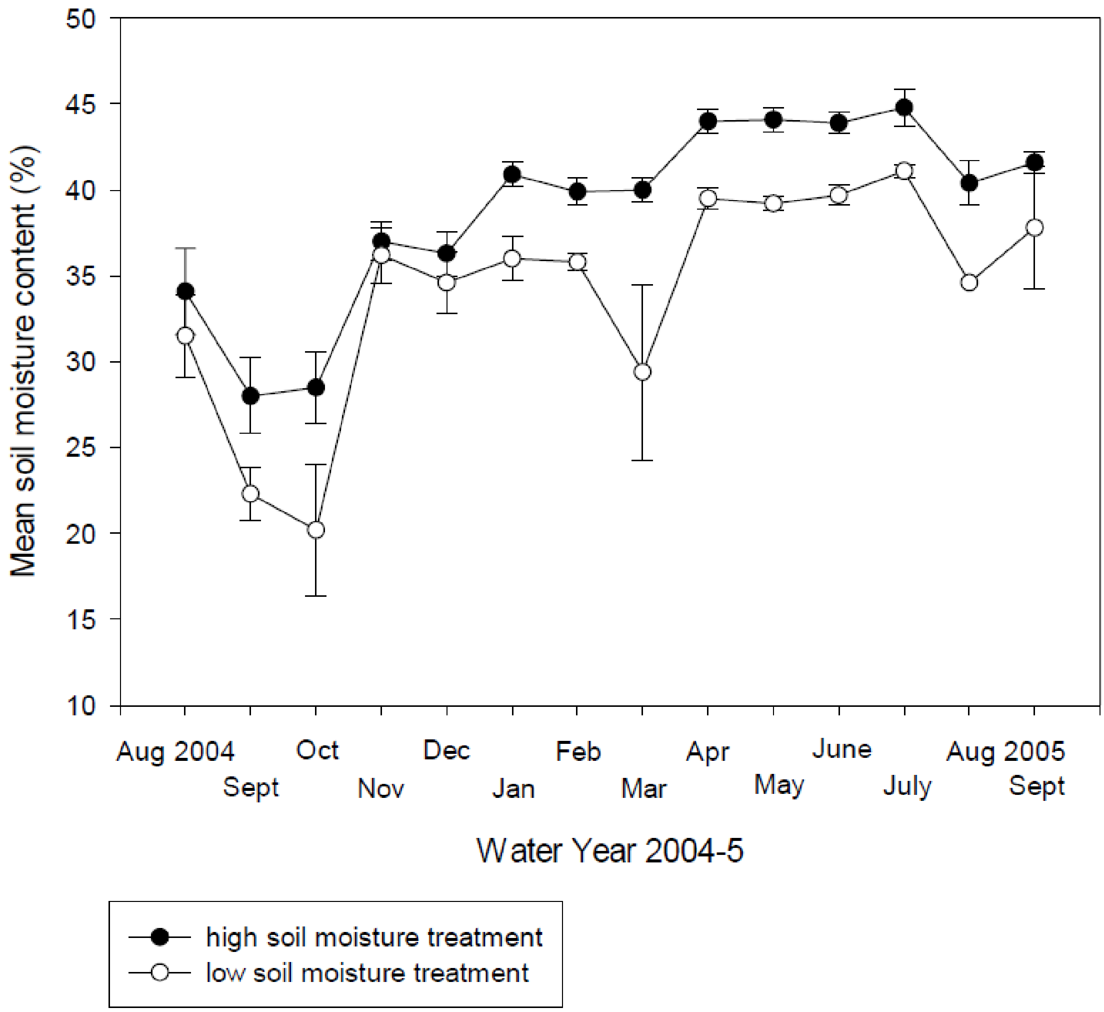


Figure 5. Mean monthly soil moisture content (percent) at 60–80 cm depth in the east compared to the west side of the experiment (high and low soil moisture treatments). (Source: Coffman 2007)

