


Santa Clara River Parkway Floodplain Restoration Feasibility Study

FINAL REPORT
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Prepared for:
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Cover photographs:

Top - Scarlet monkeyflower, *Mimulus cardinalis.*
Upper Middle - Example of riparian vegetation in the lower Santa Clara River corridor.
Lower Middle – Santa Clara River estuary.
Bottom – Juvenile steelhead.
**All photographs by Stillwater Sciences*.

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SUMMARY

The 116-mile-long Santa Clara River flows from the San Gabriel Mountains in Los Angeles County, through Ventura County, and eventually into the Pacific Ocean near the City of Ventura. The lower 33 miles of the river and its floodplain have been significantly altered in the recent past due to flood protection infrastructure, including reinforced levees, water diversions and flow regulation, roads, agriculture, aggregate mining, and urbanization. These structures have constrained or disrupted natural geomorphic and hydrologic processes, often causing riparian and aquatic habitat loss or degradation.

Despite the historical alterations to the riparian system, the lower Santa Clara River presents a unique opportunity to conserve and restore riparian functions and ecosystems compared with other coastal southern California rivers, most of which are highly degraded. There are several reasons why this opportunity is both significant and unique. First, the climate gradients and dynamic hydrology and geomorphology of the Santa Clara River watershed support a variety of natural aquatic and terrestrial communities and native species. Second, the Santa Clara River is one of the least altered rivers in southern California, with relatively intact patches of riparian and floodplain habitats in the lower reaches, particularly when compared to many of its dammed and channelized neighbors to the south. Third, the watershed's position provides a regionally important north-south connection between protected terrestrial wildlife areas in the southern California coastal ecoregion, and the river itself provides an important aquatic habitat linkage from the coast and estuary to upstream habitats in the mainstem and its tributaries, including the wild and scenic reaches of Sespe Creek. Together, these watershed attributes provide critical habitat for several rare and endangered species, and a movement corridor for a number of native species that require access to large areas to survive.

The Santa Clara River Parkway project seeks to ameliorate historical impacts in the lower Santa Clara River and conserve existing riparian habitats by acquiring and restoring existing habitat and flood-prone property from willing sellers. The Santa Clara River Parkway Floodplain Restoration Feasibility Study was undertaken to assist with the acquisition, management, and eventual restoration of lands within the Parkway. This report summarizes previous studies and analyses to: 1) provide an understanding of physical processes, habitat dynamics, and biological resources; 2) assess opportunities and constraints to property acquisition and restoration implementation; and 3) describe strategies for acquiring, managing and restoring the Parkway that are technically and scientifically sound, feasible to implement, and support long-term Parkway objectives.

The primary actions of the Santa Clara River Parkway project—acquisition of high-quality habitat and flood-prone lands, and active and passive process-based floodplain restoration—are intended to partially ameliorate the impacts and constraints from development within the lower Santa Clara River, and to enhance the river's capacity to provide a number of human and ecological benefits within current and foreseeable future land uses, water supply needs, and other policy constraints in the river corridor. The benefits expected from process-based floodplain restoration include:

- Increased length and width of riparian and in-channel aquatic habitat, and greater connectivity between habitats along the mainstem, in upland areas, and along major tributaries.
- Reduced flood risk outside the Parkway area and reduced levee maintenance and other public works costs associated with damages during flood flows, by allowing high discharges to spill onto acquired floodplain areas.
- Expanded and protected open space areas and natural habitats that provide recreational and educational opportunities for the community.
- Stream bank stabilization and food web contributions by riparian vegetation.
- Improved water quality by restoring and conserving stands of riparian and wetland vegetation that filter nutrients and sediment from runoff.
- Improved water supply through groundwater infiltration and recharge during floodplain inundation.

For the purposes of this study, acquisition and restoration strategies were evaluated based on several criteria to ensure that implementation would be feasible and appropriate for the lower Santa Clara River. Consequently, each recommended strategy needed to meet the following criteria: 1) be considered feasible and effective at achieving the ecological objectives of the Parkway project; 2) be technically appropriate given the physical and biological attributes and human uses of the river corridor; 3) work within current and foreseeable constraints, such as the legacy of historical impacts to the fluvial system, land use and zoning, water resource development and management, flood control requirements, infrastructure, impaired water quality, and environmental regulations; 4) offer specific opportunities, such as the presence of existing high-quality habitat, on which to base acquisition and restoration in the lower river corridor; and 5) work toward the flood control objectives of the Parkway project.

These criteria were used to screen potential acquisition and restoration efforts, which resulted in six primary restoration strategies:

1) 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) active and passive revegetation;
4) non-native invasive species removal;
5) creation of a network of water-quality treatment wetlands; and
6) aquatic habitat enhancements focused on fish passage improvements.

These strategies seek to restore physical functioning and improve ecological conditions, given that watershed-wide impacts of grazing, urban development, instream mining, infrastructure, and surface and groundwater regulation preclude a return to presumed historical conditions.

The objectives of the restoration strategies are as follows:

- The land acquisition strategy will provide long-term, protected and sustainable venues for restoration strategies to be implemented in a cost-effective and environmentally optimized manner;
- The levee removal and setback and infrastructure modification strategy will assist in improving physical functioning of the river to naturally create and sustain riparian and other riverine habitats, and providing lateral connectivity between the river and floodplain habitats;
- Revegetation will increase riparian habitat quantity and quality in currently degraded or newly restored areas and contribute to ecosystem functions;
- Non-native species removal will also improve riparian habitat quality as well as directly remove some limitations to special-status species populations;
- Ecosystem-based placement of water-quality treatment wetlands will maintain a range of chemical parameters that support healthy native species assemblages and meet water quality criteria; and
- Aquatic habitat enhancements will increase instream habitat quantity, quality, and connectivity.

1 INTRODUCTION

1.1 Genesis & Goals of the Santa Clara River Parkway

In 2000, the California State Coastal Conservancy (Coastal Conservancy) proposed the establishment of the Santa Clara River Parkway. The primary goal of the Parkway is to create, protect and restore 25 miles of continuous river and floodplain corridor from the mouth of the Santa Clara River to the Sespe Creek confluence. The Parkway is being created through the acquisition of river channel, floodplain, and agricultural lands vulnerable to flooding, and conversion of those lands back to riparian and upland habitats. Initial funding of $9.2 million was provided by Governor Gray Davis, as appropriated by the legislature, to the Coastal Conservancy for land acquisition and planning. Land acquisition is being conducted on a willing seller basis and is focused on the lower river, where a number of parcels have already been acquired (approximately 3,250 acres covering 11 miles of river). The Coastal Conservancy has partnered with The Nature Conservancy's LA-Ventura Project to acquire, manage, and restore Parkway lands. 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.

Other goals of the Parkway project are to: 1) conserve and restore aquatic and riparian habitat for native species, 2) provide enhanced flood protection, and 3) provide public access and environmental education within the Parkway. Habitat restoration will focus on allowing and/or providing self-sustaining natural physical and biological processes and will be guided by historical reference conditions, to the extent appropriate, and focal species habitat requirements. Flood protection will be improved by relocating vulnerable infrastructure to reduce or remove flood hazards, increasing flood attenuation where possible, and by minimizing future encroachment of urban development into the floodplain by acquisition of flood-prone lands from willing sellers. Public access, which is not a part of the focus of this study, will be provided through a continuous public trail system, and permanent interpretive panels installed at key locations will provide opportunities for environmental education.

1.2 Purpose of the Floodplain Restoration Feasibility Study

The Santa Clara River Parkway Floodplain Restoration Feasibility Study was designed to assist the Coastal Conservancy and its partners with the acquisition, management, and eventual restoration of lands within the Santa Clara River Parkway. The Feasibility Study synthesizes several previous watershed assessments and restoration and management planning projects, but expands upon these previous efforts with in-depth research on current and historical watershed function from both geomorphic and ecological perspectives. The goals of the Feasibility Study are to develop:

1. an understanding of the historical, current and potential future geomorphic and ecological processes within the lower Santa Clara River system; and
2. a strategy for acquiring, managing and restoring the Parkway that is technically and scientifically sound, feasible to implement, and supports long-term Parkway objectives.

To achieve these goals, the Feasibility Study has included:

- an assessment of hillslope, fluvial, and estuarine geomorphic processes (Stillwater Sciences 2007a),
- a water resources investigation including land use, infrastructure, hydrology, hydraulics, and water quality (URS Corporation 2005);
- detailed vegetation classification and mapping (Stillwater Sciences and URS Corporation 2007);
- an analysis of riparian vegetation dynamics (Stillwater Sciences 2007b); and
- an analysis of focal species habitat conditions (Stillwater Sciences 2007c).

This report summarizes these and previous studies and analyses to provide an understanding of physical processes, habitat dynamics, and biological resources (Chapter 2), to assess opportunities and constraints to property acquisition and restoration implementation (Chapter 3), and to describe acquisition and restoration strategies, priorities, and feasibility within the Parkway area (Chapter 4).

Through the acquisition and restoration efforts described in this report, the Parkway project is eventually expected to result in: (1) a 10,000- to 12,000-ac continuous protected riparian corridor along the lower 25 mi of the river[1] (3,250 ac have already been acquired); (2) an associated increase in riparian and adjacent habitat potentially ranging from 3,000 to 5,000 ac; and (3) a decrease in flood stage in the lowest reaches of the river potentially ranging from 6 to 7 ft. It is hoped that the information provided in this report will be used throughout the lower Santa Clara River watershed to support informed river management and restoration solutions.

[1] 6,000 ac was a previously reported acquisition goal for the Parkway project but has been expanded based on the findings of this Feasibility Study.

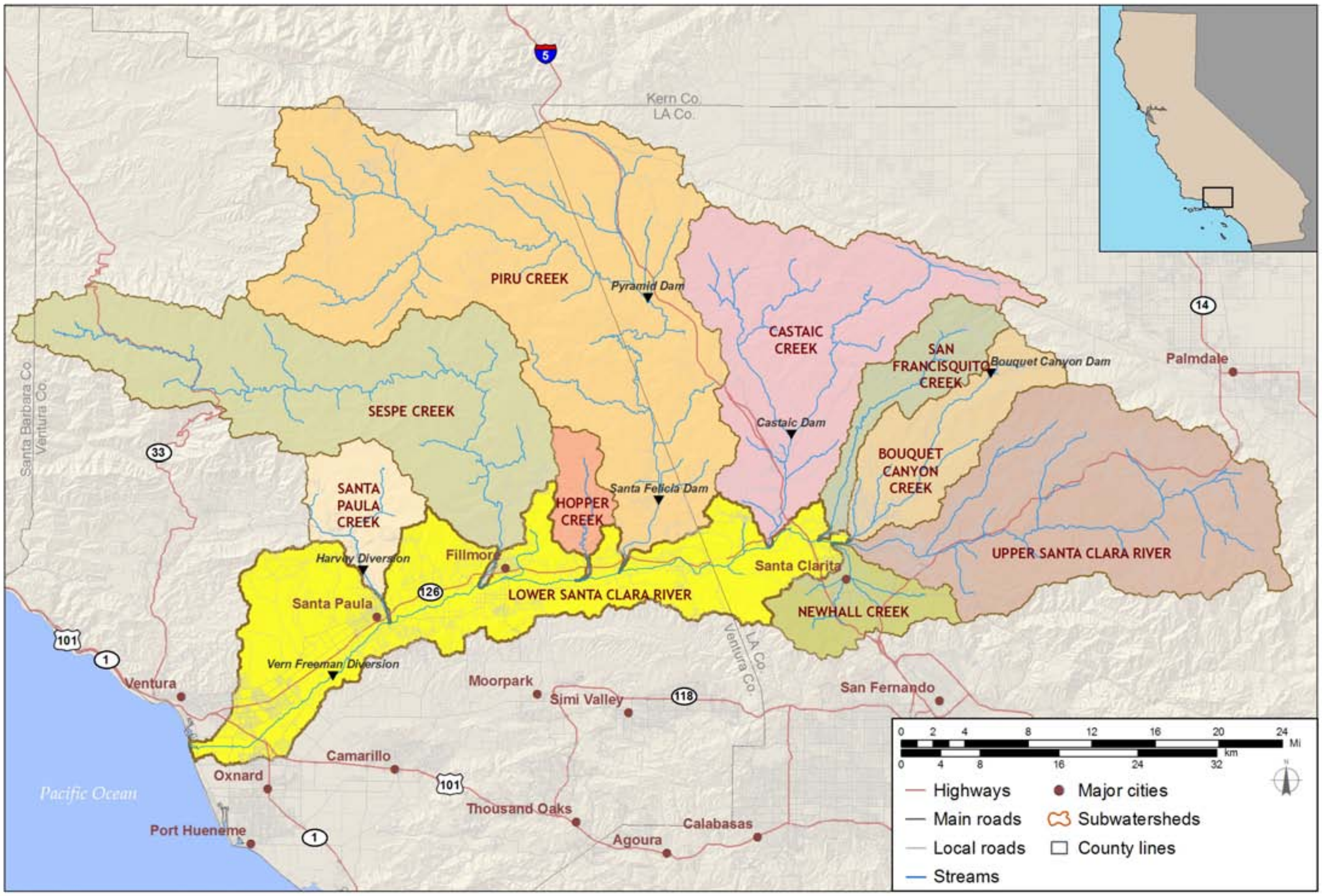

Figure 1-1. The Santa Clara River watershed.

1.3 Study Area

The 116-mile long Santa Clara River flows in a westerly direction from headwaters on the northern slopes of the San Gabriel Mountains in Los Angeles County, through the Santa Clara River Valley and the Oxnard Plain in Ventura County, and finally empties into the Pacific Ocean near the City of Ventura (Figure 1-1). The river is one of the largest watersheds on the southern California coast, draining an area of 1,626 mi^2, with elevations from sea level to 8,832 ft.

Many large coastal southern California rivers (*i.e.*, the Los Angeles, Santa Ana, and San Gabriel rivers) have been confined to concrete channels in their lower reaches to provide flood protection for surrounding urban areas. This has eliminated riparian vegetation and crippled the fluvial geomorphic processes that maintain a functioning riparian-floodplain ecological system. The Santa Clara River is therefore significant in the region because it retains many natural attributes no longer exhibited by the other large coastal southern California rivers, including patches of high-quality aquatic and riparian habitats capable of sustaining threatened and endangered species such as arroyo toad (*Bufo microscaphus californicus*), southwestern willow flycatcher (*Empidonax traillii extimus*), least Bell's vireo (*Vireo bellii pusillus*), slender-horned spineflower (*Dodecahema leptoceras*), and southern California coast steelhead (*Oncorhynchus mykiss irideus*).

While the Santa Clara River presents a unique opportunity to conserve and restore riparian functions and ecosystems compared with other more highly degraded coastal, southern California rivers, its river channel, floodplain, and habitats have been significantly altered in the recent past. Flood protection infrastructure including reinforced levees, water diversions and large dams, roads, agriculture, aggregate mining, and urbanization have constrained or disrupted natural geomorphic and hydrologic processes, often causing riparian and aquatic habitat loss or degradation. The Parkway project seeks to partially ameliorate these impacts in the lower Santa Clara River by acquiring and restoring existing habitat and flood-prone property from willing sellers in a 25-mile reach of the lower river from the mouth to the Sespe Creek confluence (Figure 1-2).

This Feasibility Study includes the Parkway project extent as well as the reach from Sespe Creek upstream to the Los Angeles/Ventura County line (for a total of 38 river mi) (Figure 1-2). The Feasibility Study area of analysis is defined by the extent of the 500-year floodplain (*i.e.*, the area inundated by a 500-year recurrence interval flood as defined by HEC-RAS hydraulic modeling), also referred to as the riparian corridor. This area includes the lower portions of the three major tributaries: Piru, Sespe, and Santa Paula creeks.

To describe the wide variety of physical and ecological conditions that occur in the river, it is useful to subdivide the lower Santa Clara River into 12 reaches (numbered from downstream to upstream), based on physical and biological criteria such as tributary junctions (where flow and sediment supply can change dramatically), degree of channel confinement (or its inverse measure, active channel width), land use history, and dominant vegetation (Table 1-1). These reaches range in length from approximately 1.5 to 6 miles and range in 500-year floodplain width from approximately 720 to 1,870 ft. Riverwash and riparian herbaceous and scrub vegetation types dominate the 500-year floodplain of most reaches, suggestive of the flashy hydrology and dynamic channel morphology of the lower river. Available habitat for focal species (discussed in Section 2.4.2) typically increases with channel width, which also tends to be greater in the more downstream reaches of the river.

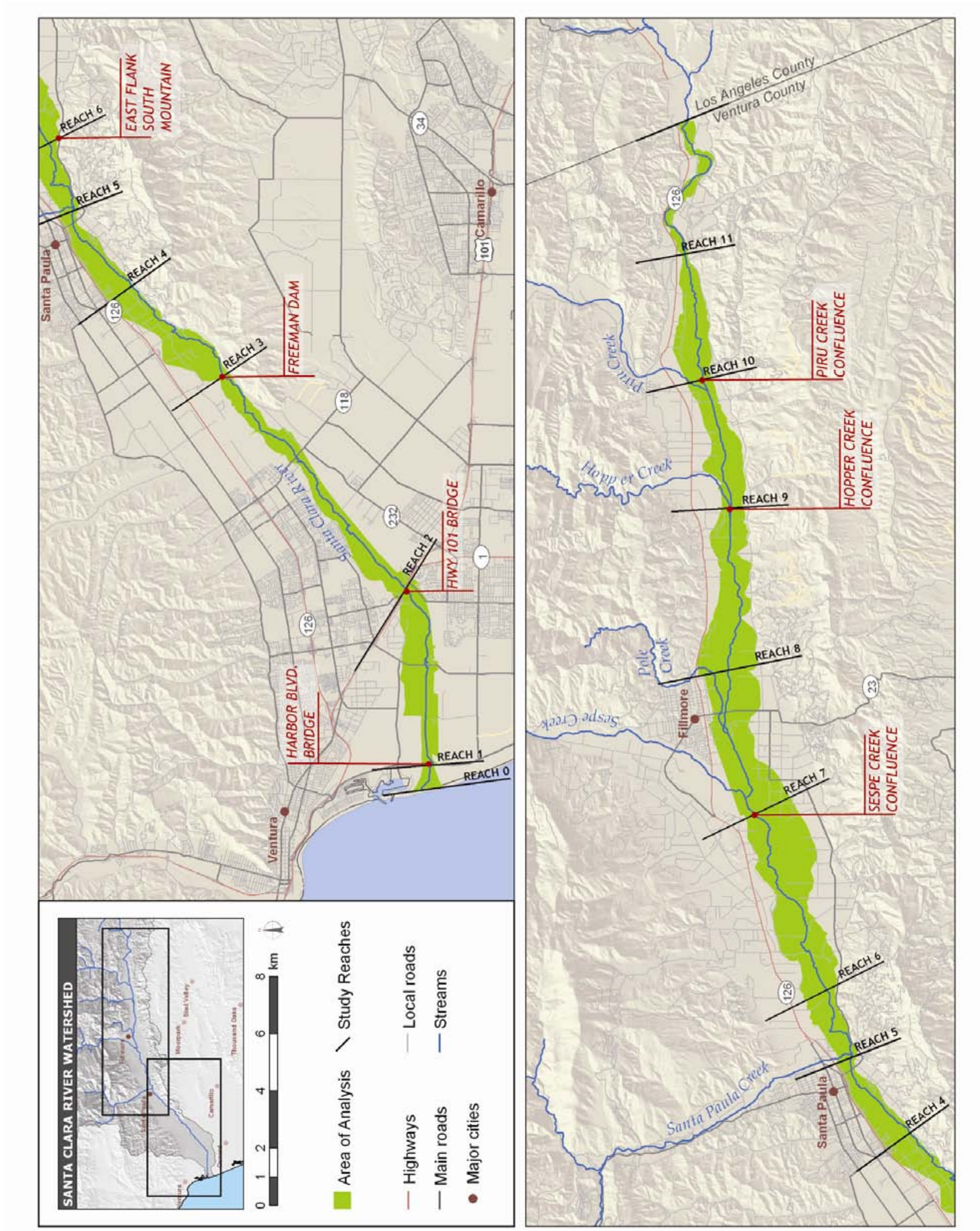

Figure 1-2. The Parkway project and Feasibility Study areas of analysis.

Table 1-1. Lower Santa Clara River reach characteristics.