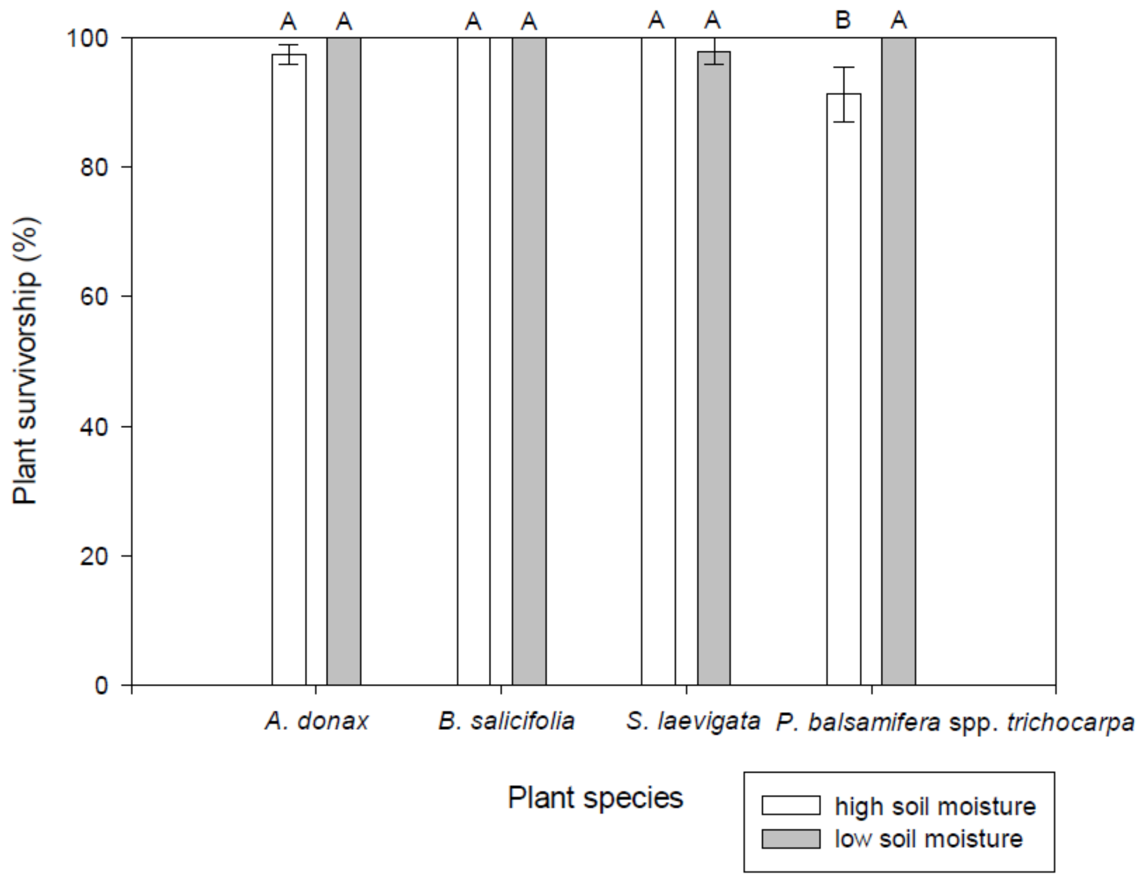


Figure 6. Effects of soil moisture availability treatments on percent plant survivorship of *A. donax* compared to three native riparian plant species at the end of the first growing season (fall 2003) based on the four-way ANOVA (competition x soil moisture x nutrients x light). Letters (A and Bs) denote results of post-hoc hypothesis tests (comparison of means) between individual treatments, with significance recognized at α <0.05. (Source: Coffman 2007)