REACH NUMBER Reach Name	River mile[1] Start	River mile[1] End	Reach-average slope[2]	Active channel width[3,4] (ft)	1.5-yr recurrence interval flow (cfs)[4]	Reach type[4, 5]	Dominant land use[3]	Dominant vegetation type[3]	Available focal species habitat (acres)[3]	Local characteristics
REACH 0 Estuary Reach	0 *[Pacific Ocean]*	0.5 *[Harbor Blvd. Bridge]*	<0.0010	2,600	6,569	gaining	Developed	Open water	856	Lagoon/estuary of the river, dominated by salt marsh and beach habitats. Levees along both banks. Receives treated effluent from waste water treatment plant on right bank. Mouth is open 70% of the year on average.
REACH 1 Hwy 101 Reach	0.5 *[Harbor Blvd. Bridge]*	4.6 *[Hwy 101 Bridge]*	0.0025	728	6,569	gaining	Developed	Cottonwood-willow forest	4,412	Wide floodplain; part of natural distributary area for the river. Largely straight channel. Levee on left bank, with urban development behind.
REACH 2 Below Freeman Reach	4.6 *[Hwy 101 Bridge]*	10.8 *[Freeman Dam]*	0.0027	1,148	6,569	gaining	Developed	Riverwash	3,188	Wide floodplain, part of natural distributary area for the river. Levees on left bank, and portion of right. Urban development to channel edge along most of the right bank. Gravel mining occurred until 1988. Highly regulated flows downstream of Freeman Dam.
REACH 3 Above Freeman Reach	10.8 *[Freeman Dam]*	13.5 *[Shell Rd.]*	0.0025	869	6,569	losing	Agriculture	Herbaceous (non-native)	1,456	Left bank impinges on South Mountain. Gravel mining occurred throughout the reach until 1988. Freeman Diversion Dam provides grade control at the downstream end.
REACH 4 Below Santa Paula Reach	13.5 *[Shell Rd.]*	15.7 *[Santa Paula Ck.]*	0.0039	1,260	6,569	losing	Developed	Arundo donax	1,237	Left bank close to South Mountain; urban development to edge of right bank. Some revetment on right bank. Gravel mining occurred until 1986. Receives unregulated inflow from Santa Paula Creek.
REACH 5 Above Santa Paula Reach	15.7 *[Santa Paula Ck.]*	17.5 *[East flank South Mtn.]*	0.0031	1,496	6,569	gaining	Agriculture	Mixed riparian scrub	768	Left bank impinges on South Mountain.

REACH NUMBER Reach Name	River mile[1]		Reach-average slope[2]	Active channel width[3,4] (ft)	1.5-yr recurrence interval flow (cfs)[4]	Reach type[4, 5]	Dominant land use[3]	Dominant vegetation type[3]	Available focal species habitat (acres)[3]	Local characteristics
	Start	End								
REACH 6 Below Sespe Reach	17.5 *[East flank South Mtn.]*	22.1 *[Sespe Ck.]*	0.0036	1,555	6,569	losing	Agriculture	Cottonwood-willow forest	2,939	Wide floodplain, with sinuous and braided channel. Levee on left bank opposite Sespe Creek confluence. Receives unregulated inflow from Sespe Creek.
REACH 7 Above Sespe Reach	22.1 *[Sespe Ck.]*	25 *[1 mi. east of Chambers Rd.]*	0.0048	1,870	3,178	losing	Agriculture	Arundo donax	2,319	Levee on right bank, with urban development behind.
REACH 8 Hopper Reach	25 *[1 mi. east of Chambers Rd.]*	28.5 *[Hopper Ck.]*	0.0055	1,385	2,154	gaining	Agriculture	Herbaceous	1,728	Wide floodplain, with sinuous and braided channel. Received unregulated inflow from Hopper Creek.
REACH 9 Below Piru Reach	28.5 *[Hopper Ck.]*	31.6 *[Piru Ck.]*	0.0053	1,778	2,154	losing	Agriculture	Riverwash	1,088	Wide floodplain, with sinuous and braided channel veering towards left bank mountains. Receives highly regulated flow from Piru Creek.
REACH 10 Above Piru Reach	31.6 *[Piru Ck.]*	34 *[2.5 mi. east of Piru Ck.]*	0.0062	1,821	1,907	losing	Agriculture	Riverwash	1,186	Wide floodplain, with centered channel. Highly regulated flows due to upstream dams on several tributaries.
REACH 11 County Line Reach	34 *[2.5 mi. east of Piru Ck.]*	38.4 *[LA County line]*	0.0055	479	1,872	gaining	Agriculture	Cottonwood-willow forest	513	Last narrow valley segment (from upstream). Heavy agriculture use adjacent to floodway. Highly regulated flows due to upstream dams on several tributaries.

1 River miles represent the distance along the river channel upstream from the Pacific Ocean. Source: AMEC (2005), supplemented by 2005 LiDAR data where necessary.
2 Source: URS (2005)
3 Within the 500-year floodplain
4 Source: AMEC (2005)
5 Gaining reaches are areas of rising groundwater, losing reaches are areas of where discharge from upstream infiltrates during low flow conditions.

1.4 Concepts & Rationale for Floodplain Restoration

Impacts to the physical and biological resources of the Santa Clara River, assessed through a number of studies and analyses, have been used to provide the rationale for Parkway acquisition and restoration. Impacts include:

- Continuing encroachment of urban and agricultural land uses into the riparian corridor, construction of reinforced levees, and development of transportation infrastructure that has reduced the floodplain area and available riparian habitat compared to historical conditions and caused channel incision.
- A reduction in floodplain area, combined with flashy flood patterns of the river, which has increased the flood hazard to developed areas and infrastructure.
- Historical clearing of riparian vegetation, in combination with lowering of the groundwater table through direct extraction and channel incision, which has decreased riparian vegetation extent and suppressed riparian vegetation recovery.
- Historical aggregate mining that has caused considerable channel incision, which led directly to need for the Freeman Diversion Dam that further disrupts longitudinal connectivity of aquatic habitat.
- Invasive species, particularly arundo (giant reed; *Arundo donax*), that out-compete native plant species and further reduce the quantity and quality of riparian habitat.
- A reduction in riparian habitat area that has negative impacts on native animal and plant species, some of which are listed as threatened or endangered.
- A reduction in the suitability and diversity of aquatic habitats that has negative impacts on native fish and invertebrates, including endangered tidewater goby (*Eucyclogobius newberryi*) and unarmored threespine stickleback (*Gasterosteus aculeatus williamsoni)*.
- Barriers to upstream fish migration that impede the southern California coast steelhead to reach spawning habitats and limit the population of this endangered species.

IMPACTS TO THE RIVER

- Encroachment and development of infrastructure in the riparian corridor
- Construction of levees
- Reduction in floodplain area
- Clearing of riparian vegetation
- Lowering of the groundwater table
- Aggregate mining
- Invasive species
- Reduction in riparian habitat
- Reduction in aquatic habitat suitability and diversity
- Barriers to upstream fish passage

Many of the anthropogenic impacts to the watershed are the results of human interventions that were undertaken to develop local agriculture and the local economy. Strategies for Parkway acquisition and floodplain restoration, therefore, require an understanding and integration of the needs and concerns of local landowners, water users, and industry. In addition, effective restoration actions must be feasible to implement within the constraints of the contemporary and foreseeable physical and political landscape. Among other issues, permanent infrastructure; lasting effects from historical land uses; and water supply, flood control, and land use policy and management shape the suite of restoration actions that are both technically and politically suitable for the lower Santa Clara River.

The primary actions of the Santa Clara River Parkway project—acquisition of high-quality habitat and flood-prone lands and active and passive process-based floodplain restoration—are intended to partially ameliorate the impacts and constraints from development within the lower Santa Clara River and its floodplain, and to enhance the river's capacity to provide a number of human and ecological benefits within current and foreseeable future land use, water supply, and other policy constraints in the river corridor. The benefits expected from process-based floodplain restoration are depicted in Figure 1-3 and potentially include the following:

- Reduced flood risk outside the Parkway area and reduced levee maintenance and other public works costs associated with damages during flood flows, as flood flows spread out and slow down over the floodplain.
- Improved water quality by stands of wetland and riparian vegetation that filter nutrients and sediment from runoff.
- Improved water supply through groundwater infiltration and recharge during floodplain inundation.
- Streambank stabilization and food web contribution by riparian vegetation.
- Increased length and width of riparian and in-channel habitat, and greater connectivity among habitats along the mainstem, in upland areas, and along major tributaries.
- Expanded and protected open space areas and natural habitats that provide recreational and educational opportunities for the community.

BENEFITS OF RESTORATION

- Reduced flood risk
- Reduced levee maintenance
- Improved water quality
- Groundwater recharge
- Stabilized stream banks
- Increased extent and diversity of riparian and in-channel habitats
- Open space for recreation and education

The Feasibility Study presents a process-based approach to restoration planning in the Santa Clara River Parkway. Process-based restoration focuses on establishing natural rates and magnitudes of geomorphological, hydrological, and biological processes that sustain biodiversity and biological productivity, with the understanding that the habitat-forming processes are dynamic (Pess *et al.* 2006). A process-based approach to restoration is typically the most cost-effective and sustainable approach to large-scale river corridor or watershed restoration. The typical alternative, active reconstruction and restoration of river and floodplain habitats following a "form-based" approach (*i.e.*, construct the desired feature rather than reestablish the feature-supporting process), is generally more costly and more likely to fail unless alterations to natural processes have also been addressed (Downs and Gregory 2004). In addition, the relatively unpredictable physical processes in the channel and floodplain environment of the Santa Clara River (*e.g.*, dynamic channel bed, extreme flood events, and very high sediment yield) limit any ability to implement a form-based approach, where "designed" quantities and types of habitat would be expected to meet the needs of specific focal species and persist for many decades. A process-based approach to restoration design has, therefore, been adopted that provides the floodway with the needed room for physical processes (such as floodplain inundation, bed scour, bank erosion and sediment deposition) to occur without risking nearby land uses, and that provides a template for the habitat types needed to sustain native plants and animals (Figure 1-3). Active, form-based restoration efforts may then be considered at specific sites, as appropriate, within a larger process-based restoration framework.

This effort represents a proposed shift in the management paradigm on the lower Santa Clara River—from the sole use of levees and other structures to manipulate and control river processes, to a vulnerability modification approach that will eventually reduce flood risk by ensuring adequate space for floods and other river processes and minimizing the extent of vulnerable infrastructure and development in the floodway. This approach includes land acquisition and conservation easements; incorporates the floodplain as a primary element in the reduction of flood damage and recognizes its value as an important biological resource; and incorporates in-channel and riparian

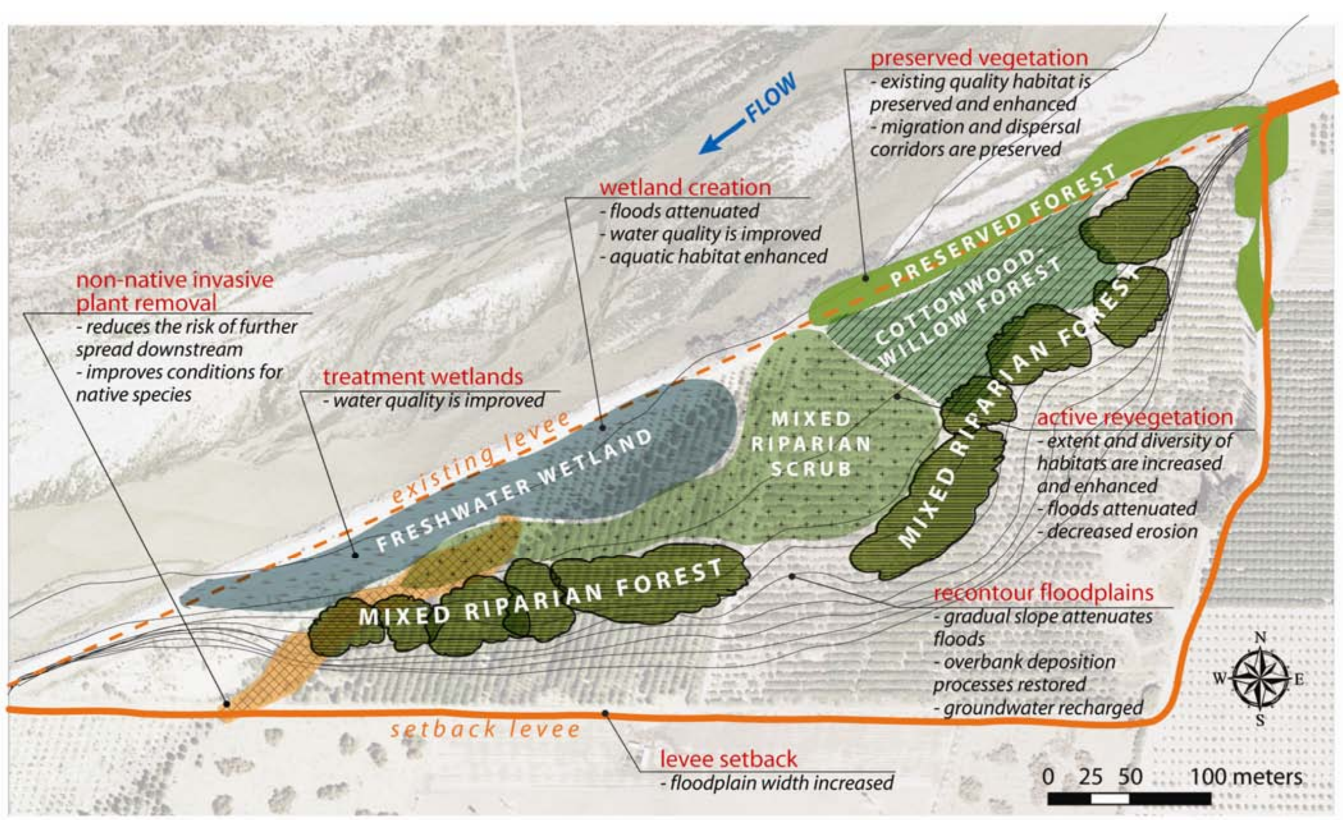

Figure 1-3. Conceptual restoration design illustrating the diverse benefits of process-based floodplain restoration on the lower Santa Clara River. Ideally, restoration actions would be implemented on multiple, contiguous parcels along the river to maximize effectiveness.

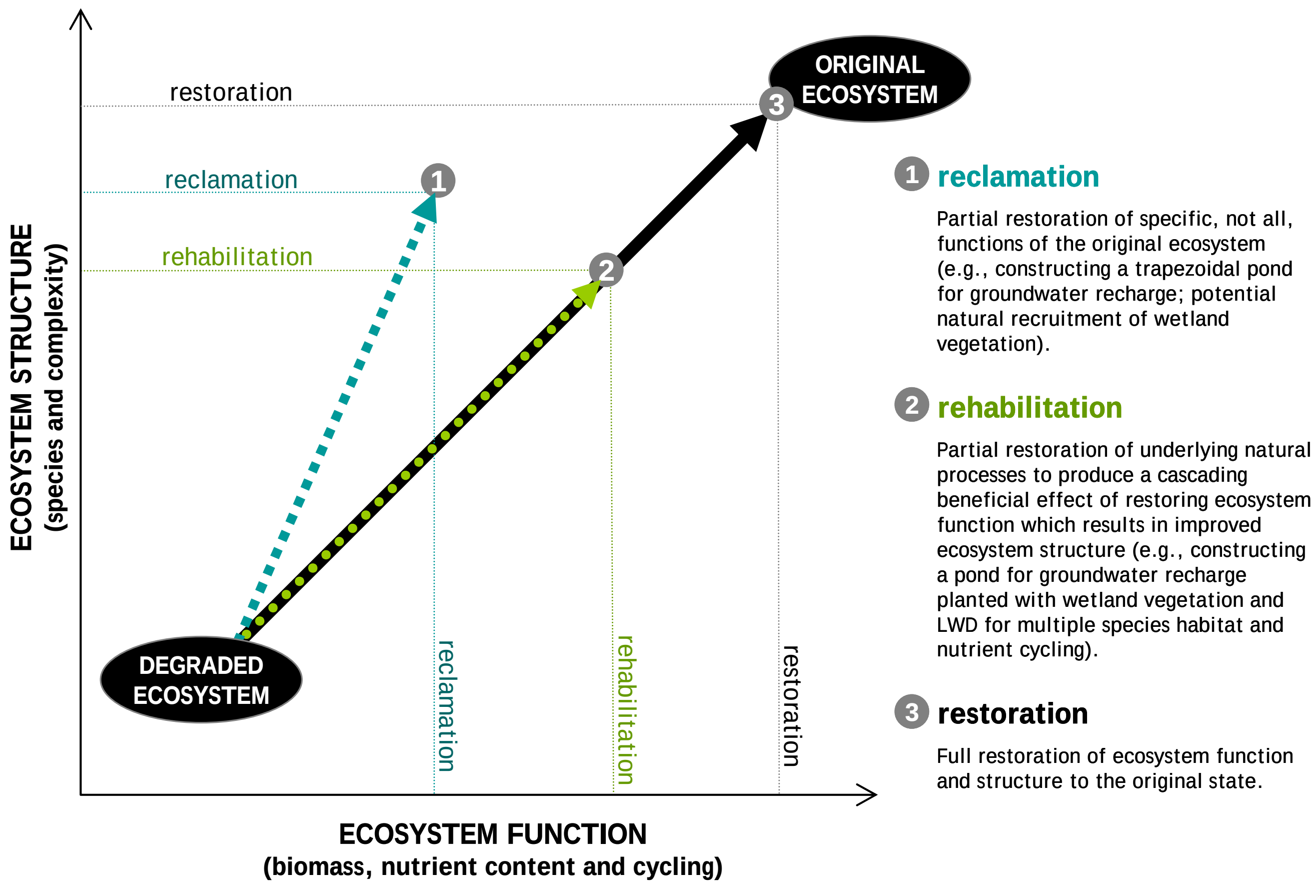

Figure 1-4. Restoration, reclamation and rehabilitation trajectories from degraded toward reference ecosystem conditions (modified from Bradshaw [2002] and Downs and Gregory [2004]).

habitat protection, restoration, and/or creation in land use planning. In addition to providing measurable and immediate reductions in flood risk and benefits to the river ecosystem, the Parkway strategy will afford the Santa Clara River the area and resiliency necessary to respond to unpredictable or uncertain changes in the watershed, such as climate change and sea-level rise, with minimal impacts to adjacent land uses.

Although the term "restoration" is used throughout this document, completely restoring the Santa Clara River to pre-colonial ("historical") conditions is not possible and, for many reasons, may not be desirable. This Feasi bility Study will guide efforts to rehabilitate river function to the fullest extent possible within current and foreseeable land use, water supply, and other constraints in the river corridor. Rehabilitation of the river corridor will include increases in ecosystem function (*e.g.*, nutrient cycling) with increasing ecosystem structure (*e.g.*, number of native species), putting the river on a trajectory towards the original ecosystem state (NRC 1992, Bradshaw 2002, Downs and Gregory 2004) (see Figure 1-4).

1.5 Selected Restoration Efforts & Studies in the Watershed

Several conservation and restoration efforts, and prior studies of river ecosystem conditions, have been undertaken across the Santa Clara River watershed over the past two decades. These efforts have commonly included a variety of stakeholders in the watershed and developed measures to protect natural resources, and restored some of the natural resources that were negatively impacted from previous activities in both the upper portion of the Santa Clara River in Los Angeles County and the lower portion of the Santa Clara River in Ventura County. These efforts have been critical in refining the goals, objectives, and approach of the Parkway project and this Feasibility Study, because they provide a wealth of information to build upon while highlighting areas in which further work is needed.

Santa Clara River Enhancement and Management Plan

The Santa Clara River Enhancement Plan (SCREMP) was designed to provide guidance in the preservation, enhancement, and sustainability of the physical, biological, and economic resources that occur within the 500-yr floodplain limits of the Santa Clara River mainstem (AMEC 2005). The SCREMP arose from efforts by former Ventura County Supervisor Maggie Kildee and the U.S. Fish and Wildlife Service (USFWS) (Ventura office) with funding from the Coastal Conservancy. In 1991, the interested parties decided to work together to develop a coordinated management effort, and the Project Steering Committee (PSC) was convened (AMEC 2005). The PSC, made up of 26 members, including private land owners, local government, industry, special districts, interest groups, and state and federal resource and regulatory agencies, compiled the SCREMP. The SCREMP process emphasized improved coordination and information exchanges among all PSC members and on resolution of conflicting uses of the river. The study sought to give balanced consideration to habitat objectives, natural river processes, private property rights, economic interests, and community objectives in support of preparing a plan that contains mechanisms for implementing the PSC's recommendations (AMEC 2005).

By 1999, the PSC released preliminary, river-wide and reach-specific recommendations on multiple topics. These involved public outreach, private property rights, water quality, water rights, salt water intrusion, water supply, river gradient, public flood protection facilities, maintenance of design flow capacity, private flood protection, cultural resource protection, fish passage, habitat conservation priorities, biological management, control of exotic species, biological mitigation, public access and recreation, recreational property acquisition, and permit streamlining (CRWQCB 2004). Several of these recommendations have begun to be implemented by a collection of local agencies.

Santa Clara River Natural River Management Plan

The Santa Clara River Natural River Management Plan (NRMP) for the Upper Santa Clara River within Los Angeles County was devised by the Newhall Land Company (formerly The Valencia Company). Its purpose was to address cumulative impacts of Newhall Land development projects over the next 20 years on 486 hectares (1,200 acres) of affected drainages, including the South Fork of the Santa Clara River, the mouth of Bouquet Creek, San Francisquito Creek, and the Santa Clara River from Castaic Creek confluence to 2.5 miles upstream of the Bouquet Canyon Development (AMEC 2005, CalTrans 2005). The NRMP was written as a US Army Corp of Engineers (USACOE) General Permit and proposed as the basis for a Regional Development Plan. The NRMP was reviewed and approved by Los Angeles County, USACOE, California Department of Fish and Game (CDFG), and other regulatory agencies (AMEC 2005). The NRMP contains maintenance procedures (to be followed by Los Angeles County Dept. of Public Works) designed to avoid impacts to endangered species and minimize impacts to riparian resources (CalTrans 2005). This includes maintaining natural river hydraulics and sediment transport along a 15-mile mainstem reach in Los Angeles County, providing for a conservation easement of riparian habitat within this reach, providing for groundwater recharge by maintaining sand-bedded channels, establishing vegetated buffers in urban areas, and installing filters and wetlands to protect the water quality of the Santa Clara River (AMEC 2004). Management of riparian corridor and upland properties to be protected through the NRMP has been delegated to regional land trusts and conservancies.

Santa Clara River Trustee Council Restoration Plan

The Santa Clara River Trustee Council Restoration Plan (Restoration Plan) was designed to provide a framework for restoration alternatives to restore, rehabilitate, replace or acquire the equivalent of the damaged natural resources resulting from the 1994 ARCO oil spill along the Santa Clara River (Santa Clara River Trustee Council 2002). In 1997, a settlement of $7.1 million was reached between ARCO and federal, state, and county agencies. From this settlement, the Trustee Council, made up of representatives from CDFG and the U.S. Fish and Wildlife Service (USFWS), was formed and given the responsibility of developing the Restoration Plan for the resources in and along the Santa Clara River. It was also tasked with allocating the settlement funds and ensuring the success of the restoration activities. Restoration activities include land acquisition/conservation easements (60% of funds), invasive, non-native plant species control (20% of funds), restoration project grants program (10% of funds), information and education (5% of funds), and watershed evaluation and monitoring (5% of funds). The first land purchase authorized under the Restoration Plan was 337 acres of riparian habitat in Ventura County (at the confluence of the Santa Clara River and Piru Creek) that will be managed and maintained by The Nature Conservancy

(OSPR News 2006). Through the Restoration Plan process, the Trustee Council also funded studies to assess populations of steelhead trout (Kelley 2004, Stoecker and Kelley 2005) and riparian birds (Labinger and Greaves 2001a, b), map riparian vegetation (Stillwater Sciences and URS Corporation 2007), research biological control of giant reed (Dudley, in progress), and prioritize sites along the river for purchase and/or conservation easement (Court *et al.* 2000). The results of these studies were used, in part, to describe the ecosystem conditions presented in Section 2 of this report and to develop appropriate restoration strategies and priorities (Section 4).

Santa Clara River Watershed Project Management Plan (Reconnaissance and Feasibility)

Following an initial Reconnaissance Phase Study in 2002, the USACOE-Los Angeles District determined that there was a federal interest in a watershed-based study that could provide a holistic approach to evaluating resource problems and opportunities, and that would lead to the development of a watershed protection plan that balances the need for sustainable development with the need for watershed protection (Buxton 2006). When completed, the next phase of the project (the Feasibility Phase) will provide technical data required for identifying and understanding the water resource problems and opportunities in the watershed, with particular attention to the effects of future land developments on the river (Buxton 2006). The Feasibility Phase study is intended as a scientific study that will be a tool for decision makers involved in regional flood control management (AMEC 2005). The first phase of the Feasibility Study, the Project Management Plan, was completed in 2003. The original projected time for the entire Feasibility Study was three years, although funding limitations have delayed many of the original studies.

The Nature Conservancy's Lower Santa Clara River Focus Plan and Upper Santa Clara River Watershed Conservation Plan

The Nature Conservancy (TNC) has been involved in conservation planning and implementation in the Santa Clara River watershed since 1999 and is an important partner to the Coastal Conservancy in implementing the Parkway project. TNC's overall land preservation strategy for the region, termed their "LA-Ventura Project", comprises 3 major features: 1) the Santa Clara River watershed (to assist in the implementation of the Santa Clara River Parkway Project); 2) the coastal areas of McGrath State Beach and Ormond Beach; and 3) and several wildlife linkages between the Los Padres National Forest, Angeles National Forest and the Santa Monica Mountains. To date, the Nature Conservancy has worked with local partners to acquire 2,500 ac (18 properties)—about 11 mi—along the Santa Clara River in Ventura County (~1/3 of river length in Ventura County) (TNC 2007). In conjunction with land acquisition, TNC has also developed plans for conserving natural resources in both the lower reaches (Ventura County) and upper reaches (Los Angeles County) of the Santa Clara River.

The Lower Santa Clara River Focus Plan (Focus Plan) addresses conservation planning (under both a longer-term vision and shorter-term focused objectives) related to riparian and aquatic resources along the lower 30 miles of the river (Cox *et al.* 2001). The long-term vision includes protection of over 3,500 acres of riparian and alluvial scrub habitat, maintenance of viable populations of native resident and anadromous fish in the lower Santa Clara River, and adoption of permanent county-wide open space protection measures. Key focused objectives and strategies identified to reach the long-term vision include land acquisition, partnerships, marketing/funding, science, and land use planning. To determine where to focus conservation efforts, the Focus Plan ranks the biological resources in the lower Santa Clara River and the stresses to the biological resources. The Focus Plan also details an 'Initial Conservation Design' for the lower Santa Clara River based on riparian 'nodes', which are thought to be viable habitat patches independent of each other, and a continuous riparian corridor. The Focus Plan is currently being updated and expanded as *AConservation Plan for the Lower Santa Clara River and Surrounding Areas* (TNC 2007).

Los Angeles County Upper Watershed General Plan

The Los Angeles County Upper Watershed General Plan (General Plan) serves as the blueprint for future growth and development within unincorporated areas in Los Angeles County as a whole and the upper Santa Clara River in particular (Los Angeles County General Plan Update 2007). One component of the General Plan is the designation of proposed Significant Ecological Areas (SEAs). SEAs, originally developed by Los Angeles County in the 1970s, are land and water areas that are considered valuable to plant and animal communities, some of which may be threatened or endangered. More specifically, SEAs are areas where the County requires development to be designed around existing important biological resources (in contrast to areas where development is prohibited completely).

The SEA proposed for the Santa Clara River encompasses the entire Los Angeles reach of the Santa Clara River and functionally covers 5,410 acres of land considered severely degraded (Los Angeles County General Plan Update 2007). The proposed Santa Clara River SEA supports many regional biological values, including habitat for endangered species, important migration corridors, and essential habitat for life-stages of various species (AMEC 2005). Management recommendations for the SEA include ensuring development is outside the existing floodplain to minimize the need for future bank stabilization, critical reviews of proposals for new or increased groundwater extraction to prevent dewatering of riparian vegetation, and implementing of best management practices (BMPs) for agricultural activities (AMEC 2005).

Upper Santa Clara River Watershed Arundo/Tamarisk Removal Plan

The Ventura County Resource Conservation District (VCRCD), with funding from the State Water Resources Control Board (SWRCB), is leading this programmatic effort to map, remove, and monitor arundo and tamarisk *(Tamarix* spp.) in the Santa Clara River watershed (impacts associated with arundo and tamarisk infestations are discussed in more detail in Section 2.4.1). Efforts in the upper watershed began with mapping of arundo and tamarisk along the upper Santa Clara River and its tributaries, and the completion of an Environmental Impact Report (EIR) to assess and mitigate the impacts of large-scale, programmatic arundo and tamarisk removal projects (VCRCD 2006a).

In 2006, the Upper Santa Clara Arundo River Watershed Removal Program (SCARP) Long-term Implementation Plan (VCRCD 2006b) was completed. This plan includes a programmatic California Environmental Quality Act (CEQA) and National Environmental Policy Act (NEPA) document and related environmental documentation and permits for the implementation, maintenance, and monitoring of arundo and tamarisk removal projects within the riparian corridor of the upper Santa Clara River watershed. Any agency or organization that wishes to undertake an arundo and/or tamarisk removal project in the upper watershed may apply to the VCRCD to use the programmatic SCARP environmental documents and permits. To be eligible for the programmatic SCARP documents, removal projects must use methods described in the SCARP, be coordinated through the VCRCD, and include a minimum of one year of post-project monitoring (N. Cabanting, Wildscape Restoration, pers. comm., 2007). It is anticipated that the first removal projects under SCARP will be implemented in 2008. Priority will be given to projects located in the upper reaches of the mainstem and tributaries (N. Cabanting, Wildscape Restoration, pers. comm., 2007).

More recently, the VCRCD has begun efforts to expand the SCARP to the lower watershed. The arundo and tamarisk mapping conducted in the upper watershed will be combined with the mapping conducted for the Parkway project in the lower watershed (Stillwater Sciences and URS Corporation 2007). Eventually, a new EIR will be completed for the lower watershed and a similar suite of environmental documents offered through the current SCARP will be available to agencies and organizations conducting arundo and tamarisk removal projects in the lower watershed. Removal of arundo and tamarisk, in addition to other non-native invasive plant and animal species is one of the Parkway project restoration strategies developed in Section 4.4 of this report. Coordination between the SCARP and Parkway project efforts should greatly enhance the feasibility and effectiveness of arundo and tamarisk removal projects in the lower watershed. In addition, removal projects coordinated through the SCARP in the lower watershed should be informed by current research on the biological control of arundo funded by the Santa Clara River Trustee Council.

2 THE LOWER SANTA CLARA RIVER SYSTEM

This chapter describes a conceptual model, based on existing literature, data, and recent Feasibility Study investigations, of the processes that shaped historical conditions in the lower Santa Clara River and how watershed impacts have changed those processes and conditions in ways that result in the riparian corridor we now see. A conceptual understanding of historical watershed conditions is critical in determining *how the ecosystem* ***once*** *functioned*, while an understanding of present conditions reveals *how the ecosystem functions* ***now***. The integration of historical information over time helps form the foundation for determining how the changes in ecosystem function occurred. Understanding each of these elements makes it possible to hypothesize the potential future trajectory of watershed conditions and thus can help guide sustainable corridor restoration strategies.

2.1 Historical River System Conditions

In their analysis of historical steelhead populations, Boughten *et al.* (2006), describe the probable baseline conditions of southern California steelhead-bearing rivers prior to 1894–1904 when the first USGS maps were developed for the area. This and other information on the historical conditions of southern California watersheds in general, and the Santa Clara River in particular (*e.g.*, Freeman 1968, Schwartzberg and Moore 1995), provide insight into the physical processes and biological resources of the Santa Clara River prior to widespread European ranching and colonization.

Our current understanding of historical conditions in the Santa Clara River will be greatly enhanced by the results of the Ventura County Historical Ecology Study, which is a collaborative effort being led by the San Francisco Estuary Institute and funded by the Coastal Conservancy. This study is scheduled to be completed in early 2009 and will synthesize historical data resources to create a practical understanding of fluvial, riparian, and wetland resources prior to significant Euro-American modification.

Historical photograph of the lower Santa Clara River watershed (circa 1900).
(Photo courtesy of Ventura County Watershed Protection District)

Before widespread European ranching and colonization (approximately pre-1820, following establishment of the first mission in 1782), the lower Santa Clara River may have had perennial stream flow in all reaches except in the driest years, a higher channel elevation, and a reasonably continuous and broad riparian forest. There are historical reports that describe perennial stream flow for several southern California rivers, including the Santa Ana, Santa Margarita, and San Luis Rey, that are now intermittent as a likely result of water impoundment, diversion, and groundwater pumping (Everman 1886, Cooper 1887, and Hutchinson 1965 as cited in Nautilus Environmental 2005, Schwartzberg and Moore 1995, Boughten *et al.* 2006). In addition, it has been argued that the maintenance of grasslands by Native Americans increased water yield (in contrast to chaparral or sage-scrub habitats) and contributed to historical perennial stream flow (Keeley 2002a and 2002b, as cited in Boughten *et al.* 2006). In the Los Angeles River basin, perennial stream flow resulted in lower water temperatures and supported suites of aquatic species, such as red-legged frog, threespine stickleback, freshwater lamprey, and freshwater shrimp, which are now extinct or are primarily found only in northern California (Mendenhall 1908, McGlashan 1930 and Miller 1961, as cited in Boughten *et al.* 2006).

Prior to removal of riparian vegetation for ranching and other land uses, the Santa Clara River flowed at elevations closer to the floodplain surface (Freeman 1968, Boughten *et al.* 2006). Boughton *et al.* (2006) suggest that prior to the first USGS maps in the late 1800's and early 1900's, many southern California river channels had already experienced significant incision as a result of vegetation clearing, ranching, other human land alteration, and climatic events. Similarly, Faber *et al.* (1989) cites analysis of historical aerial photographs that supports the idea that much of the middle and higher elevation floodplain surfaces along the lower Santa Clara River had already been converted to agriculture by 1927.

These land uses, and possible climatic conditions of the time, resulted in decreased stream bank stability and increased stream power that allowed high flows to entrench the channel. Prior to incision, the Santa Clara River channel would have supported higher groundwater elevations and more frequent floodplain inundation under lower flows (*i.e.*, floodplain inundation would often have occurred at lower discharges and with lower velocity flows compared to current conditions). These channel conditions would have facilitated the recruitment and establishment of large tracts of riparian vegetation. In addition, prior to incision and the increased supply of fine sediment caused by watershed land clearing, rivers like the Santa Clara likely supported a far greater proportion of gravel and cobble substrates in their lower reaches than under present-day conditions (Boughton *et al.* 2006). These substrates would have provided suitable spawning habitat for fish species along a greater extent of the river, as well as providing habitat for benthic macroinvertebrates on which fish feed.

Perennial stream flow, higher channel and groundwater elevations, and an unconfined floodplain likely supported a diverse mosaic of woodland, scrub, herbaceous and seasonal wetland habitats. Simons, Li & Associates (1983) report that the Santa Clara River floodplain was historically as much as two miles wide in its lowermost reaches. The riparian area likely supported dense, multi-storied stands of broadleaf trees, including cottonwood, sycamore, and various willows, that extended from a few to several miles wide (Faber *et al.* 1989, Schwartzberg and Moore 1995, Boughton *et al.* 2006). Prior to any vegetation removal, the extent and composition of riparian vegetation in the Santa Clara River watershed would have supported a diversity of native animal species (Knopf *et al.* 1988, RHJV 2004). In addition, the greater extent of riparian vegetation would have provided a higher degree of ecosystem services such as filtering run-off, shading the river, and providing energy from leaf litter and woody debris that serves as habitat for instream organisms (Gregory *et al.* 1991, Malanson 1993, Naiman and Decamps 1997) (see Figure 1-3).

2.2 Impacts to & Changes in River System Conditions

Historical land-use change and the evolution of water and river management practices within the Santa Clara River watershed can be grouped into five distinct historical periods (Table 2-1, Figure 2-1) that provide a conceptual understanding of how ecosystem changes in the watershed have occurred.

Beginning in the 1820s, floodplain forests were cleared to prepare the land for grazing and farming and for fuel. In the past several decades, vegetation was removed to increase flood conveyance. The removal of riparian vegetation dramatically decreased habitat availability for native plants and animals. Removal of riparian and adjacent upland vegetation is also likely to have caused significant changes to rainfall–runoff relationships as deep-rooted native perennial grasses in the valleys and hillslopes were replaced by shallow-rooted, non-native annual grass species, which are less able to resist soil erosion. Drought in the 1860's caused a shift from traditional cattle grazing to sheep, probably accelerating the removal of vegetation and subsequent erosion and facilitating the invasion of non-native annual grasses. The expansion of farming in the Santa Clara River valley during the continued drought of the 1870s probably further contributed to erosion and changes in runoff characteristics. The effects of increased grazing and farming in the watershed is suspected of promoting severe channel erosion throughout the watershed following the 1884 flood, which ultimately resulted in tributaries devoid of large, stabilizing vegetation prone to future incision and erosion.

Table 2-1. Historical periods characterizing land use and impacts to the Santa Clara River watershed.

Period	Description
Pre-European Colonization *prior to 1820*	Natural events (including wildfires) are suspected of acting relatively independent of human activities, with the exception of Native American grassland management.
Ranching and Colonization *1820–1890*	Significant European arrival in the watershed, extensive riparian vegetation removal, the introduction of livestock, and resultant changes in vegetation cause loss of riparian habitat, changes in rainfall-runoff relationships and hillslope erosion rates, and associated decreases in the quality of instream aquatic habitat.
Irrigation and Diversions *1890–1955*	Floodplain agriculture necessitates tributary diversions and the construction of small dams, causing changes in surface water and groundwater dynamics, potentially increasing the “flashy” nature of the river and decreasing water quality through agricultural runoff.
Dams and River Modifications *1955–1990*	Completion of major dams, construction of an extensive network of levees and bank protection, and intensive river and floodplain aggregate mining result in a notable decrease in runoff and sediment, an increase in flood flow confinement and channel incision, associated decreases in aquatic habitat connectivity, and continued decreases in water quality.
Urbanization *1990 to present*	Continued rapid population increases in the watershed cause large-scale conversion of floodplain agricultural land to residential developments, further affect rainfall-runoff relationships in the watershed and potentially contribute to greater river erosion, further water quality degradation from urban runoff, and continued decreases in availability of aquatic habitat.

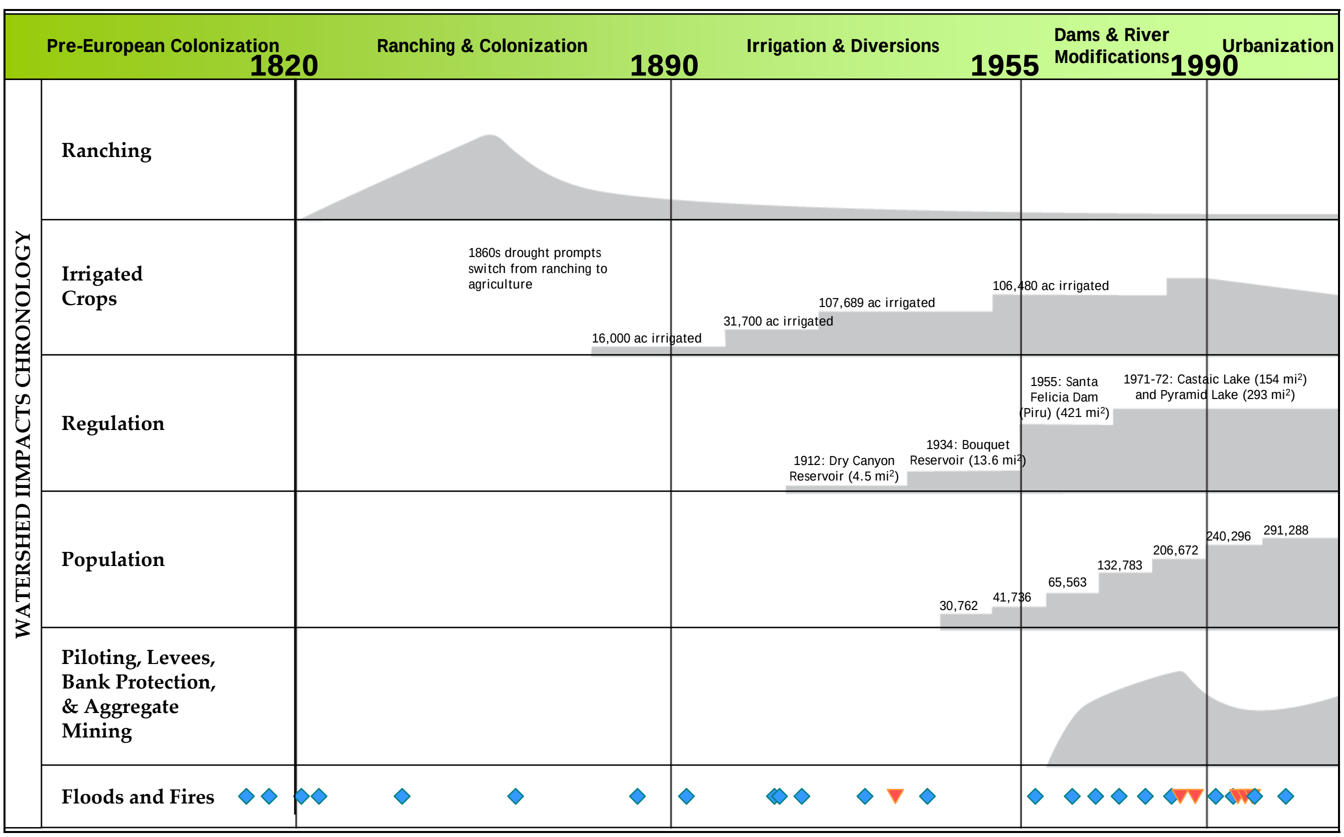

Figure 2-1. Chronology of impacts to the Santa Clara River watershed.

The post-1890 period is characterized primarily by the expansion of water-intensive agriculture: first sugar beet and then citrus crops (particularly following the First World War), which required large-scale irrigation. In this period, irrigation using surface flow from the Santa Clara River was supplemented by pumped groundwater supplies. Following the formation of the Santa Clara River Protective Association (now United Water Conservation District) in 1925, diversions began first from Piru Creek (1930) and then Santa Paula Creek (1931). Irrigated acreage in Ventura County increased from 31,700 ac in 1919 to 107,700 ac in 1949. The impact was an initial reduction in baseflow within the Santa Clara River, and a subsequent lowering of the groundwater table due to pumping (see Freeman 1968). Lowering of groundwater in particular may have led to the degradation of mature riparian vegetation (in areas where riparian vegetation was not replaced by orchards), which is reliant primarily on groundwater during the summer dry season.[2] Large floodplain areas with extensive riparian vegetation may have attenuated floods along the Santa Clara River; the removal and degradation of large riparian stands would have therefore increased the "flashy" response of the river to flood events. The removal of riparian vegetation would have also resulted in decreased complexity of floodplain habitat and increased water temperature.