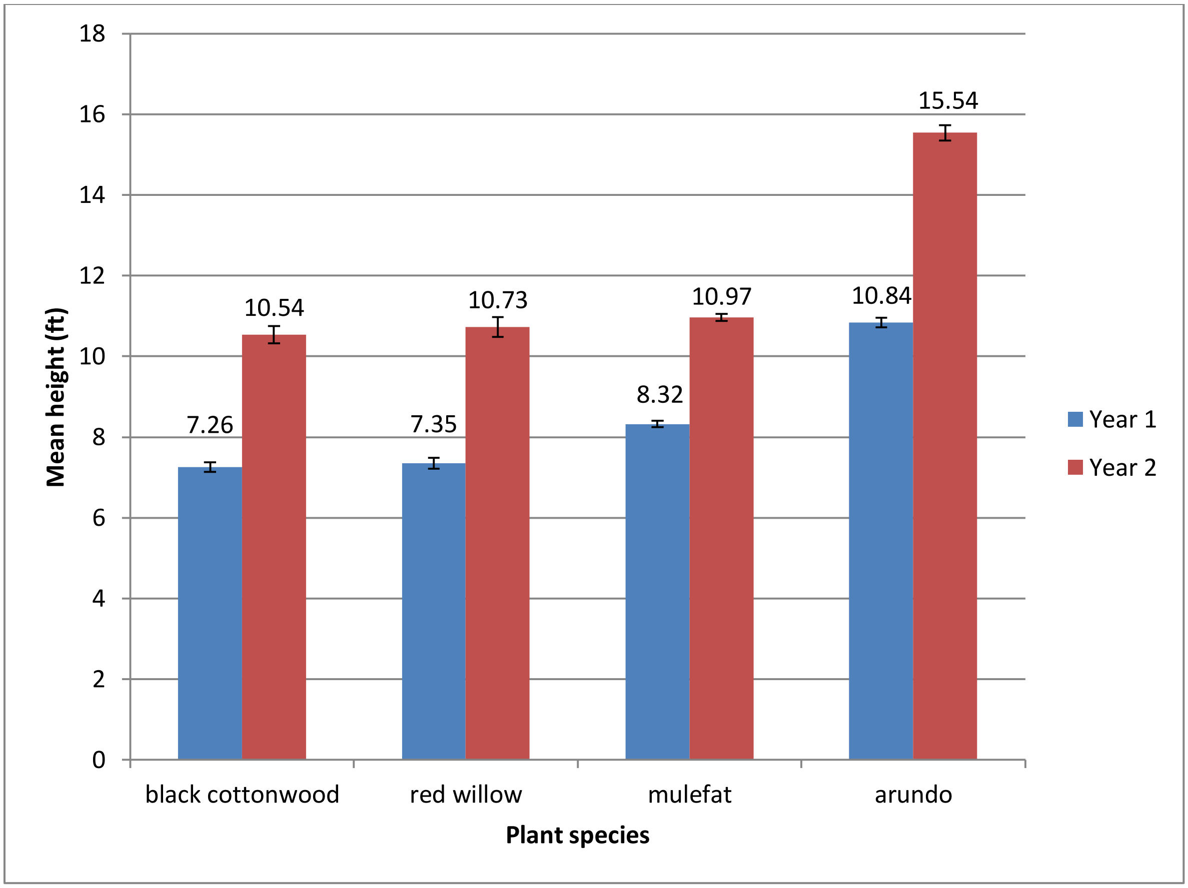


Figure 7. Comparison of mean heights (in feet) of native black cottonwood (*Populus balsamifera* ssp. *trichocarpa*), red willow (*Salix laevigata*), mulefat (*Baccharis salicifolia*) cuttings and non-native *Arundo* (*Arundo donax*) at the end of the first (year 1 = 2003) and second (year 2 = 2004) growing seasons. Mean heights include each of three native riparian cuttings and *Arundo* planted within all treatments combined (soil moisture, nutrients, light, and competition).

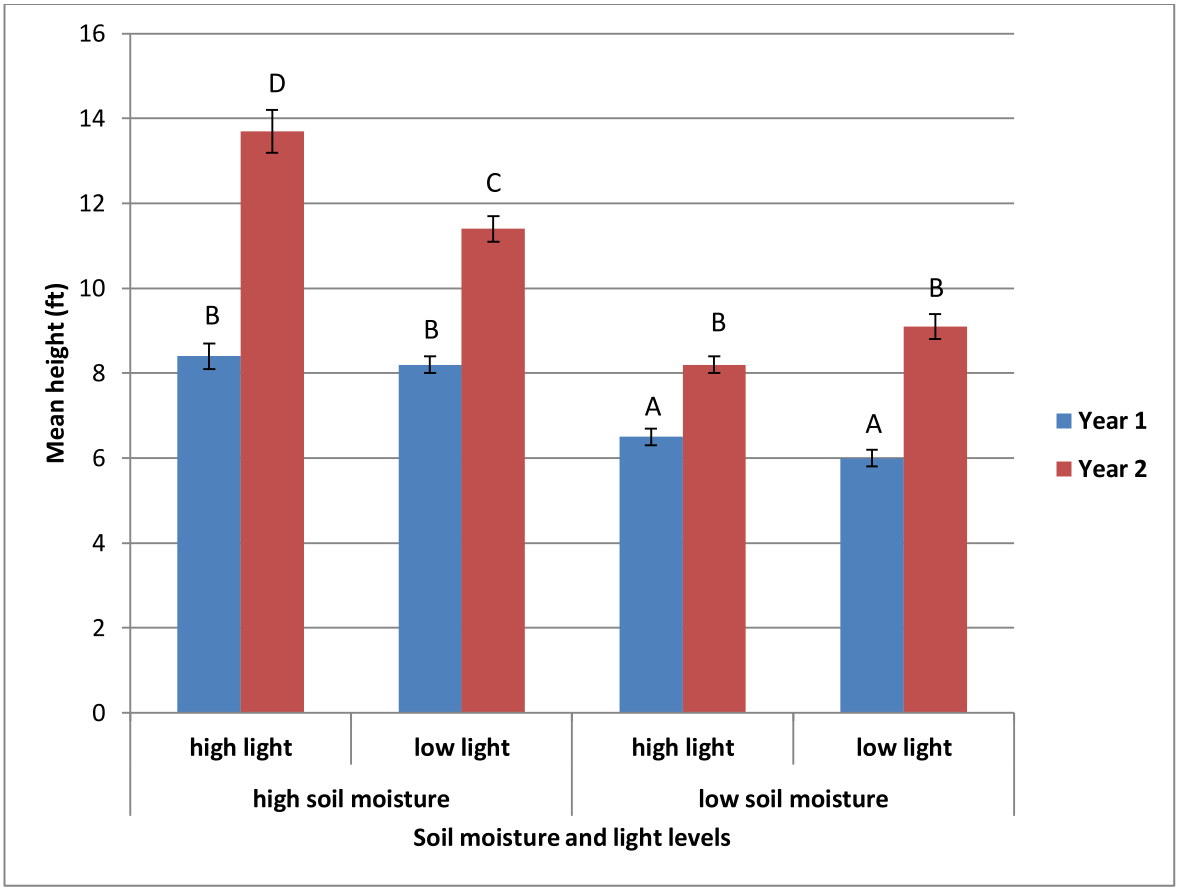


Figure 8. Comparison of mean heights in feet (± SE) of black cottonwood (*Populus balsamifera* ssp. *trichocarpa*) cuttings at the end of the first (year 1 = 2003) and second (year 2 = 2004) growing seasons grown under varying soil moisture and light treatment levels. Letters denote results of post-hoc hypothesis tests (comparison of means) between individual treatments, with significance recognized at α <0.05.