By 1912, the first dam in the watershed had been constructed in Dry Canyon, located in the eastern portion of the watershed (the dam was subsequently decommissioned due to leakage issues). In 1926, the St. Francis Dam was completed on San Francisquito Creek (also in the eastern watershed); however the dam failed catastrophically in March 1928, resulting in one of the largest and most tragic dam failures in United States history. The long term effects of the St. Francis Dam disaster on the morphology of the Santa Clara River are unknown, but are potentially significant and ongoing. From 1955, with the completion of the 200 ft high Santa Felicia Dam on Piru Creek (regulating 421 mi^2), the watershed was subjected to an increasing amount of direct flow regulation and channel manipulation. At present, approximately 34% of the watershed is regulated by large dams and storage reservoirs, reducing runoff to the lower watershed by approximately 25% (Warrick 2002) and suspended and bedload delivery to the mainstem by approximately 21% (Brownlie and Taylor 1981,Warrick 2005). The effects of reduced sediment yield are generally most severe immediately downstream of dams, where channel incision is often observed due to more effective erosion of the channel bed by sediment-starved water (*e.g.*, Williams and Wolman 1984). Construction of multiple large dams and water diversions, including the Vern Freeman Diversion Dam on the mainstem and various dams and diversions

[2] Historical groundwater levels and the magnitude of groundwater table lowering are not well documented. It is anticipated that the Ventura County Historical Ecology Study will improve understanding of these critical factors.

on major tributaries, also interrupted longitudinal aquatic habitat connectivity, decreasing the ability of the lower Santa Clara River to sustain a spatially distributed, diverse community of aquatic organisms including anadromous southern California coast steelhead, unarmored threespine stickleback (*Gasterosteus aculeatus williamsoni*), and pacific lamprey (*Lampetra tridentata*).

The lower Santa Clara River floodplain and channel were increasingly modified—first in 1959 with the dredging of pilot channels; in 1961 with the construction of the extensive levee system from South Mountain to Highway 101; and, following the flood of 1969, construction of various additional levees, groins, and bank protection projects that continue to the present day in conjunction with urban expansion onto the floodplain. By design, the levees constructed along the Santa Clara River have confined high flows to the active channel width and have significantly reduced the riparian area historically inundated by large floods. The levees have also reduced the effective flow width during floods and stabilized the river's planform, resulting in an alteration of channel morphologic development and sediment transport. Furthermore, the levees have effectively reduced the flood water storage capacity of the river, thus forcing the majority of high flows to be conveyed solely within the active channel rather than being allowed to spread out upon the floodplain (Stillwater Sciences 2007a).

During high flows, the narrowing of the active flow width combined with the increase in flood water volume moving through the river channel due to levee confinement has increased flood stages and velocities. Thus, there has been greater potential for bed and bank scour. Since the levees were first constructed in 1961, a pattern of channel bed lowering, or incision, has developed particularly in the downstream-most reaches, which are confined by the majority of the river's levees (see Section 2.3.7). The presence of multiple flood-control structures and reinforced levees also interrupted lateral habitat connectivity, decreasing the degree of linkage between instream aquatic habitat and riparian vegetation and/or freshwater wetlands in the floodplain. During this period, alterations to natural geomorphic processes would have impacted the variety of substrate, water velocity, water temperature, chemical (*e.g.*, salinity, dissolved oxygen), and cover conditions, which vary seasonally and spatially from the headwaters to the ocean, and which are necessary to provide diverse aquatic habitat.

Of great importance to the channel morphology is the instream aggregate extraction that began with small-scale operations in the early twentieth century and accelerated during the 1970's and 1980's, coinciding with increased rates of channel incision upstream of aggregate mining pits in this period. In 1986, the creation of the Ventura County 'red line', restricting the depth of instream aggregate extraction, marked the beginning of the decline of in-

Looking upstream to Vern Freeman Diversion Dam (2003).
(photograph by Stillwater Sciences)

stream mining in the lower river. The construction of the permanent Vern Freeman Diversion Dam in 1992, at the approximate historical bed level, allowed mainstem bed elevations to recover upstream of the dam, although local scour has continued to occur downstream. Aggregate mining was identified as the greatest anthropogenic factor in the morphodynamics of the lower Santa Clara River (Simons, Li & Associates 1983), affecting channel incision dynamics that can undermine in-channel structures and potentially interrupt sediment supply for beach replenishment (Noble Consultants 1989).

The primary new human influence in the watershed is the continuation of rapid population increases in the watershed, causing large-scale conversion of floodplain agricultural land to residential, transportation, and municipal infrastructure. The human population in the watershed has increased approximately ten-fold since the 1940's, with much of the growth occurring adjacent to the mainstem corridor. Increases in population and urbanization will undoubtedly continue into the foreseeable future, and they are likely to have an increasingly noticeable effect on geomorphic and biological processes in the lower river corridor. Typical impacts of urbanization include further construction of levees and bank protection that can alter bed and bank erosion dynamics (as mentioned above), increased impervious area that can lead to 'flashy' flood events (*i.e.*, higher peak discharges and shorter time-to-peak discharge) and increased channel erosion. Additionally, decreases in water quality and flow restrictions create conditions that can fail to meet aquatic species' preferences for flow velocities, flow depths, and water temperature, and within which organisms can experience chronic (or periodically acute) toxicity.

In the future, the Santa Clara River is likely to be affected by changes in temperature, precipitation, and sea-level resulting from global warming. In addition to predicted changes in temperature and precipitation (see Section 2.3.2), climate change may alter the frequency and/or intensity of severe storms and droughts, as well as wildfires and flooding. The effects of these altered processes, driven by shifts in climate patterns, are difficult to predict particularly when considered in conjunction with human impacts to the watershed.

2.3 Key Physical Attributes

Geomorphic processes in the Santa Clara River are dominated by extreme events associated with the river's highest flows, and they are strongly influenced by the geologic, meteorologic, and fire regime context of the watershed. These events transfer water and sediment from the hillslopes to the estuary and nearshore waters, and they are integral to changes in form of the mainstem Santa Clara River and its floodplain over time. The exchange of sediment between the river channel and floodplain during flood events (*i.e.*, episodes of erosion and deposition) determines the hazards and assets possessed by the river corridor: the hydrologic and geomorphic processes that create "hazards," such as flooding, unwanted bed and bank erosion, and deposition, are the same processes that help sustain river ecosystems by creating such "assets" as aquatic and riparian habitat diversity. Understanding physical attributes and processes in the Santa Clara River watershed is, therefore, a necessary precursor for understanding the hazards and assets of the lower river corridor that are critical in determining the feasibility of proposed restoration strategies and the development and maintenance of habitats that support native plant and animal species.

2.3.1 Tectonics

The Santa Clara River watershed is located within the San Andreas Fault system, a geologically active area that forms the dynamic boundary between the Pacific and North America tectonic plates. The position of unchanneled valleys, creeks, and the Santa Clara River itself are strongly influenced by geologic structure and the location of active faults (Figure 2-2). Below the confluence with Sespe Creek, the Santa Clara River roughly follows the axis of a west-trending synclinal valley, which is bounded by active strands of the San Cayetano Fault (Rockwell 1988) to the north and the Oak Ridge Fault (Azor *et al.* 2002) to the south. Convergence along this axis has led to rapid uplift in coastal and interior mountain ranges throughout the region (Orme 1998, Blythe *et al.* 2000, Duvall *et al.* 2004) and persistent regional geologic instability since about 28 million years ago has exposed a wide variety of highly deformed, fractured, and faulted rock types in the Santa Clara River watershed (Yeats 1981, Rockwell *et al.* 1984, Rockwell 1988), contributing to high bedrock erodiblity throughout the watershed. For example, the sedimentary bedrock along the mainstem valley flanks is often poorly consolidated, intensely folded, and has steeply tilted beds, making it very susceptible to landsliding (*e.g.*, Harp and Jibson 1996) and erosion by dry raveling (Scott and Williams 1978). Even areas underlain by granite, gneiss, and schist (which are normally thought to be relatively resistant to erosion) have also

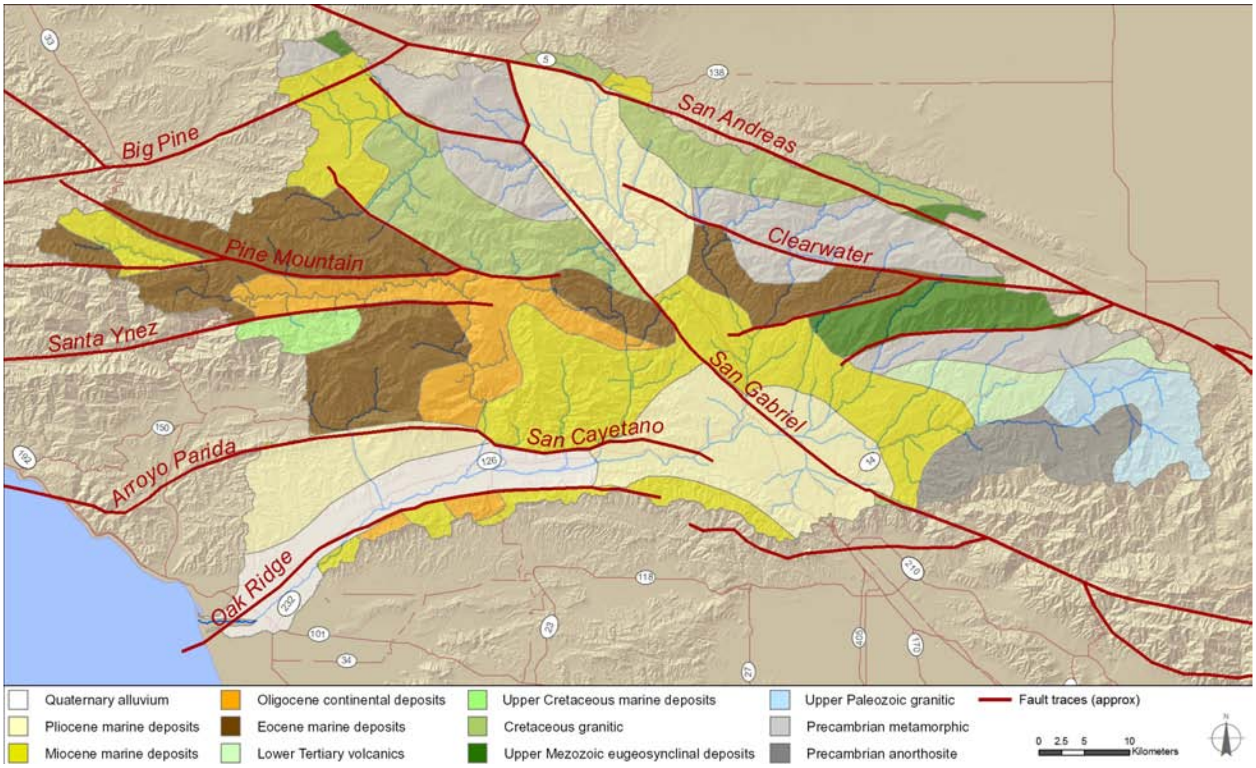

Figure 2-2. Rock units and faults within the Santa Clara River watershed.

been described as being highly erodible (*e.g.*, Scott and Williams 1978, Wells *et al.* 1987) due to extensive deformation and fracturing.

2.3.2 Climate

The Santa Clara River watershed experiences a semi-arid Mediterranean-type climate, with cool wet winters and warm dry summers. Proximity to the Pacific Ocean moderates both seasonal and diurnal temperatures, air moisture, and precipitation (Figure 2-3). Air moisture is greatest at the coast and decreases to near-desert conditions towards the eastern watershed boundary. Most precipitation occurs between November and March and varies significantly throughout the watershed due to topographic features (Figure 2-3). For example, average annual rainfall is more than 34 inches in the mountainous headwaters of Sespe Creek, while only about 8 inches in the drier eastern portions of the watershed near the Mojave Desert (PWA 2003).

The climate of the Santa Clara River watershed is also affected by the El Niño-Southern Oscillation (ENSO), a climatic phenomenon which is characterized by warming and cooling cycles (oscillations) in the waters of the eastern equatorial Pacific Ocean. ENSO events typically have 1–1.5 year durations, a 3–8 year recurrence interval, and are related to changes in atmospheric circulation, rainfall, and upper ocean heat content (see Deser *et al.* 2004 and references contained therein). In southern California, El Niño years are a)

b)

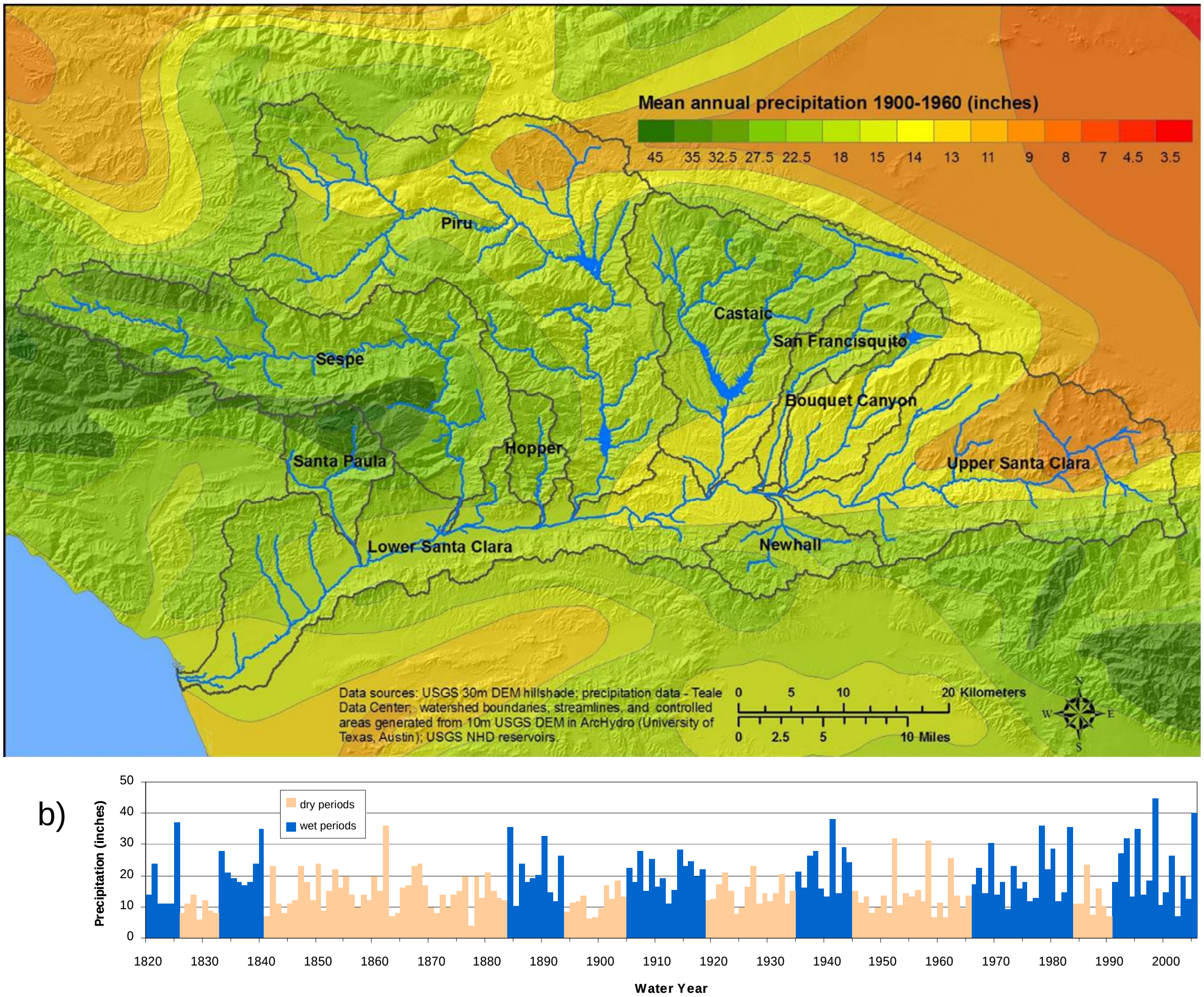

Figure 2-3. a) Distribution of mean annual precipitation (1900 to 1960); b) Annual precipitation at the Santa Paula Creek gage (VCWPD no. 245) and the multi-year cycle of wet and dry periods based on data and narrative accounts from Lynch (1931) and Freeman (1968).

characterized by relatively high rainfall intensities, with rivers and streams exhibiting higher annual peak flow magnitudes than they do in non-El Niño years (Cayan *et al.* 1999, Andrews *et al.* 2004). For El Niño years there is a greater than 70% probability of peak flow exceeding 40,000 cfs near the mouth of the Santa Clara; for a non-El Niño year the probability of such a flow is less than 10%. A recent wet-period ENSO cycle (from 1969 to the present) has been marked by strong El Niño years every 3–7 years, a relative increase in the number of large storms, and mean sediment fluxes for Southern California rivers (from the Pajaro River south to the Tijuana River) that have been approximately five times greater than during the preceding dry period (1944–1968) (Inman and Jenkins 1999).

Predictions of climate change in California in the next century include warmer winters (by 5–6° F), slightly warmer summers (by 1–2° F), and increased winter precipitation (primarily as rain rather than snow), particularly in the mountains (Field *et al.* 1999). ENSO events may increase in intensity and/or frequency (Field *et al.* 1999). In southern California the change in precipitation timing is expected to lead to increased winter runoff and decreased summer stream flow. Climate change is also expected to have indirect effects on ecosystems, including changes in the frequency and/or intensity of extreme weather events such as severe storms and droughts, and ecological processes, such as wildfires, flooding, and disease and pest outbreaks.

2.3.3 Fire Regime

Historical records indicate that much of the Santa Clara River watershed has burned at least once since the late 19th century, with many areas of the lower watershed, including South Mountain and the lower Sespe, Hopper, and Piru creek watersheds, burning up to nine times since 1878 (CDF 2007) (Figure 2-4). Fires in 2003 burned 119,105 ac or 11.4% of the watershed slopes, and the Day Fire in 2006 burned 162,842 ac, mostly in the Santa Clara River watershed. Sediment production within the Santa Clara River watershed is significantly affected by the 'flood–fire' sequence, in which post-fire winter

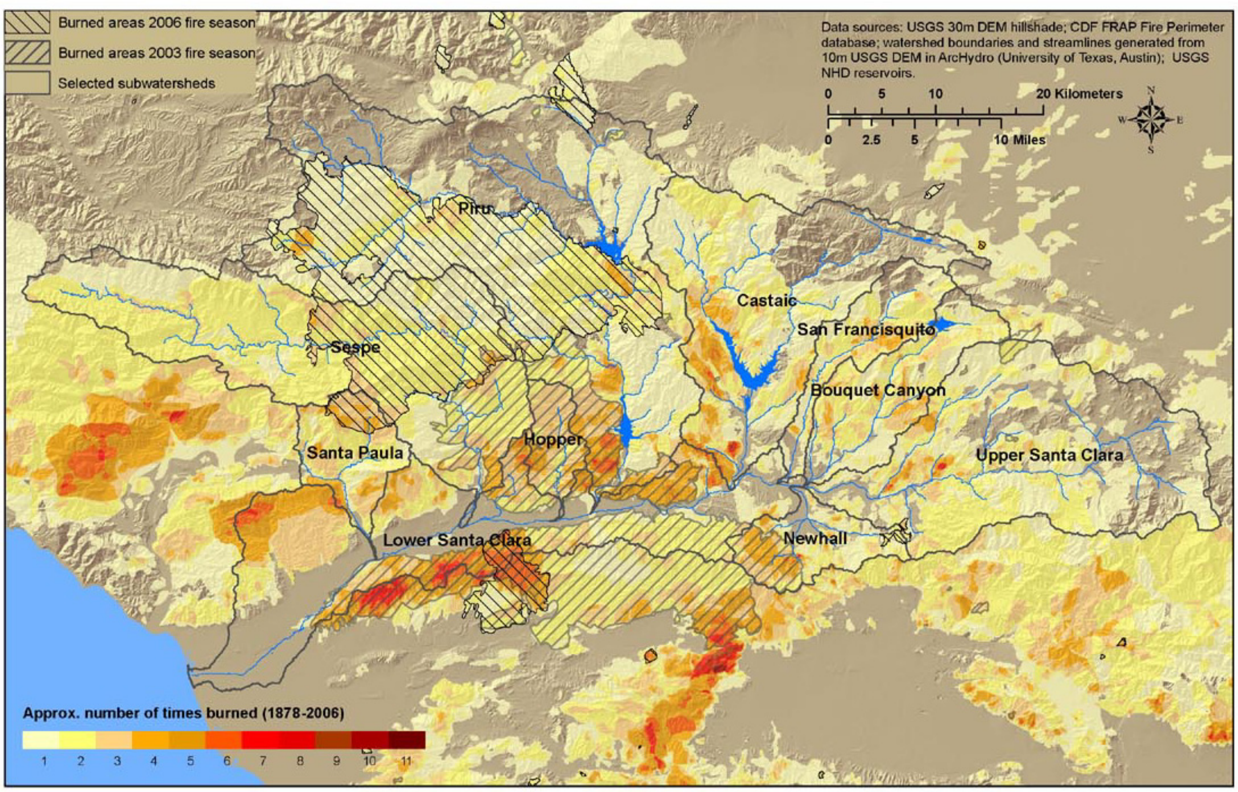

Figure 2-4. Fire reoccurrence within the Santa Clara River watershed since 1878 and extent of the 2003 and 2006 fire seasons.

rains lead to increased runoff and accelerated erosion, which in turn results in debris flows, landslides, and floods.

Although riparian ecosystems generally function as barriers to wildfire, the fires in 2003 burned large expanses of riparian habitat along the Santa Clara River in what appears to be an arundo-fire regime cycle (Bell 1997, Dudley 2000, Coffman 2007). Arundo accumulates large quantities of biomass (dense thickets of dead and live stalks) that increases both the susceptibility of the riparian corridor along the Santa Clara River to fire, and the risk of fire spreading to surrounding shrublands, towns, and agriculture (Coffman 2007). Immediately following fires, elevated soil ammonium-nitrate and phosphorus levels and lack of competition from native species stimulates arundo growth rates (Coffman 2007). Within one year following the burning of the riparian corridor in 2003, arundo had reached 99% cover in some burn areas and had densities nearly 20 times higher and productivity 14–24 times higher than native plants (Coffman 2007). The resulting extensive and dense stands of arundo further increase the susceptibility of the riparian corridor to subsequent fire.

2.3.4 Hydrology

Consistent with other rivers in the region, the Santa Clara River watershed experiences highly variable annual rainfall and peak flows. Generally, flows in the river are relatively small: 75% of the time flows are less than 150 cfs at the Montalvo gage (approximately 4.5 mi upstream of the mouth) and 50% of the time flows are less than 10 cfs (URS 2005). However, large peak flows associated with winter storm events exceed 100,000 cfs once every 10 years on average (URS 2005) (Figure 2-5). The two largest peak flows on record occurred during the 1969 flood event (165,000 cfs) and the more recent 2005 flood event (136,000 cfs). During the rainy season, flows can increase, peak, and subside rapidly in response to high intensity rainfall, with the potential for severe flooding under saturated or near-saturated watershed conditions (Figure 2-5). Between winter rainfall events in wet years, the river may exhibit continuous baseflow to the ocean from residual watershed discharge; in dry years, flow may be intermittent.

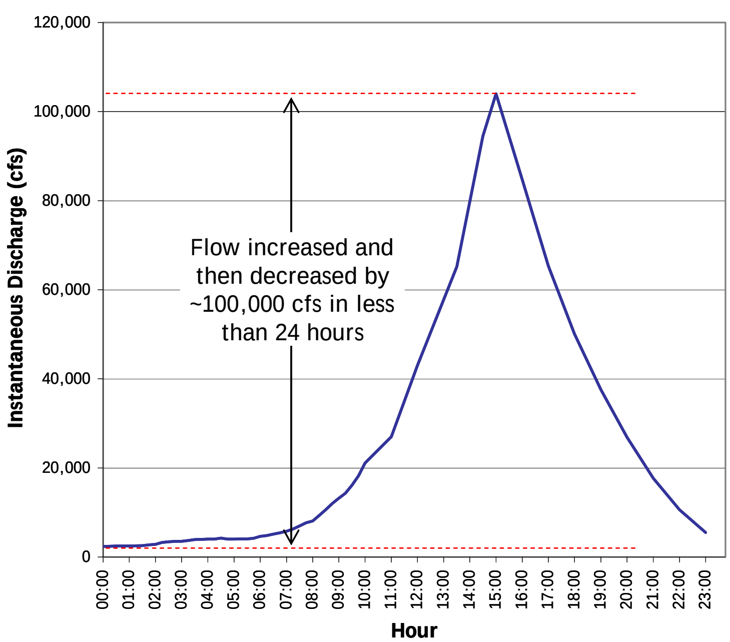

Figure 2-5. Daily flow hydrograph at the Montalvo gage (USGS 11114000) from February 12, 1992.

During the dry summer season, flows in the mainstem and tributaries are intermittent or non-existent, depending primarily on areas of rising groundwater or inflows from dam releases or other anthropogenic sources, such as irrigation runoff and treated wastewater effluent. Groundwater discharges to the mainstem Santa Clara River occur when groundwater levels are high. In the lower Santa Clara River, two geologic features are important to surface water-groundwater interactions on the mainstem—the Piru and Fillmore narrows (located in the County Line Reach [11] and Above Santa Paula Reach [5], respectively; see Figure 1-2). In these locations, constrictions in the width of unconsolidated deposits, combined with subsurface bedrock controls, cause groundwater to rise and discharge to the Santa Clara River, depending on groundwater levels and surface flow conditions (AMEC 2005, URS 2005). In areas away from the bedrock controls, surface flow is lost through the highly permeable bed materials to groundwater.

Tributaries of the Santa Clara River include Santa Paula, Sespe, Hopper, Piru, Castaic, San Francisquito, and Bouquet Canyon creeks. These tributaries, in addition to the upper Santa Clara River (upstream of the Los Angeles County line) provide approximately 85% of the flow that exits the mouth of the Santa Clara River (URS 2005). The remaining flow is delivered from numerous barrancas (small, generally incised tributary streams) and unnamed ephemeral creeks. As in the mainstem, flows in the tributaries are relatively small except during high-intensity, short-duration storm events. On average, storm-induced flow exceeds 41,000 cfs in Sepse Creek, 18,000 cfs at the Los Angeles County line, 8,500 cfs in Santa Paula Creek, and 500 cfs in Piru Creek approximately once every 10 years (URS 2005) (Figure 2-6). Due to Santa Felicia Dam, flow in Piru Creek is highly regulated and varies much less than the other main tributaries (*e.g.*, daily peak discharge within Piru Creek below Santa Felicia Dam has ranged from 20 to 900 cfs between 1955 and 2003).

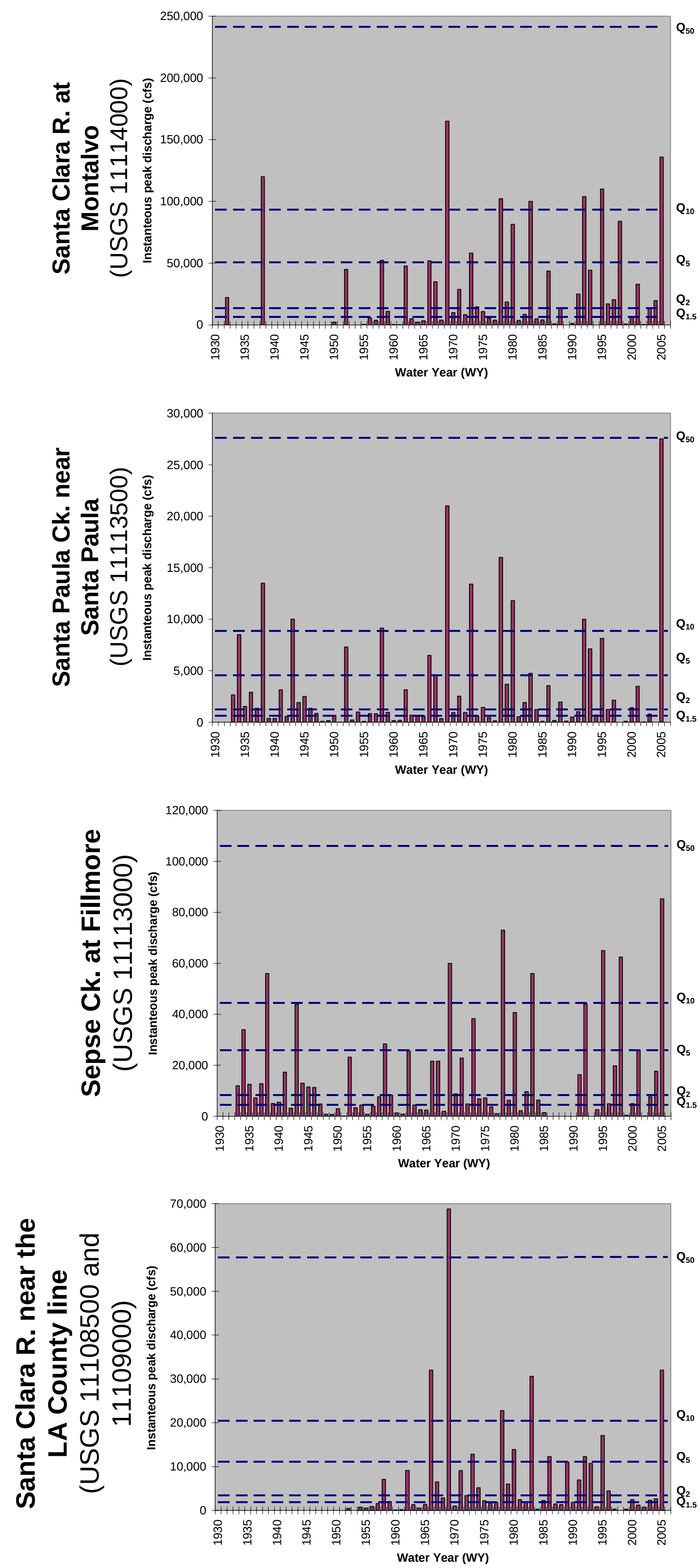

Figure 2-6. Annual maximum discharge for the four main USGS gages in the lower Santa Clara River watershed. Years with no available data are plotted as a zero value.

More than one-third of the watershed area lies upstream of dams and debris basins that regulate water and/or sediment discharge to the lower river corridor. Major dams include Santa Felicia Dam on Piru Creek and Castaic Dam on Castaic Creek (see Figure 1-1). Throughout the year, controlled releases of water from Piru Reservoir supplement surface flows in the river between the confluence with Piru Creek and Vern Freeman Diversion Dam. Additional flow is supplied from water reclamation plant discharges and imported water runoff from the upper watershed in the middle reach from the vicinity of Santa Clarita in Los Angeles County down to the Ventura County line.

Water in the estuary is supplied predominantly by upstream flow from the Santa Clara River and effluent from the Ventura Water Reclamation Facility (waste water treatment plant), with local agricultural runoff and wave overwash also contributing to the overall supply (Swanson *et al.* 1990, as cited in ESA 2003). The Ventura Water Reclamation Facility discharges an average of 7.2 million gallons per day of treated wastewater into the estuary (Nautilus Environmental 2005), which is equivalent to an average year-round stream flow of approximately 11 cfs. During the winter months when river flows dominate and generally maintain an open mouth, effluent discharge is a relatively small portion of total discharge volume. However, the average daily effluent discharge is far more than the average summer and fall streamflow that would be expected from an unregulated southern California river with a closed mouth (ESA 2003). Discharge of treated effluent from the wastewater treatment plant while the mouth is closed can cause the water level of the estuary to rise above the sand barrier, causing the barrier at the mouth to breach at a time of year when this would not naturally occur (Swanson *et al.* 1990, as cited in ESA 2003).

2.3.5 Sediment Production

Rapid tectonic uplift rates, frequent high-intensity storm events, and erodible bedrock lead to extremely high rates of sediment production from hillslopes in the Santa Clara River watershed. The Santa Clara River's location within the San Andreas Fault zone also makes its slopes especially prone to earthquake-induced landsliding. In 1994, the magnitude 6.7 Northridge earthquake triggered nearly 7,400 landslides in the Santa Clara River watershed (Figure 2-7). Over the long term, the supply of sediment to channels is thought to be fairly continuous (Scott and Williams 1978), with wet-season contributions from overland flow, landslides, and soil slumps, and dry-season contributions from dry ravel. Over the short-term, sediment is delivered from tributaries to the mainstem more episodically, in flows associated with big storms, and also in moderate storms that follow fires (Florsheim *et al.* 1991, Wells 1981). Naturally high rates of sediment production are exacerbated by post-fire soil rilling and human land uses in the watershed.

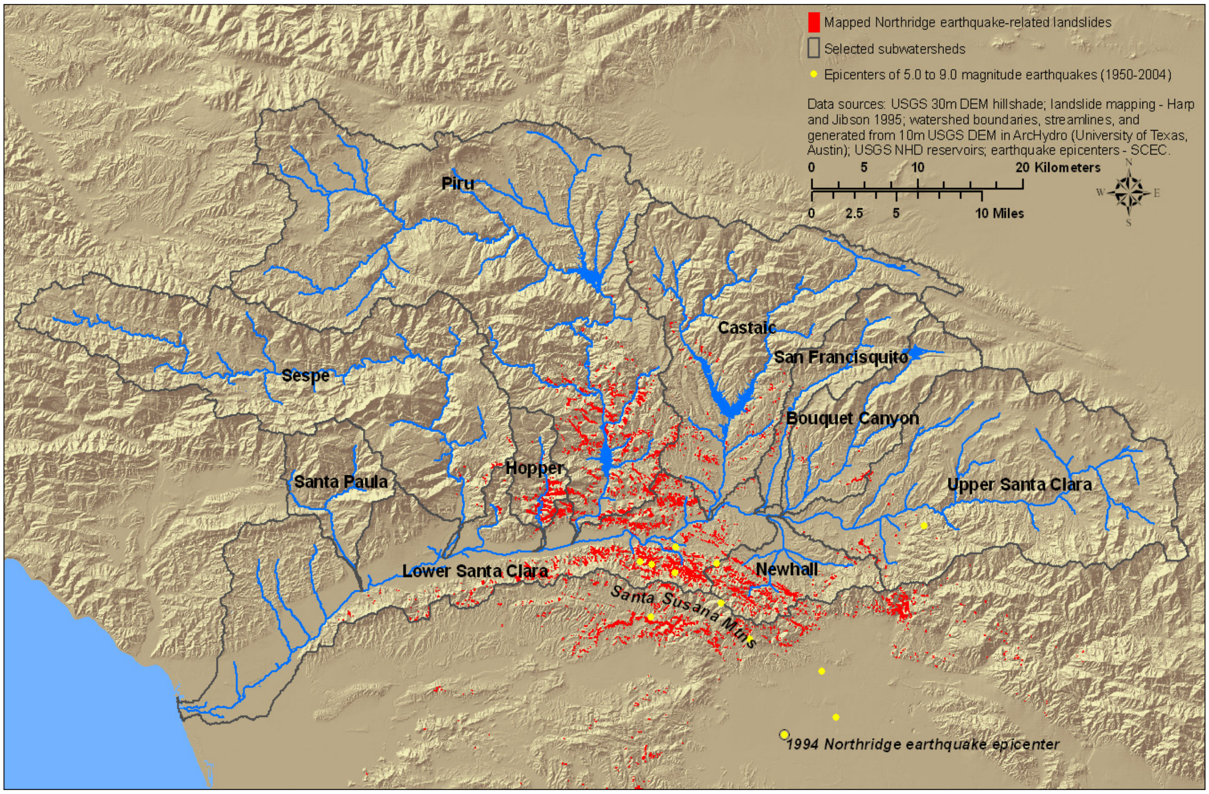

Figure 2-7. Landslides triggered by the 1994 Northridge earthquake (magnitude = 6.7).

2.3.6 Sediment Transport

Sediment transport processes in the Santa Clara River are dominated by extreme events associated with the river's highest flows. For instance, an estimated 55% of the roughly 63.5 million tons of sediment that passed the USGS gage at Montalvo near Highway 101 between 1968 and 1975 was transported during high flows in just two days during two separate floods of record in January and February 1969 (Williams 1979). Analysis of the Montalvo gage data for the period 1968–1985 indicates that about 94% of the suspended load was transported by storm runoff in just 57 days, or 1% of the nearly 5,700 days covered by the flow record. A more recent study concludes that for the period 1928–2000, 25% of the total sediment discharge occurred in just four days (Warrick 2002).

Bedload particle sizes at the Montalvo and Los Angeles County line gages, measured during low to moderate flow, consist mainly of fine and coarse sand, with fine gravel-sized particles also present at higher flows. Bedload particle sizes in Sespe Creek at Fillmore are generally coarser than the sediment in the mainstem Santa Clara River, and range from coarse sand to medium gravel.

The Santa Clara River discharges a considerable amount of sediment through the mouth/estuary complex, primarily during high-intensity low-recurrence storm events. In general, the coarser sediment (coarse sand and larger) that is delivered from the Santa Clara River during storm events contributes to the building of near-shore and offshore deltas, which in turn provides sediment for littoral transport (and down-coast beach deposition) and supplies sediment that builds the barrier beach and causes mouth closure during periods of low river discharge. The magnitude of sediment transport out of the watershed depends on whether the storm causes net bed aggradation or incision throughout the mainstem Santa Clara (which is a function of the relative flow and sediment contribution from Sespe Creek (Figure 2-8).

Overall, the yield of sand and gravel from the Santa Clara River has been suggested to have decreased by approximately 25% from pre-development rates (Brownlie and Taylor 1981). The high discharge events in the Santa Clara River that deposit sediment to the offshore delta are dominated by 'hyperpycnal flows' in which the river discharge is denser than ocean water due to high suspended sediment concentration (Warrick 2002, Warrick and Milliman 2003). The density and velocity associated with hyperpycnal flows from the Santa Clara River cause the suspended sediment to pass through the estuary and nearshore zone, and be either temporarily deposited on the offshore delta or lost to the Santa Barbara Channel.

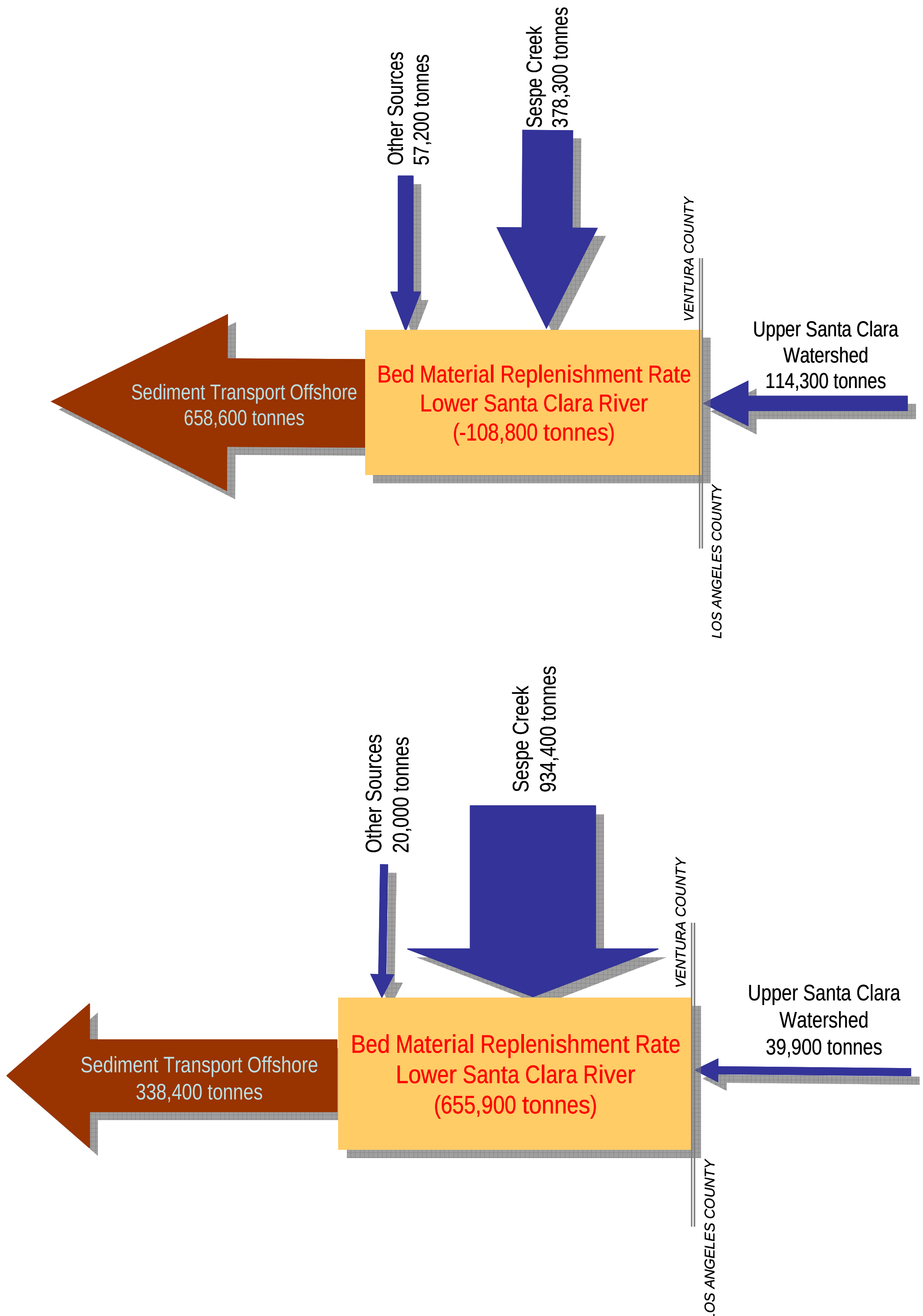

Figure 2-8. Illustration of the conceptual model of sediment transport dynamics within the lower Santa Clara River presented in Simons, Li & Associates (1983). Case A (top) demonstrates a degradational (incision) event, based on the Simons, Li & Associates (1983) analysis of data from the January 25, 1969 flood. Case B (bottom) shows an aggradational event based on their analysis of data from the February 10, 1978 flood.

2.3.7 Channel Morphology

Conditions in the Santa Clara River contrast sharply with those observed in alluvial rivers in humid environments, which have provided the basis for many of the classic generalizations of fluvial geomorphology. These include the concept of "dominant discharge" or "bankfull", the flow that, over the long-term average, performs the most work in terms of sediment transport and is most directly responsible for shaping and maintaining the channel in a characteristic equilibrium morphology (Wolman and Miller 1960). In humid environments, the most common flow occurs at an intermediate discharge, the sediment transport rate increases steadily with increasing flow, and total sediment load exhibits a maximum at an intermediate discharge (Figure 2-9).

However, within the Santa Clara River watershed, there is such a wide range of flows, and such a rapid increase in sediment load with increasing discharge, that the total coarse sediment load instead increases monotonically across the entire range of flow data, with a maximum at the highest flow (Figure 2-10). Hence the "dominant discharge" for the Santa Clara River is not an intermediate flood, it is the largest discharge on record.