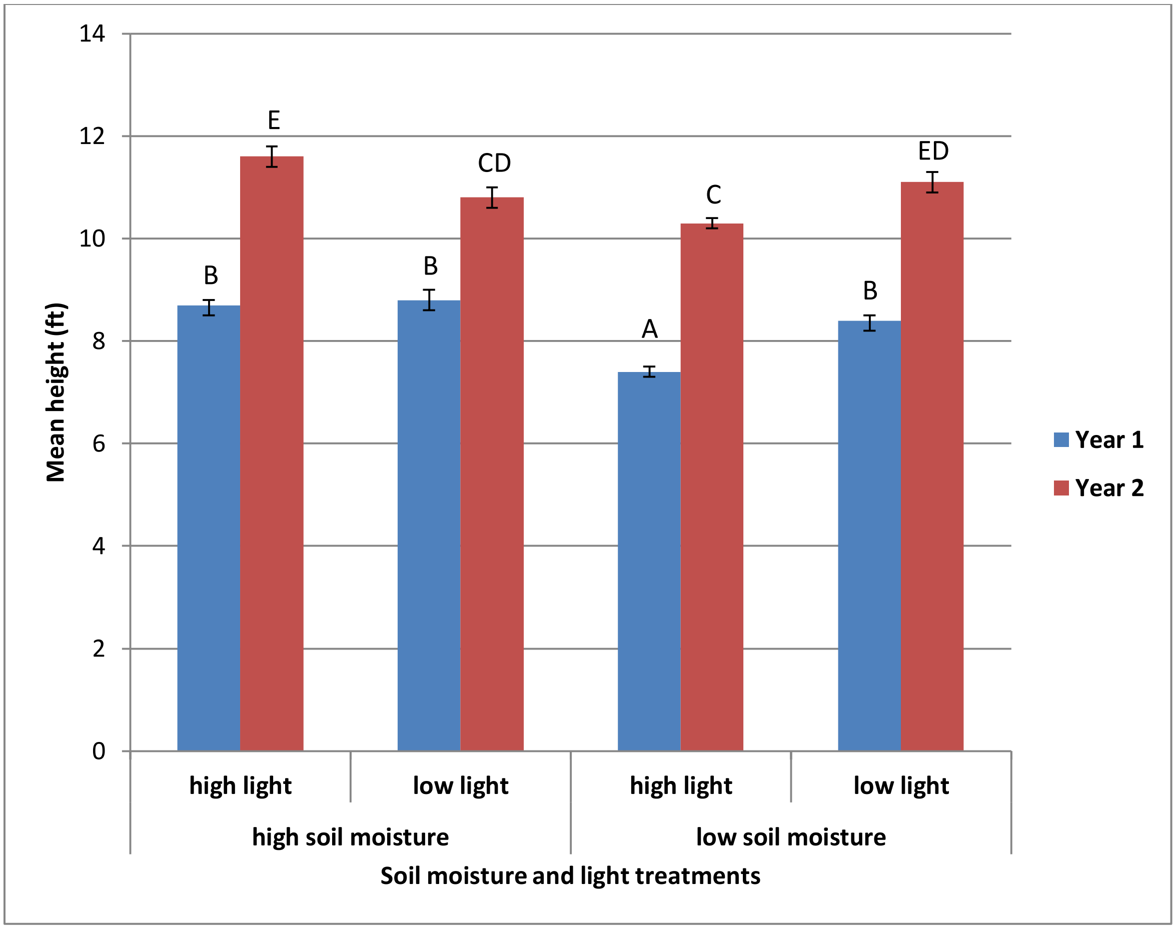


Figure 9. Comparison of mean heights in feet (± SE) of mulefat (*Baccharis salicifolia*) cuttings at the end of the first (year 1 = 2003) and second (year 2 = 2004) growing seasons grown under varying soil moisture and light treatment levels. Letters denote results of post-hoc hypothesis tests (comparison of means) between individual treatments, with significance recognized at α <0.05.

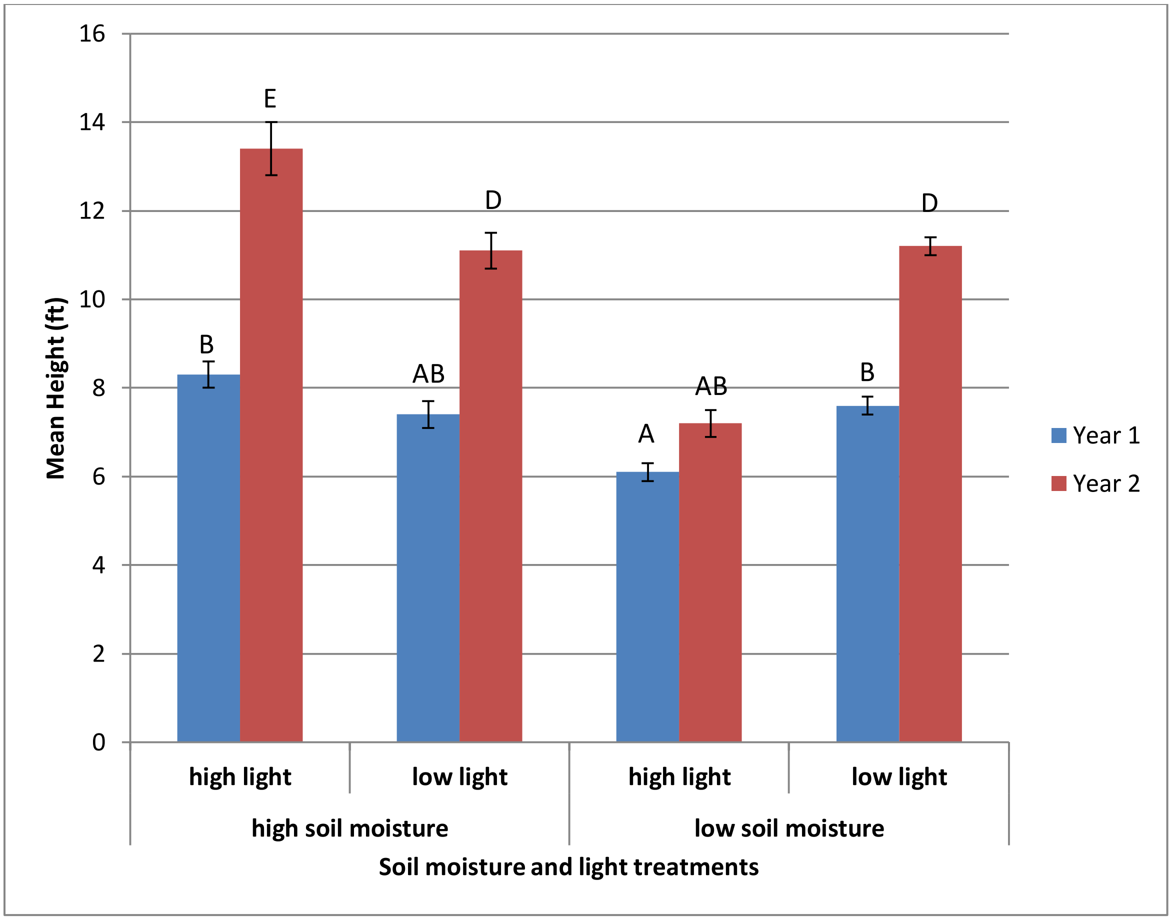


Figure 10. Comparison of mean heights in feet (± SE) of red willow (*Salix laevigata*) cuttings at the end of the first (year 1 = 2003) and second (year 2 = 2004) growing seasons grown under varying soil moisture and light treatment levels. Letters denote results of post-hoc hypothesis tests (comparison of means) between individual treatments, with significance recognized at α <0.05.