The fact that the dominant, channel-forming flow is the largest flow on record implies that the Santa Clara River will not generally behave like a classic alluvial river. For example, the channel will probably not typically overflow its banks every one to three years, or maintain a well-defined, regularly-spaced riffle-pool sequence. In general, morphology will not exhibit equilibrium tendencies, showing small, year-to-year fluctuations around a long-term average condition. Instead, the channel and its floodplain will experience significant shifts in planform and channel cross-section in episodic high flows, thus increasing the chance of a rapid onset of hazardous conditions during a large flood event.

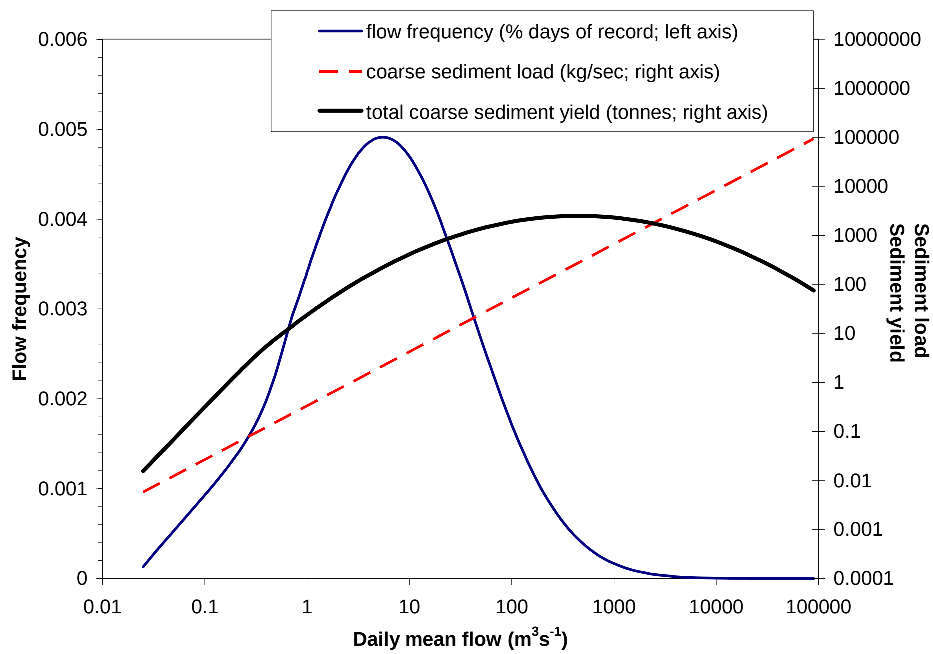

Figure 2-9. Flow frequency (left axis, scaled to 1) and sediment load (right axis) plotted against flow, showing conceptual, dominant discharge model of Wolman and Miller (1960). Blue line tracks flow frequency (for mean daily flow), red line tracks sediment transport rate (in tons/day) and black line tracks total sediment load (in tons). Sediment load increases to a maximum at an intermediate flow.

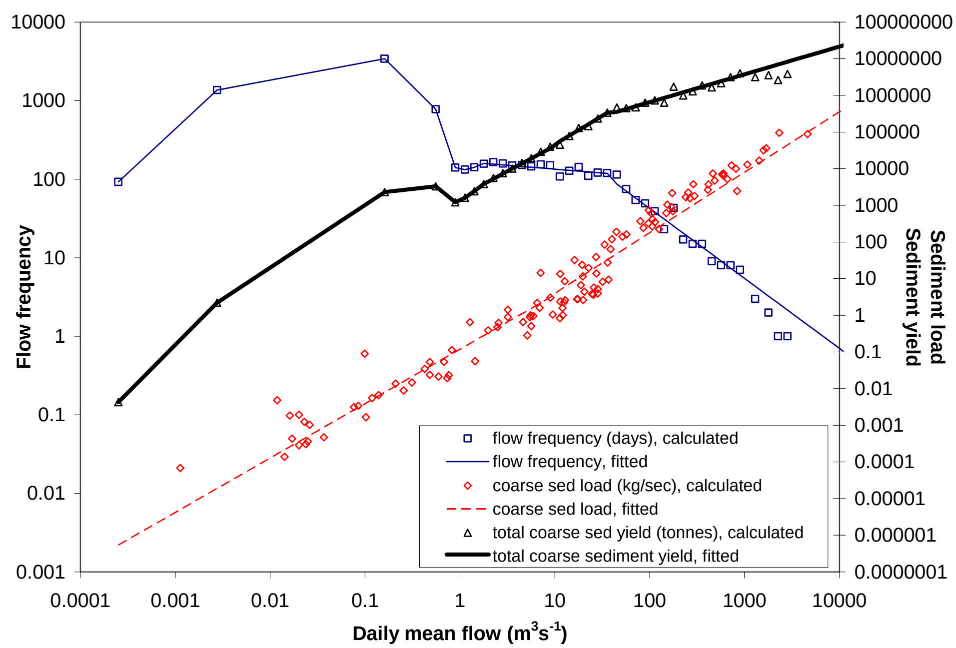

Figure 2-10. Flow frequency (left axis) and coarse sediment load (right axis) as a function of daily mean flow for the Santa Clara River at Montalvo (USGS11114000). Blue line tracks flow frequency, red line tracks sediment transport rate (in tons/day) and black line tracks total sediment load (in tons). The dominant discharge (*i.e.*, the one that carries most of the total sediment load) is the largest discharge of record. Details of this analysis are presented in Appendix C.

Estuary Bed Characteristics

The surface sediments of the estuary are characterized by highly stratified layers of coarse sand with relatively small amounts of silt and clay (ESA 2003), although cobble and boulder-sized sediment have also been observed being transported from the estuary during storm events (O'Hirok 1985; J. Warrick, USGS, pers. comm., 2005). Deposition of silt and clay-sized material has been observed due to fluvial delivery following storm events (USFWS 1999a) and flocculation (aggregation of fine sediment) induced by mixing of river and ocean water (O'Hirok 1985).

Channel/Estuary Planform Dynamics

In planform, the lower Santa Clara River is characterized by a wide, relatively straight floodway with one or more low-flow channels that are reconfigured after each flood event (Figure 2-11). The full mainstem channel bed is occupied only during high-magnitude floods (Stillwater Sciences 2007a). Erosion of alternate outer banks of the active floodway in some

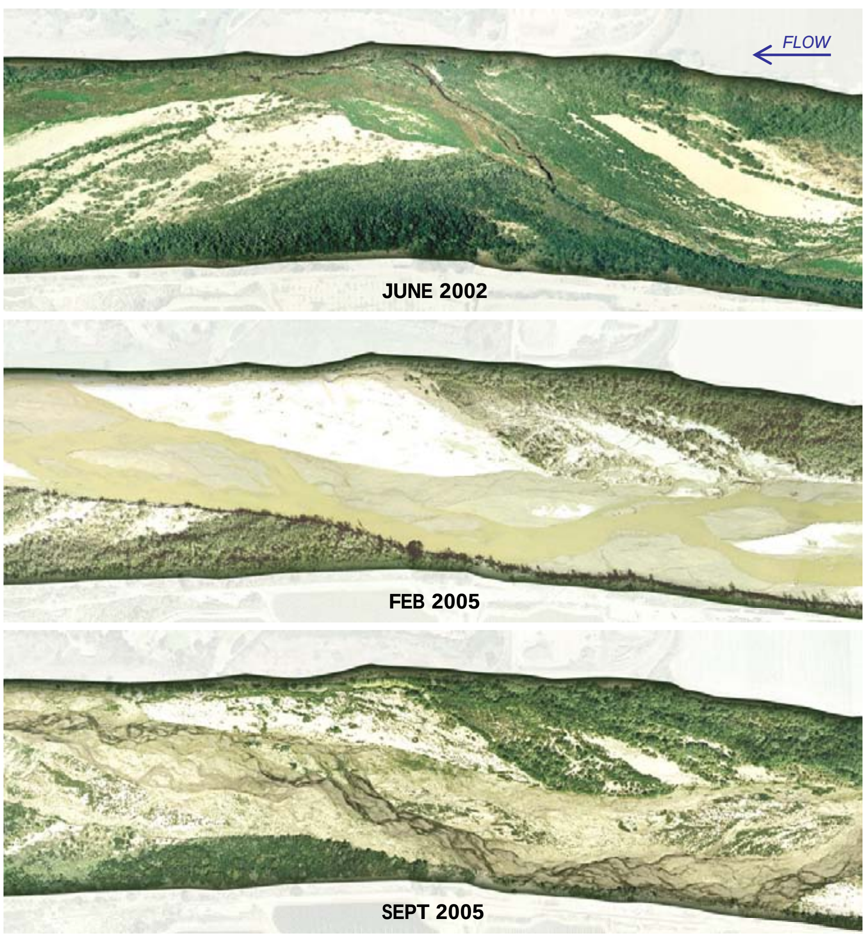

Figure 2-11. Channel planform dynamics in the lower Santa Clara River.

reaches following large floods in January-February 2005 suggests that the entire floodway of the contemporary lower river behaves in a manner similar to a broad, single-thread meandering channel at very high flows. As floods recede, the river becomes more braided in character, with multiple flow courses. There is insufficient perennial flow to retain multiple flowing channels in a majority of the lower Santa Clara River and, in general, a single dominant channel defines the channel thalweg (Figure 2-11). In some reaches, however, residual flow continues to be carried by secondary channels. The low-flow channel boundary changes rapidly and comprehensively during flood events according to the magnitude of the event and other factors. Changes in the boundary of the mainstem channel, in contrast, will be more limited but of greater importance in determining the relationship between the river's geomorphology and human activities on the floodplain, because boundary changes imply flood inundation and possible erosion and/or deposition processes that can impact nearby land uses.

Evidence digitized from aerial photographs taken after large flood events since 1930 indicates that overall, the active width of channel bed of the 37-mi-long lower Santa Clara River has become narrower by almost 50% from 1938–2005 (from 1,585 to 827 ft) (Stillwater Sciences 2007a). Further, over large stretches, the relationship between active width and flood magnitude that might be expected in a semi-arid river has diminished over time. As such, few reaches of the lower Santa Clara River vary their active width commensurately with flood discharges, demonstrating the influence of human activities on channel morphology.

Similar to the mainstem Santa Clara, the estuary has undergone considerable changes over the past 150 years (Figure 2-12). Agricultural encroachment and development within the historical estuary footprint have contributed to an approximate 75% decrease in estuary extent (Swanson *et al.* 1990). Comparison of the 1969, 1993, and 2002 aerial photographs indicated that the shoreline and river mouth migrated to the south following the 1993 flood (compared to conditions in 1969) and that the estuary "channel" had begun to erode towards the north, while the mouth advanced to the south by 2002. Significant changes to both the river mouth and channel location also occurred as a result of the 2005 flood events.

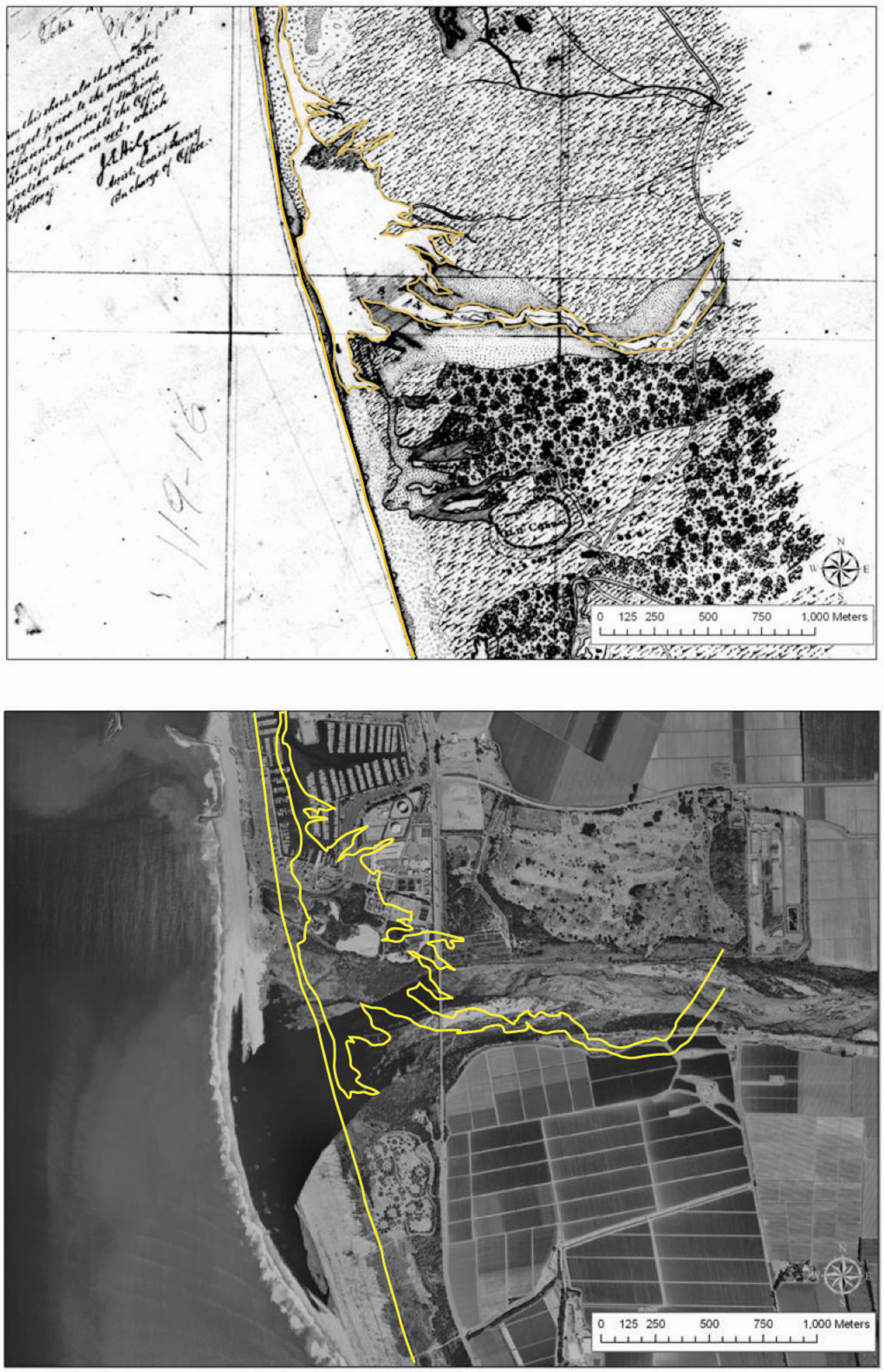

Figure 2-12. 1855 and 2005 maps of the Santa Clara River estuary. (top) The 1855 U.S. Coast and Geodetic Survey (USC&GS) map shows a meandering river channel with a broad floodplain and an extensive estuary/lagoon complex with a distributary channel network at the southern extent of the mouth complex. (bottom) The 1855 shoreline and the river mouth (and associated estuary) (yellow trace) are inland and the mouth/estuary complex is further north compared with the 2005 location.

Channel Profile

Examination of channel thalweg surveys indicate that, overall, the lower Santa Clara River has incised by 2.3 ft from 1949–2005 (Figure 2-13). Incision is focused in the lower parts of the river, where the maximum single-station incision over the 56-year period is 25.1 ft just downstream of Freeman Diversion. Using a base date of 1949 for consistency, the lower Santa Clara River shows:

- a trend of incision from 1949 to 2005 downstream of the Santa Paula Creek confluence;
- a variable trend of minor incision and aggradation from Santa Paula Creek to Sespe Creek, and
- moderate aggradation upstream towards the Los Angeles County line.

Incision gives way to aggradation towards the upper end of the lower Santa Clara River (maximum single-station aggradation of 10.2 ft) such that over the period of record, the gradient of the lower Santa Clara River has in-

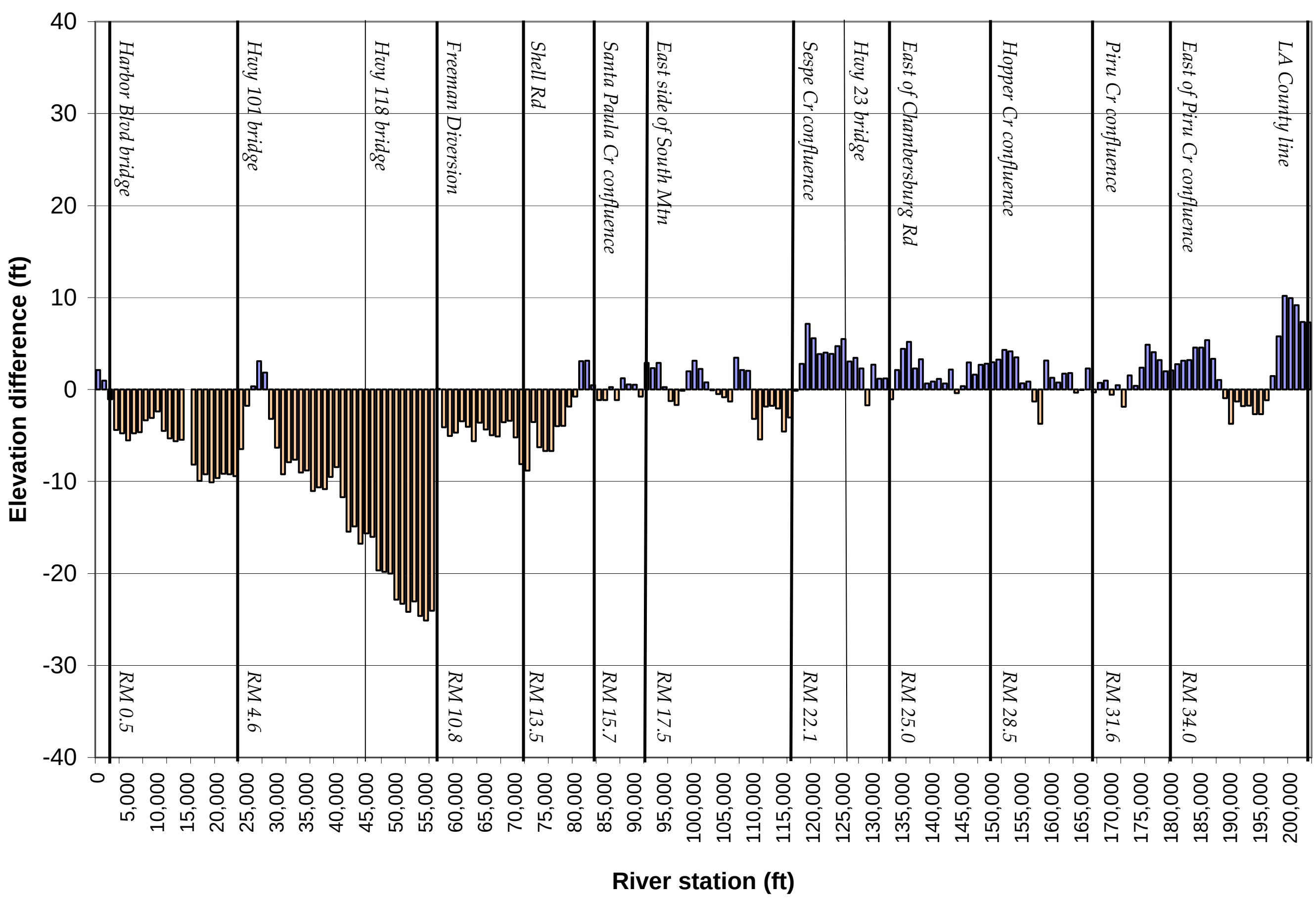

Figure 2-13. Net thalweg elevation change in the Santa Clara River from 1949 to 2005. River miles provided for reach boundaries.

creased slightly from 0.0040 to 0.0041. Narrower and deeper rivers are more effective at transporting sediment and it is notable that the downstream end of the lower Santa Clara River now has a greater stream power (a measure of the potential to transport sediment) than farther upstream, and this is contrary to upstream-to-downstream trends in stream power found in many natural rivers. Such changes in the lower Santa Clara River over the period of record help to explain why flood events now result in the net export of sediment from the watershed (*i.e.*, net incision); but a full explanation of the changes requires some additional context in terms of recent human activities in the watershed.

2.3.8 Groundwater

The lower Santa Clara River is underlain from east to west by the Piru, Fillmore, Santa Paula, Montalvo, and Oxnard Plain groundwater basins. The general vertical structure of the basins is recent and relatively thin alluvial deposits overlying older alluvial deposits that are much thicker. The recent alluvial deposits are generally younger than 10,000 years and are locally derived from the mountains bounding the Santa Clara River (UWCD and CLWA 1996). Because the overlying deposits are young by geologic standards, they are also relatively thin compared to the much thicker and older deposits which they overlie. The underlying sedimentary deposits are as old as 1.8 million years and up to 10,000 ft thick (UWCD and CLWA 1996). Since the alluvial deposits are relatively porous, nearly all of the groundwater basins along the lower Santa Clara River are unconfined aquifers: they are able to receive water from the surface and their water table surface fluctuates freely in response to recharge and discharge rates. Only the Oxnard Plain is a confined aquifer.

Broadly speaking groundwater flow follows the east to west trend of the Santa Clara River. The upstream and downstream bounds of the groundwater basins are typically defined by an aquaclude, or barrier to subsurface flow. At these locations, groundwater return flow to the surface is common (and results in the gaining reaches of the river – see Table 1-1). The unconfined aquifers in the lower watershed range from approximately 6,400 to 15,000 ac, while the Oxnard Plain is approximately 83,000 ac (Table 2-2) (UWCD and CLWA 1996).