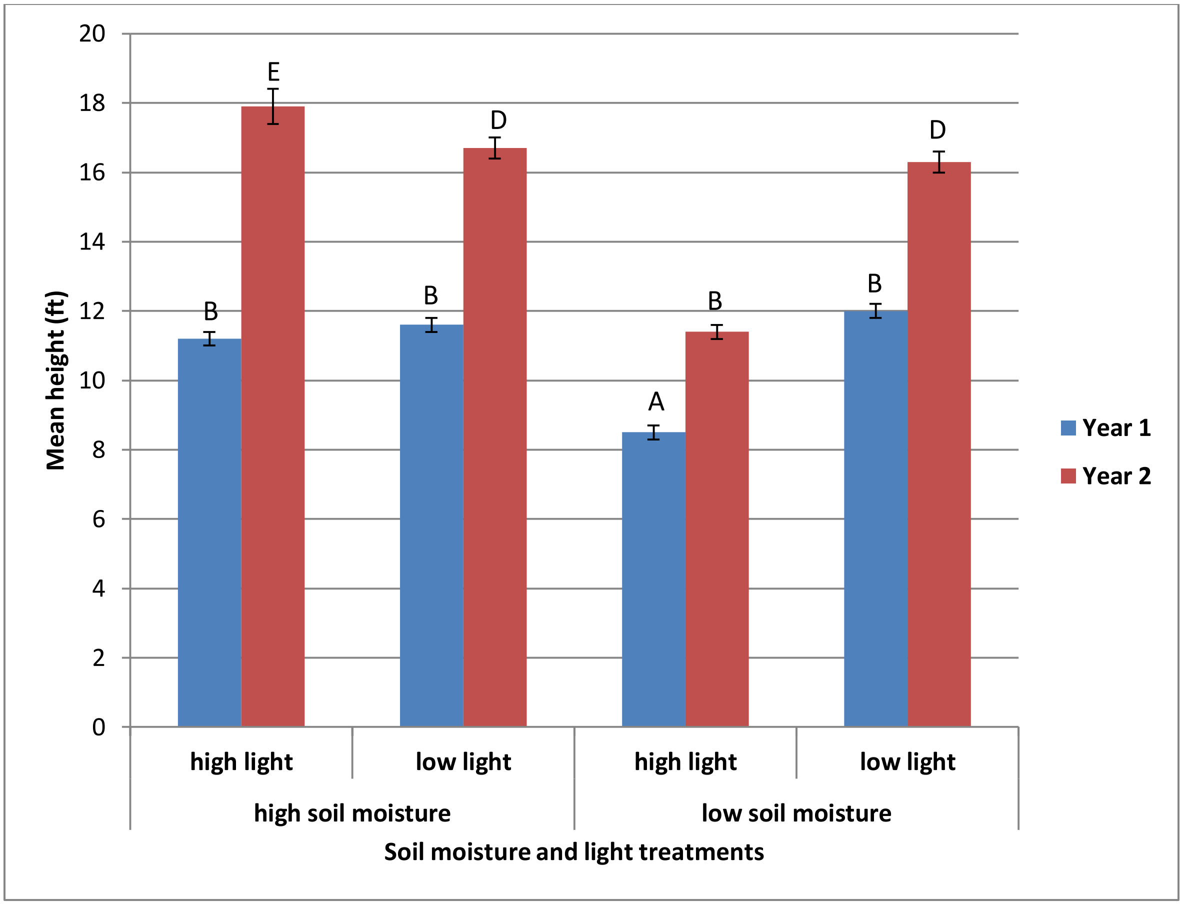
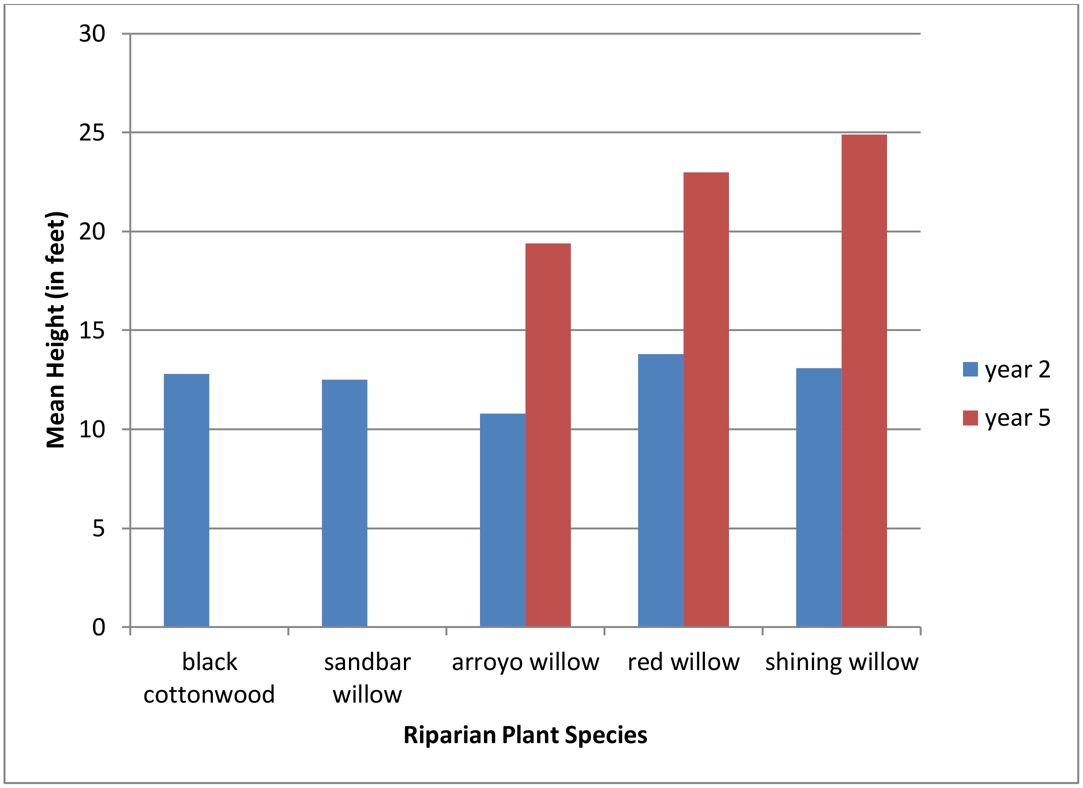
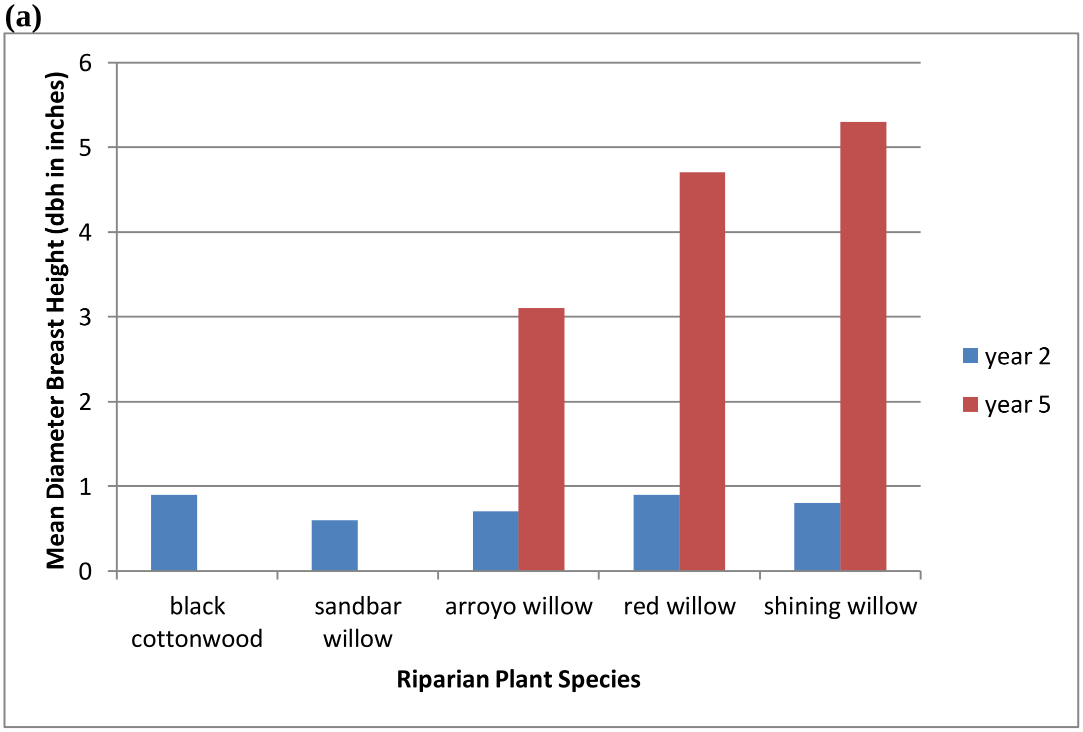


Figure 11. Comparison of mean heights in feet (± SE) of *Arundo* (*Arundo donax*) culms at the end of the first (year 1 = 2003) and second (year 2 = 2004) growing seasons grown under varying soil moisture and light treatment levels. Letters denote results of post-hoc hypothesis tests (comparison of means) between individual treatments, with significance recognized at α <0.05

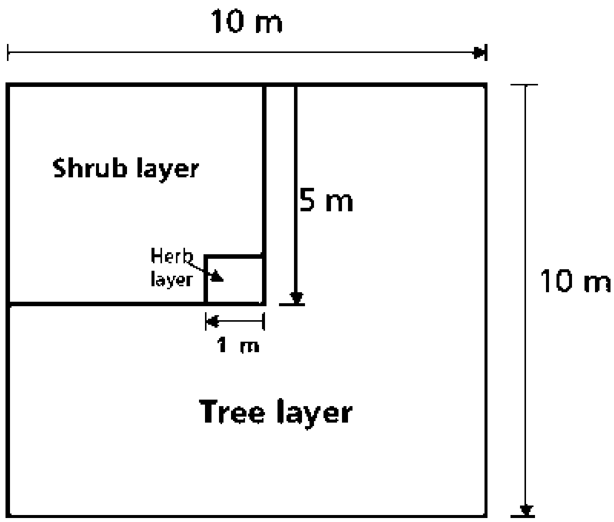


(a)

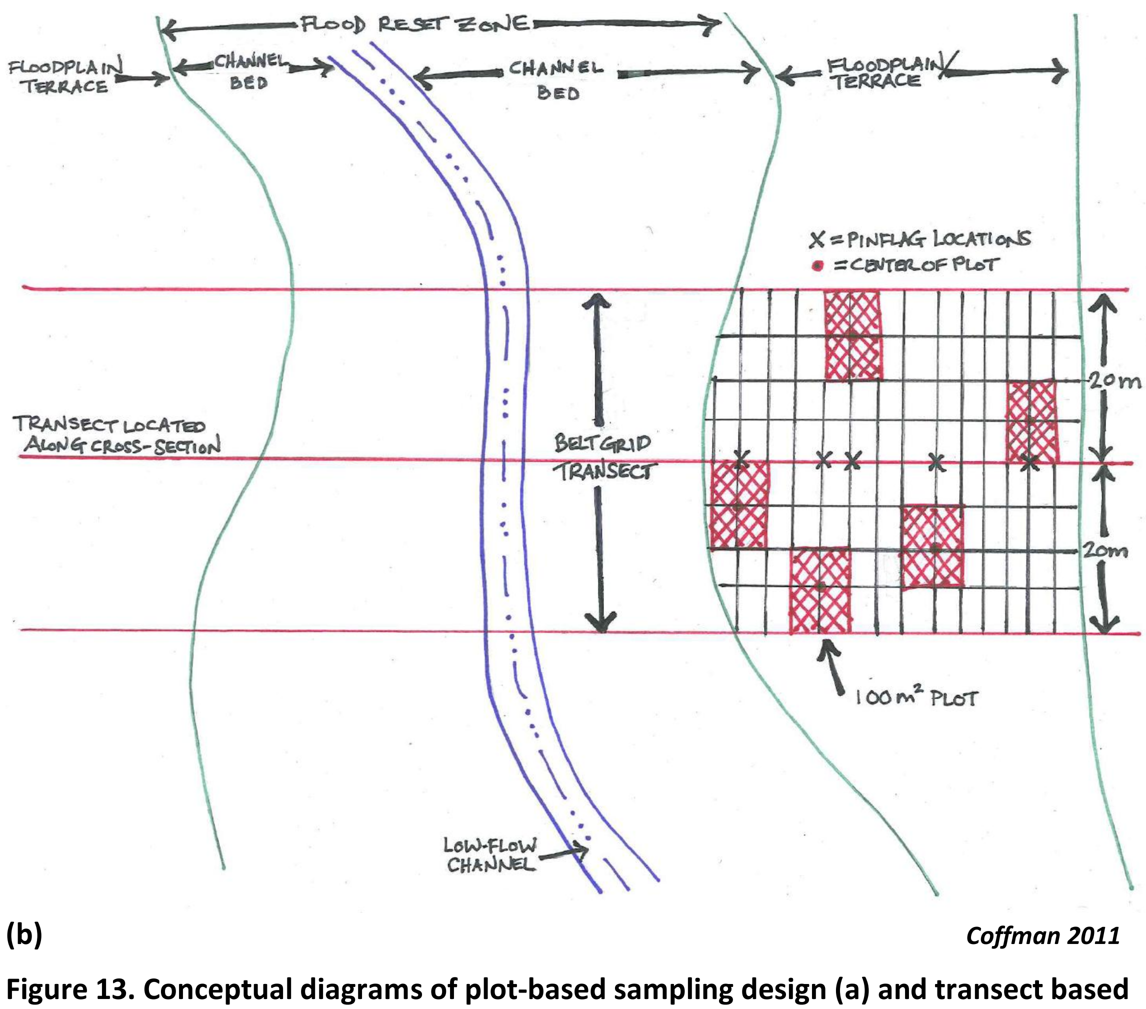


(b)