Mechanisms for groundwater recharge are varied, but in the upstream-most, unconfined basins – Piru, Fillmore, and Santa Paula – percolation of surface flows from the Santa Clara River and its tributaries is the primary recharge mechanism, particularly in the winter when surface flows are highest (UWCD and CLWA 1996). In the fall, these basins are recharged by the Piru spreading grounds which are fed by flow releases from Lake Piru (UWCD and CLWA 1996). The Montalvo groundwater basin is primarily recharged from the Saticoy and El Rio spreading grounds, which receive water diverted from the lower Santa Clara River at Freeman Diversion Dam, although it also receives water directly from Santa Clara River surface flows in the winter (UWCD and CLWA 1996). Rainfall, irrigation return flows, water treatment facility effluent, and water from the adjoining upstream basin also contribute to recharge in the unconfined aquifers (Table 2-2). The Oxnard Plain basin is also primarily recharged by the Saticoy and El Rio spreading grounds, but via the Montalvo basin. Historically, groundwater discharged into the ocean through the Oxnard Plain basin, but intensive groundwater pumping caused groundwater levels to decline below sea level in parts of the basin, allowing sea water to enter the freshwater aquifer (i.e., saltwater intrusion) (UWCD and CLWA 1996).

Table 2-2. Characteristics of the groundwater basins underlying the lower Santa Clara River.*

Groundwater basin	Approx. area (acres)	Estimated max. depth (ft)	Average annual extraction (ac-ft)	Primary replenishment mechanisms
Piru	12,000	8,000	11, 106	Santa Clara River surface flow (winter), Piru spreading grounds (fall), precipitation, irrigation returns
Fillmore	15,000	8,000	48,447	Santa Clara River surface flow (winter), Piru spreading grounds (fall), Piru groundwater basin, precipitation, irrigation returns, treated sewage effluent
Santa Paula	13,700	>10,000	23,339	Santa Clara River surface flow (winter), Piru spreading grounds (fall), Fillmore groundwater basin, precipitation, irrigation returns
Montalvo	6,400	*no data*	25,586	Santa Clara River surface flow (winter), Saticoy and El Rio spreading grounds (fall), Santa Paula groundwater basin, precipitation, irrigation returns
Oxnard Plain	83,200	2,000	67,195	Montalvo groundwater basin, , marine infiltration

*Information in this table was extracted from UWCD and CLWA (1996).

Groundwater and the surface flow of the lower Santa Clara River are clearly intimately linked. Generally, in wetter years, the water table surface is shallow and return flow from the groundwater basins to the surface is an important component of river discharge (see Section 2.3.4). In contrast, during drought years return flow is either minimal or absent and many reaches of the river lose water (see Table 1-1). Groundwater extraction, one of the primary methods of supplying irrigation water to the region, also removes a portion of the groundwater available for surface return flow (see Table 2-2), and has a variable impact depending on the water year type and the total volume of water extracted. Because riverine flora and fauna depend on the availability of surface flow and high water tables, the annual and seasonal condition of the groundwater basins and return flow to the river can have important consequences for aquatic species and must be considered when developing restoration strategies for the lower Santa Clara River. For example, the establishment and survival of native riparian plant species is dependant on relatively shallow water tables and, thus, groundwater levels influence where active revegetation is appropriate (see Section 4.4). Similarly, the exchange between groundwater and surface flow affects instream habitat availability and quality and will be important in evaluating restoration potential for aquatic focal species (see Sections 2.4.3 and 4.7).

2.4 Key Biological Attributes

The Santa Clara River watershed is a regionally important area for native plant and animal species for several reasons. First, the distinct climate gradients and dynamic hydrology and geomorphology of the Santa Clara River watershed help support a variety of natural vegetation types The eastern, drier part of the watershed is characterized by desert scrub, with juniper, pinyon pine and Joshua tree woodlands. The western, semi-arid portion of the watershed supports coastal sage scrub, chaparral, oak woodland, grassland, and riparian communities, several of which are considered sensitive or rare (CDFG 2005). Second, the Santa Clara River is one of the least regulated and altered rivers in southern California. In terms of hydrology, there are no large dams or storage reservoirs on the mainstem, and relatively intact patches of riparian vegetation remain along the lower reaches, particularly in

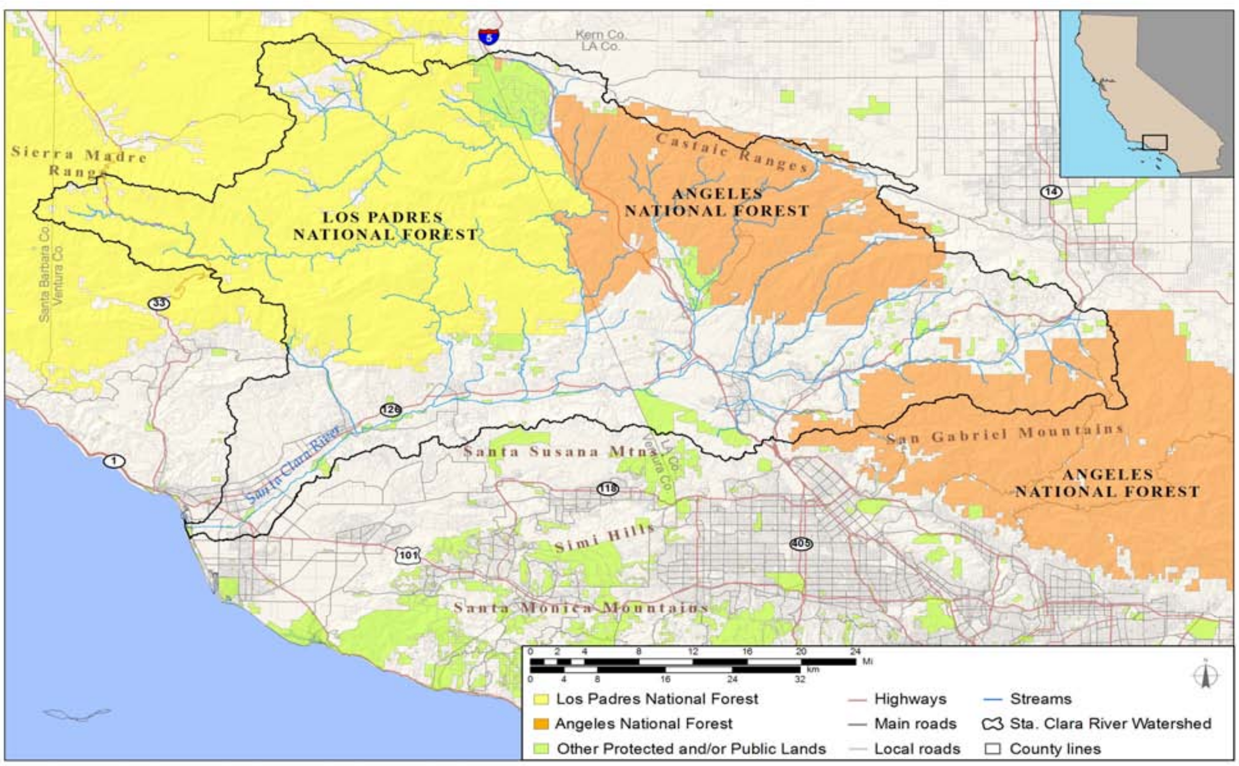

Figure 2-14. Protected lands in the Santa Clara River watershed.

comparison to its dammed and channelized neighbors. Third, the watershed's position between the Santa Monica Mountains and Sierra Madre Range provides a regionally important connection between these two large, protected wildlife areas in the southern California coastal ecoregion (Penrod *et al.* 2006) (Figure 2-14). Fourth, the watershed has the potential to support recovery of southern California coast steelhead (Stoecker and Kelley 2005, NMFS 2007). Together, these watershed attributes provide critical habitat for several rare and endangered species, and a movement corridor for a number of native species that require extensive areas to survive (Davis 1994, CDFG 2005, Penrod *et al.* 2006).

This section describes the native plants and animals that occur in the lower river corridor, and the non-native species that currently threaten native habitats and species. Understanding the distribution and population dynamics of these species is critical to identifying high-use, preferred habitats as well as rare habitat types. This knowledge can then be used to prioritize preservation efforts and develop and prioritize process-based restoration strategies that target the creation, enhancement, and/or maintenance of these habitats.

2.4.1 Riparian Vegetation and Habitats

Riparian vegetation performs many functions in natural river systems such as filtering runoff and nutrients, providing habitat for terrestrial wildlife, shading the river, and providing energy from leaf litter and woody debris that serves as habitat for instream organisms (Gregory *et al.* 1991, Malanson 1993, Naiman and Descamps 1997, Mitsch and Gosselink 2000) (Figure 2-15). In addition, large tracts of diverse natural vegetation provide open space and recreational opportunities for the local human community. Understanding the distribution and composition of riparian vegetation allows us to develop restoration strategies that maximize these benefits by preserving intact, high-quality stands of vegetation and restoring degraded areas.

Riparian Vegetation Extent

Several factors currently affect riparian forest extent, structure, and species composition on the lower Santa Clara River. Historical accounts of central

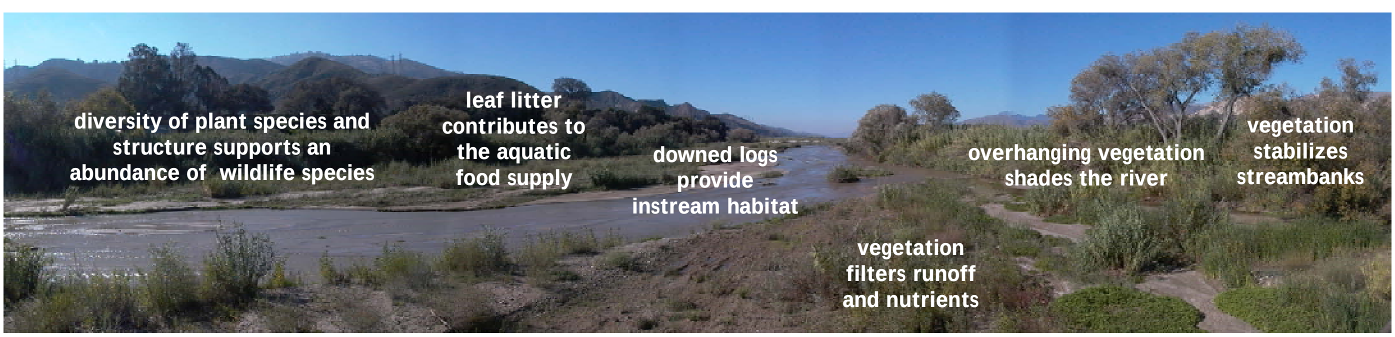

Figure 2-15. The Santa Clara River downstream of Newhall Bridge, at river kilometer 56.2 (river mile 34.9), illustrating some of the ecosystem functions provided by riparian vegetation.

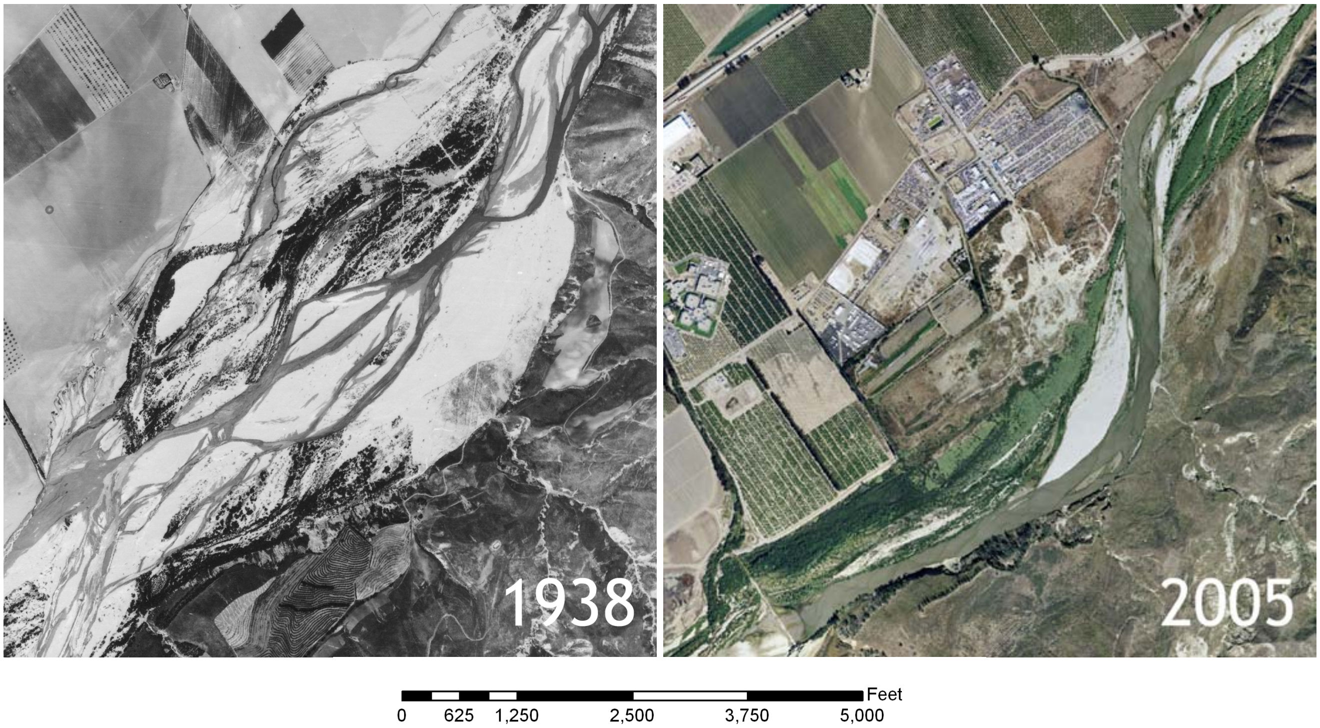

Figure 2-16. Comparison of riparian vegetation distribution in 1938 and 2005 near river mile 11.

and southern California coastal rivers describe extensive efforts to clear the "monte" —the cottonwood and willow forests that covered the lower reaches of the large rivers (Boughton *et al.* 2006). Vegetation clearing occurred primarily to prepare the land for ranching and farming and for fuel. More recently, urban development has begun replacing the farm land that replaced riparian forests. In addition to direct removal, alterations to the river's hydrology and groundwater levels have also likely reduced the extent of riparian vegetation in the lower Santa Clara River. Pumping has likely lowered the groundwater table beyond the reach of tree roots in some areas. Without groundwater to sustain seedlings, saplings and mature trees through the dry summer, the historical distribution of riparian forest cannot be sustained (Boughton *et al.* 2006). The construction of levees in the lower reaches of the river, together with development on the floodplain, dramatically reduced the area available for floods to inundate and, thus, for riparian forests to recruit and grow (Figure 2-16). In addition, numerous non-native invasive plant species have been introduced to the riparian corridor. These factors and the current condition of the lower Santa Clara River riparian corridor are described in the following sections.

Simons, Li & Associates (1983) report that the Santa Clara River floodplain was, historically, as much as 2-mi wide in its lowermost reaches. Regular flood inundation over a wide floodplain supported the recruitment of riparian trees over a vast area, while groundwater sustained plants through the summer, allowing mature forests to develop. The riparian area likely supported dense, multi-stored stands of broadleaf trees, including cottonwood, sycamore, and various willows, that extended from a few to several miles wide (Schwartzberg and Moore 1995, Briggs 1996, Boughton *et al.* 2006).

Currently, the riparian corridor of the lower Santa Clara River is much narrower compared to historical accounts (Figure 2-16 and Figure 2-17). The 2005 flood (136,000 cfs, 16-year recurrence interval) inundated just over 7,000 ac along 34 mi of the lower river (Figure 2-17). For comparison, the 1938 flood (120,000 cfs, 14-year recurrence interval) inundated over 12,000 ac in this same longitudinal area (Figure 2-17). This difference represents a nearly 40% loss in the extent of the riparian corridor. This loss is most acute in the lowest reaches of the river (river mile 0 to 7) where nearly 70% of the riparian corridor has been lost. Working to reverse this loss and restore the historical extent of the lower Santa Clara River riparian corridor (approximately 12,000 ac) is a goal of the Parkway project. Estimates of the historical extent and loss of the riparian corridor will be greatly enhanced by the Ventura County Historical Ecology Study, which is currently being conducted by the San Francisco Estuary Institute through Coastal Conservancy funding.

Riparian Vegetation Composition

A wide range of vegetation conditions currently exists in the lower Santa Clara River corridor, from coastal, tidal marsh, through bands of riparian scrub and forest, to more xeric and upland vegetation types. Major vegetation cover types in the lower Santa Clara River are mapped in Figure 2-17 and listed in Table 2-3. These major types represent aggregations of many more detailed vegetation types, including 58 alliances and approximately 130 potential associations, which were recently described and mapped (Stillwater Sciences and URS Corporation 2007).

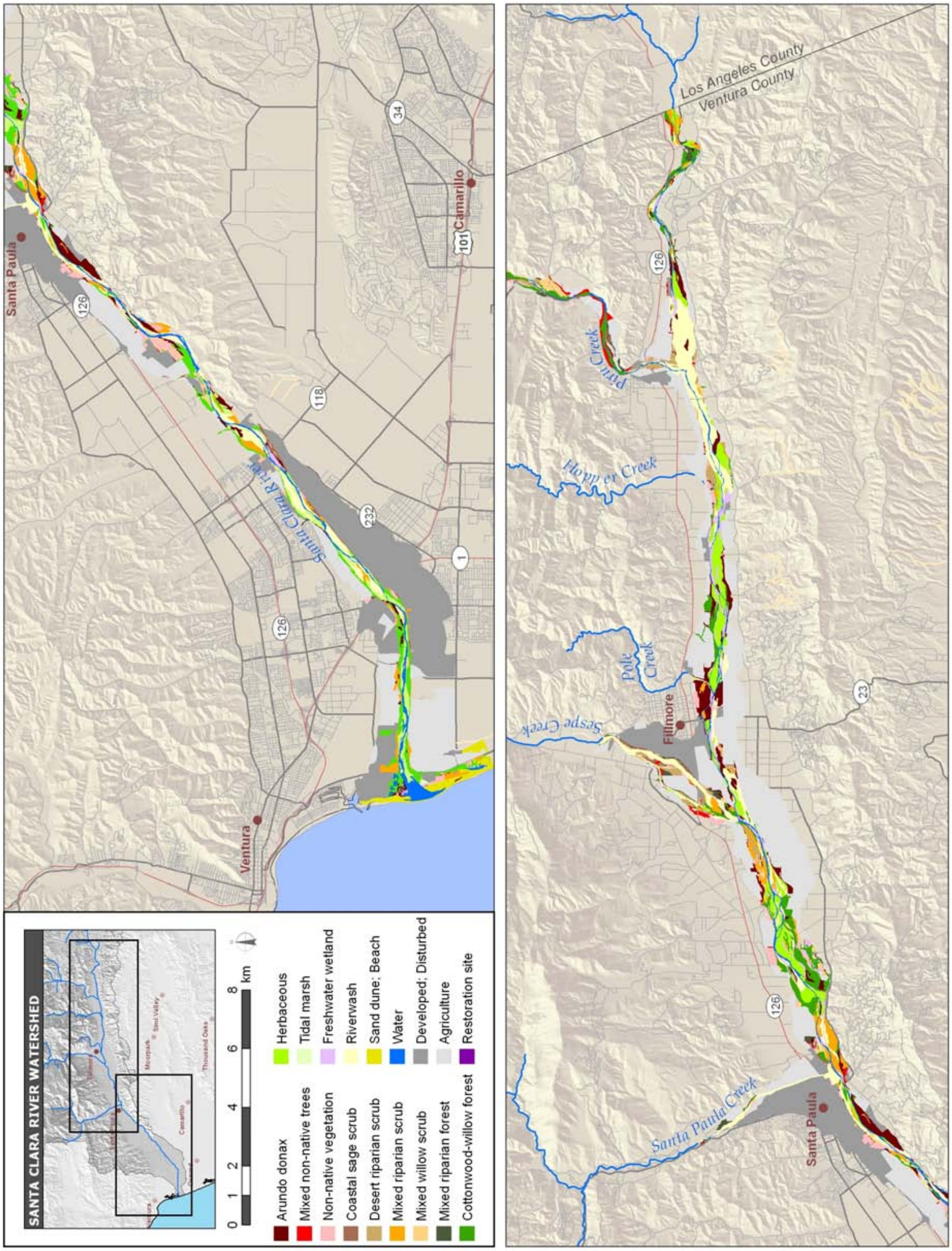

Figure 2-17. Vegetation communities within the 500-year floodplain of the lower Santa Clara River.

Table 2-3. Major vegetation types found within the 500-year floodplain of the lower Santa Clara River.