Figure 12. Comparison of (a) mean heights and (b) dbh in feet (± SE) of riparian tree and shrub species seedling cohorts at the end of the second (year 2 = 2007) and fifth (year 5 = 2010) growing seasons after 2005 floods.



(a) ***Source: Ponce-Hernandez 2004***



(b) ***Coffman 2011***

Figure 13. Conceptual diagrams of plot-based sampling design (a) and transect based sampling design (b) for riparian revegetation monitoring.

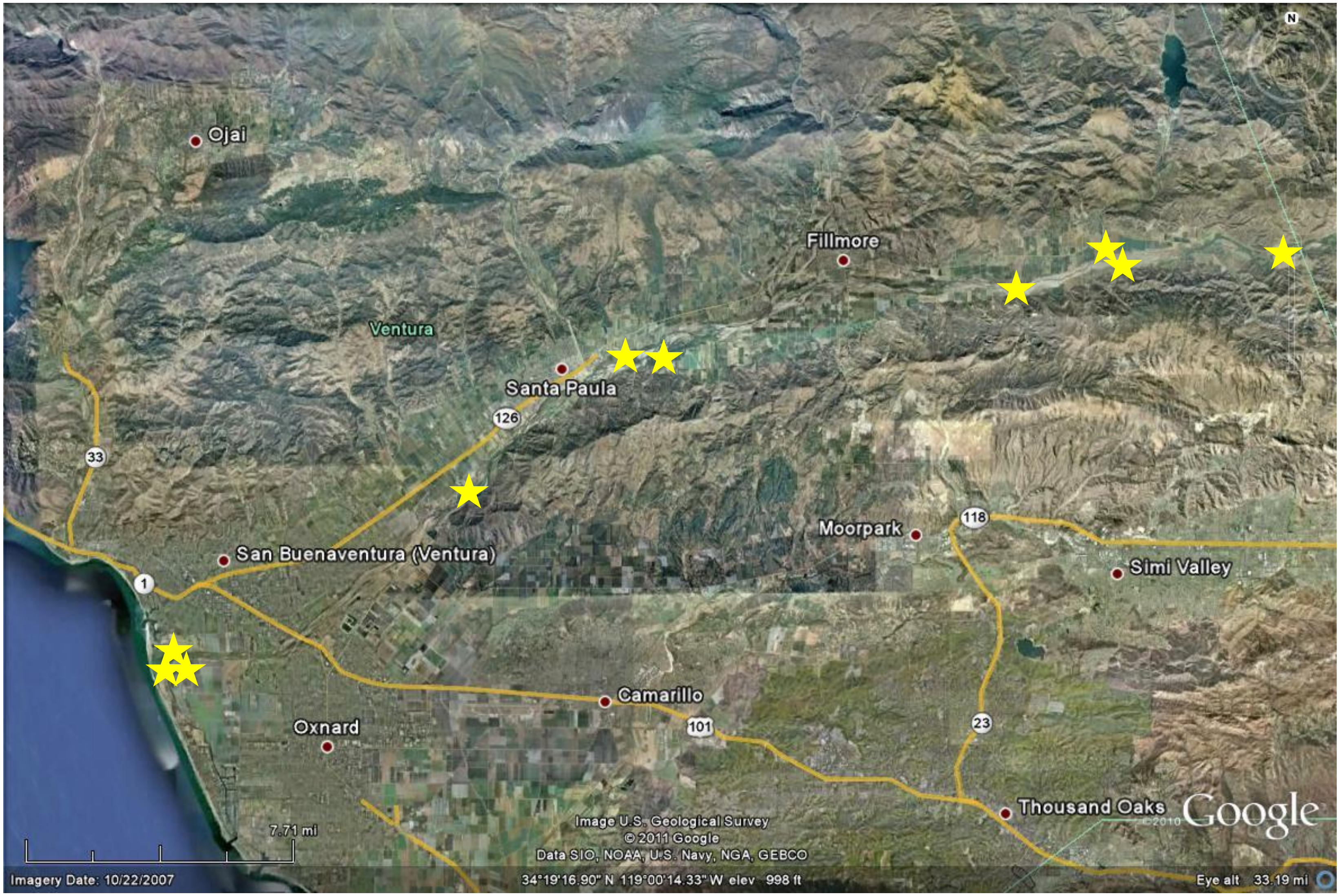


Figure 14. Location of potential reference site locations, including a variety of the largest most natural riverine wetland and riparian habitat conditions in the low gradient portions of the Santa Clara River.