Vegetation Type	Associated Species	Acres	Hectares	Percent of total
Herbaceous	• western ragweed (*Ambrosia psilostachya*) • California aster (*Lessingia filaginifolia* ssp. *filaginifolia*) • giant rye (*Leymus condensatus*) • shortpod mustard (*Hirschfeldia incana*) • non-native bromes (*Bromus* spp.) • white sweetclover (*Melilotus alba*) • tocolote (*Centaurea melitensis*)	1,936	783	27
Mixed riparian forest	• black cottonwood (*Populus balsamifera* ssp. *trichocarpa*) • Fremont cottonwood (*Populus fremontii* ssp. *fremontii*) • red willow (*Salix laevigata*) • arroyo willow (*Salix lasiolepis*) • shining willow (*Salix lucida* ssp. *lasiandra*) • red willow (*Salix laevigata*) • California walnut (*Juglans californica*) • western sycamore (*Platanus racemosa)* • coast live oak (*Quercus agrifolia*) • narrowleaf willow (*Salix exigua*) • mulefat (*Baccharis salicifolia*) • arundo (*Arundo donax*)	1,670	676	23
Mixed riparian scrub	• arundo (*Arundo donax*) • mulefat (*Baccharis salicifolia*) • arroyo willow (*Salix lasiolepis*) • red willow (*Salix laevigata*) • shining willow (*Salix lucida* ssp. *lasiandra*) • narrowleaf willow (*Salix exigua*)	1,080	437	15
Arundo donax	• arundo (*Arundo donax*) • mulefat (*Baccharis salicifolia*) • narrowleaf willow (*Salix exigua*) • red willow (*Salix laevigata*) • arroyo willow (*Salix lasiolepis*)	893	361	12
Freshwater wetland	• bulrush species (*Scirpus* spp.) • cattail (*Typha* spp.) • yerba mansa (*Anemopsis californica*) • salt grass (*Distichlis spicata*) • sprangletop (*Leptochloa uninervia*) • creeping wildrye (*Leymus triticoides*) • common reed (*Phragmites australis*) • knotweed (*Polygonum* spp.) • watercress (*Rorippa nasturtium-aquaticum*) • water speedwell (*Veronica anagallis-aquatica*)	536	217	7

Vegetation Type	Associated Species	Acres	Hectares	Percent of total
Desert riparian scrub	• big sagebrush (*Artemisia tridentata* ssp. *parishii*) • fourwing saltbush (*Atriplex canescens*) • scalebroom (*Lepidospartum saquamatum*) • California buckwheat (*Eriogonum fasciculatum*) • black sage (*Salvia mellifera*) • coyote brush (*Baccharis pilularis*) • chaparral yucca (*Yucca whipplei*)	338	137	5
Sand Dune/Beach	• beach bursage (*Ambrosia chamissonis*) • red sand-verbena (*Abronia maritima*) • pink sand-verbena (*Abronia umbellata*) • iceplant (*Carpobrotus edulis*, *C. chilensis*, and *Mesembryanthemum crystallinum*)	289	117	4
Coastal sage scrub	• California sagebrush (*Artemisia californica*) • California buckwheat (*Eriogonum fasciculatum*) • California encelia or brittlebush (*Encelia californica*) • deerweed (*Lotus scoparius*) • coyote brush (*Baccharis pilularis*) • quail bush (*Atriplex lentiformis*)	224	91	3
Mixed non-native trees	• eucalyptus (*Eucalyptus* spp.) • Peruvian peppertree (*Schinus molle*) • castor bean (*Ricinus communis*) • myoporum (*Myoporum laetum)* • arundo (*Arundo donax*) • tamarisk (*Tamarix ramosissima*)	175	71	2
Disturbed	• Primarily bare soil with sparse herbaceous vegetation	60	24	1
Tidal marsh	• salt grass (*Distichlis spicata*) • alkali heath (*Frankenia salina*) • marsh jaumea (*Jaumea carnosa*) • pacific silverweed (*Potentilla anserina* ssp. *pacifica*) • pickleweed (*Salicornia virginica*),	9	3	<1
Restoration site	Mixture of native riparian species	4	2	<1
	Grand Total	**7,214**	**2,919**	**100**

Riparian Habitat Types

Native vegetation types that occur in the lower Santa Clara River corridor are of special concern due to their ecological importance in the riparian zone, their declining distribution in California, or their role as key habitat for selected wildlife species (Stillwater Sciences and URS Corporation 2007, Stillwater Sciences 2007c).

Mixed riparian forest and scrub are abundant vegetation types throughout the 500-year floodplain of the lower Santa Clara River, including tributaries, and provide nesting, foraging, and movement habitat for a variety of native animal species (see Sections 2.4.2 and 2.4.4). Mixed riparian forest is generally found on the banks of mainstem and tributary channels where there is shallow groundwater (Figure 2-17). In these areas the community is characterized by an open to dense tree canopy and variable shrub and understory layers (Stillwater Sciences and URS Corporation 2007). In more geomorphically dynamic areas of the floodway, where mature forests cannot typically establish and earlier successional stages of vegetation generally dominate, mixed riparian forest transitions to mixed riparian scrub. In addition to whatever native riparian tree species that typically dominate stands of the vegetation community, arundo is nearly always present in either the shrub or understory layers (or both) at low to moderate densities (1–50% cover) (Stillwater Sciences and URS Corporation 2007). The structural diversity of mixed riparian forest and scrub vegetation types provide nesting habitat for numerous breeding birds such as western yellow-billed cuckoo (*Coccyzus americanus occidentalis*) which nests in dense riparian woodland, and least Bell's vireo (*Vireo bellii pusillus*), an endangered songbird which nests in dense willow thickets. Riparian forests also provide roosting and foraging habitat for several bat species including pallid bat (*Antrozous pallidus*), and cover for other mammal such as ringtails (*Bassariscus astutus*), bobcats (*Lynx rufus*), gray foxes (*Urocyon cinereoargenteus*), and mountain lions (*Puma concolor*).

(top) A stand of mixed riparian forest along the lower Santa Clara River; (bottom) Invasion of arundo on the lower Santa Clara River floodplain following a fire.
(photographs by Stillwater Sciences)

Arundo, an invasive non-native species related to bamboo, is by far the most abundant species in the lower river and is out-competing and quickly replacing native vegetation types such as mixed riparian forest. The arundo vegetation community is abundant and well distributed throughout the 500-year floodplain of the lower river. The community has a dense, continuous shrub layer completely dominated by arundo or it may have mulefat (*Baccharis salicifolia*), or various willow species (*Salix* spp.) as co-dominant species. While the extent of the mapped arundo vegetation type is 893 acres, it is important to note that arundo is nearly always present in the shrub or understory layers of mixed riparian forest and scrub communities at low to moderate densities. Arundo-specific vegetation mapping indicates that the species occurs at varying levels of percent cover in 5,242 ac of the lower river corridor (Stillwater Sciences and URS Corporation 2007).

Desert riparian scrub is a rare vegetation community that is generally found in alkaline or saline washes, scrub habitat, sandy and gravelly washes, stream terraces, and chaparral habitats. It is distributed primarily in the upper reaches and tributaries of the lower Santa Clara River (Figure 2-17). This vegetation community is characterized by a continuous, intermittent or open shrub layer, a sparse to intermittent or grassy herbaceous understory, and little to no tree layer (Stillwater Sciences and URS Corporation 2007). This vegetation type provides habitat for silvery legless lizard *(Anniella pulchra pulchra)*, foraging habitat for coastal California gnatcatcher *(Polioptila californica californica)*, and appropriate growing conditions for Nevin's barberry (*Berberis nevinii*) and Slender-horned spineflower *(Dodecahema leptoceras).*

The lowest reaches of the Santa Clara River (the Estuary Reach [0] and part of Hwy 101 Reach [1]) consist primarily of the estuary (see Table 1-1) and are dominated by open water and **sand dune and tidal marsh** vegetation types (Figure 2-17). The sand dune and beach communities are sparsely vegetated with low-growing perennial forbs. The tidal marsh areas are characterized by dense, low-growing, perennial species that are tolerant of daily tidal inundation and higher soil salinities (Stillwater Sciences and URS Corporation 2007). The coastal areas at the mouth of the Santa Clara River provide sandy burrowing habitat for silvery legless lizard, and foraging and nesting habitat for a variety of shorebirds, including long-billed curlew (*Numenius americanus*) and western snowy plover (*Charadrius alexandrinus nivosus*).

Coastal sage scrub, another rare vegetation community, is found throughout the lower Santa Clara River and along its tributaries, although it is most abundant in Below Freeman Reach (2) and along Sespe Creek, where it occurs on dry terraces and other upland portions of the 500-year floodplain Figure 2-17). This vegetation community tends to have a dominant shrub layer with open to dense cover with a sparse to dense herbaceous layer typically dominated by non-native grasses and forbs (Stillwater Sciences and URS Corporation 2007). Upland areas adjacent to the river are host to several species including including western fence lizards (*Sceloporus occidentalis*), San Diego horned lizards (*Phrynosoma coronatum blainvillii*), coast patch-nosed snakes (*Salvadora hexalepis virgultea*), northern harriers (*Circus cyaneus*), white-tailed kites (*Elanus leucurus*), coopers hawks (*Accipter cooperii*), mule deer (*Odocoileus hemiunus*) and coyote (*Canis latrans*).

Riparian Vegetation Dynamics

A variety of landscape position and physical habitat conditions shape the types and distribution of vegetation types along the river. In the lower Santa Clara River, periodic short-duration, high-intensity flood events through the meandering and braided river channel result in dynamic patterns of scour, sediment deposition, and floodplain inundation (Stillwater Sciences 2007a). These dynamic hydrologic and geomorphic processes have been documented in other semi-arid stream systems, where they have been shown to influence groundwater patterns and riparian vegetation distribution, structure and composition, and result in patches of varying successional stages and species assemblages (*e.g.*, Baker and Walford 1995, Hupp and Osterkamp 1996, Bendix 1997, Shafroth *et al.* 1998, Bagstad *et al.* 2006).

Studies of riparian vegetation dynamics have shown that water availability is the strongest driver of vegetation patterns in semi-arid systems, but results have varied on the particular source (stream flow or groundwater) and mechanism (*e.g.*, scour, inundation, or water supply) of water, and other influential physical and biological variables. Studies to identify the strongest influences on vegetation patterns in semi-arid streams have revealed the importance of the frequency and magnitude of flood disturbance (Bendix 1994, Bendix 1997, Harris 1999, Bendix and Hupp 2000), distance to groundwater (Stromberg *et al.* 1996, Shafroth *et al.* 1998), and a combination of the two (Hupp and Osterkamp 1996, Lite 2003, Bagstad *et al.* 2006, Leenhouts *et al.* 2006). Other physical variables, such as sedimentation (Baker and Walford 1995), fire regime (Bendix 1994), and flood timing (Shafroth *et al.* 1998) have also been found to affect vegetation patterns, as have post-establishment successional and competitive processes (Baker and Walford 1995, Shafroth *et al.* 1998, Bagstad *et al.* 2006).

On the lower Santa Clara River, the strongest drivers for vegetation patterns align well with those found in previous studies. Relative elevation and time since last flood were two of the

Upland (background), willow scrub (midground), and floodplain wetland and herbaceous (foreground) vegetation along the lower Santa Clara River.
(photograph by Stillwater Sciences)

strongest correlates to the distribution of vegetation alliances in the lower river (Stillwater Sciences 2007b). These results, like those of other studies, indicate that flood frequency and vegetation age are largely responsible for determining vegetation distribution, composition, and structural complexity. Riparian vegetation along the lower Santa Clara River is subject to infrequent but dramatic resets during large flood events, particularly during wet years associated with ENSO (Stillwater Sciences 2007a). In addition, distance from the river mouth was also a correlate to distribution of vegetation alliances, indicating that longitudinal position in the river corridor is also important in determining vegetation patterns (Stillwater Sciences 2007b). While the precise mechanism for this correlation is difficult to ascertain, differences in local climatic conditions between the coastal fog belt, where humidity is relatively high and evapotranspiration demand relatively low, and the more arid inland portions of the watershed are probably at least partly responsible for these species distribution trends. Since the distribution of gaining vs. losing reaches was determined in part by vegetation cover, analysis of the independent effects of groundwater reach type in comparison with other physical site variables on plant species and vegetation alliance distribution was not possible. However, the distribution of many key riparian plant species and alliances reveals significant bias for gaining vs. losing reaches (Stillwater Sciences 2007b).

This information helps inform restoration strategy development in several ways. Based on physical information from a potential restoration site, vegetation types that most frequently occur under those conditions can be identified and used to improve predictions of what species can be expected to recruit naturally or what planted species are likely to be successful in the long-term. Conversely, if a particular vegetation community is targeted for revegetation because it is rare or provides critical habitat, the physical variables most often associated with that vegetation community can be used to identify optimal revegetation sites (along with other non-ecological constraints, such as land ownership and adjacent land uses) (Stillwater Sciences 2007b).

2.4.2 Aquatic Habitats

Riverine

The following discussion is largely based on recent aquatic habitat assessments of the lower Santa Clara River that have focused primarily on southern California coast steelhead habitat preferences and availability (Puckett and Villa 1985, Comstock 1992, Kelley 2004, Stoecker and Kelley 2005). The lower 33 miles of the mainstem Santa Clara River are currently dominated by glide habitat, with small areas of dammed pool, low-gradient riffle, and step-run habitats (Stoecker and Kelley 2005). While mainstem aquatic habitat is considered relatively low quality in terms of southern California coast steelhead habitat parameters, with high substrate embeddedness and low canopy

Glide habitat on the lower Santa Clara River.
(photo by Stillwater Sciences)

cover (Stoecker and Kelley 2005), this can be at least partially attributed to the naturally broad, alluvial nature of the lower mainstem river (Stoecker and Kelley 2005). Even under historical conditions, the lowest reaches of the river would be expected to have a fairly fine channel bed with high percent embeddedness, and the broad and dynamic mainstem channel would not necessarily have supported a high percent cover of overhanging vegetation. The mainstem is more likely to have served primarily as critical migratory habitat for southern California coast steelhead accessing spawning habitats in the upper river and tributaries, and rearing and foraging habitat for species such as arroyo chub and unarmored three-spine stickleback that utilize glide or slower channel-margin habitats.

Two of the primary impacts to instream aquatic habitat in the lower Santa Clara River are: 1) barriers to fish passage resulting from low-flow conditions and diversion structures, and 2) reduced extent and quality of estuarine habitat. Other important impacts include altered river flows resulting from surface water diversion, groundwater pumping, upstream dam releases, treated wastewater effluent, and agricultural return flows; presence of non-native fish species that compete with and prey upon native species (see Section 2.4.4); and poor water quality (see Section 3.5). These impacts combine to limit habitat availability and connectivity for native aquatic species.

Barriers to passage occur when any structure in the stream channel impedes, to varying degrees of difficulty, or completely blocks upstream migration of an organism. The most significant barrier to upstream fish migration is argued to be the Vern Freeman Diversion Dam (Stoecker and Kelley 2005), located approximately 10 mi upstream from the mouth of the mainstem Santa Clara River. While a fish ladder exists at the diversion dam, National Marine Fisheries Service contends that its operation does not sufficiently accommodate the timing, duration, and magnitude of flow events that anadromous fish require for upstream migration (Stoecker and Kelley 2005). In addition, the Harvey Diversion Dam on lower Santa Paula Creek greatly reduces or eliminates instream flows on that creek during most of the year and does not have an operable fish ladder (Stoecker and Kelley 2005, Titus *et al*., *in prep.*). These two barriers prevent southern California coast steelhead from accessing critical, relatively high-quality spawning habitats in Sespe, Santa Paula, and other tributary creeks (Stoecker and Kelley 2005).

Estuarine

Estuaries are recognized as critical habitat for a variety of aquatic organisms in coastal California watersheds (Shapovalov and Taft 1954, Smith 1990, Bond 2006, Boughten *et al.* 2006). In addition to providing rearing and foraging habitat for birds and estuarine fish such as arroyo chub and tidewater goby, estuaries also provide important rearing habitat for southern California coast steelhead. Steelhead smolts may spend a considerable amount of time in the estuary habitat to acclimate to saltwater and wait for adequate flow conditions to open the mouth of the stream, allowing migration to the ocean (Stoecker and Kelley 2005). Furthermore, steelhead that rear in estuaries rather than in mainstem habitats have been found to reach greater sizes before outmigrating to the ocean, which is important in determining ocean survival (Bond 2006).

The Santa Clara River estuary (looking upstream toward Harbor Blvd. Bridge).
(photo by Stillwater Sciences)

The extent of the Santa Clara River estuary is estimated to have decreased by 75% (Swanson *et al.* 1990). In addition, upstream levees are hypothesized to increase the occurrence of hyperpycnal flow and promote estuary scouring (see Section 2.3.6). Even in an estuary with muted tidal influence, such as the Santa Clara River estuary, intertidal zones are important for providing exposed mudflats at low tide for shorebird foraging and shallow, flooded areas at increased tide heights for filter-feeding invertebrates and foraging small fish. However, the lack of sediment deposition in the Santa Clara River estuary may decrease the availability of transitional zones such as mudflats and shallow, sandy vegetated areas for estuarine biota.

Additionally, summer and fall discharges of treated effluent from the Ventura Water Reclamation Facility can cause the estuary mouth to breach prematurely (Swanson *et al.* 1990, as cited in ESA 2003) and may decrease natural salinity levels during these seasons. However, it is also believed that the Reclamation Facility provides a portion of the historical freshwater inflow that historically entered the estuary but that is now diverted or pumped off the river farther upstream (Nautilus Environmental 2005). Although the reclamation facility may provide some benefits to estuarine environment, identification of other potential impacts of the treated discharge on water quality and aquatic habitat availability requires additional investigation. The estuary is on the 303(d) list as impaired for Chem A, coliform, and toxaphene, but the source of these pollutants is currently considered to be either non-point or unknown (see Section 3.5).

The Santa Clara River and the estuary in particular, may be affected by sea level rise resulting from global warming. Globally, sea level has risen between 4 and 10 inches over the past century, primarily because of a net input of water from icecap melt and water warming (Rahmstorf *et al*. 2007). This rate of rise is an order of magnitude greater than that of the past several millennia (Douglas *et al*. 2001, as cited in Hopkins *et al.* 2008). In southern California, sea level rise is predicted to be in the range of 0.04 to 0.1 inch per year (Hopkins *et al.* 2008). Sea level sets the minimum elevation for an estuary, but land use and climate in the watershed affect processes that deliver sediment to the estuary and allow material to accumulate. The implications of sea level rise and changes in sediment deposition are difficult to predict, particularly in a system such as the Santa Clara River, where levees and floodplain development restrict the estuary's ability to migrate. These types of developed coastal regions are expected to experience a decrease in estuarine and wetland areal extent as sea-level rises (Hopkins *et al.* 2008). This loss in area will reduce the storm buffering and other ecosystem services provided by coastal wetlands and thereby increase the vulnerability of human systems.

2.4.3 Fish and Wildlife

Despite the dramatic reduction, degradation, and fragmentation of riparian vegetation, the aquatic, riparian, and upland habitats of the Santa Clara River watershed support a diverse composition of fish and wildlife species, including over 40 threatened, endangered, and sensitive plant and animal species (CDFG 2007). In addition, the lower Santa Clara River watershed has been identified as a regionally important migration corridor for mountain lion, American badger, and mule deer due to its position between two of the largest protected wildlife areas in the southern California coastal ecoregion, the Santa Monica Mountains and Sierra Madre Range, and the large extent of protected national forest lands (Penrod *et al.* 2006). The habitat value and health of wildlife populations in the lower Santa Clara River can only stand to be improved by the Parkway acquisition and restoration efforts.

Special-status Species

Table 2-4 summarizes the threatened, endangered, and sensitive species that have been documented in the vicinity of the lower Santa Clara River (*i.e.*, the seven USGS quadrangles that include the lower river corridor; CDFG 2007). Additional occurrences of these species, or other species, occur in other areas of the watershed, but are not generally included in Table 2-4. In addition to those special-status species found in the riparian corridor of the lower Santa Clara River, a number of species in Table 2-4 are found in upland habitats that likely use the riparian corridor for occasional foraging or for movement between habitats.

Table 2-4. Threatened, endangered, and sensitive species in the vicinity of the lower Santa Clara River.

Species	Status[1] Federal	State	Other	Habitat Associations and Occurrence in the Lower Santa Clara River Watershed[2]
FISH				
Arroyo chub *(Gila orcutti)*	--	--	CSC	Found in coastal streams with a preference for slow-moving water with mud or sand substrate. Documented to occur in the lower Santa Clara River, but considered to be introduced (Faber *et al.* 1989, Moyle 2002).
Santa Ana sucker *(Catostomus santaanae)*	FT	--	CSC	Found in coastal streams; considered habitat generalists, but prefer sand-rubble-boulder substrates with cool, clear water, and algae. Documented to occur in the lower and upper Santa Clara River, as well as Sespe Creek, but may be introduced (Faber *et al.* 1989, Moyle 2002).
Steelhead (southern CA coast DPS) *(Oncorhynchus mykiss irideus)*	FE	--	CSC	Spawning adults and rearing juveniles found in coastal streams and rivers (feeding adults are found in the ocean). Adults require holding pools during migration, and spawn in shallow, low-gradient riffles; juveniles rear in shallow-water, low-velocity habitats, moving towards deeper and higher velocity water as adults. Adult steelhead last documented in the lower Santa Clara River below Vern Freeman Diversion Dam in 2001; resident rainbow-trout populations occur in the headwaters of Santa Paula, Sespe, Hopper, and Piru creeks (Stoecker and Kelley 2005).
Tidewater goby *(Eucyclogobius newberryi)*	FE	--	CSC	Found in shallow lagoons and lower stream reaches with brackish, low velocity water and high oxygen levels. Documented to occur in the estuary of the Santa Clara River (Entrix 2004)
Unarmored threespine stickleback *(Gasterosteus aculeatus williamsoni)*	FE	SE	FP	Found in coastal streams with a preference for cool (<75°F), clear pools and backwater areas with abundant vegetation. Documented to occur in the Santa Clara River upstream of Piru Creek (Faber *et al.* 1989, Moyle 2002, CDFG 2007).
AMPHIBIANS				
Arroyo toad (*Bufo californicus*)	FE	--	CSC	During breeding, found in open sites open sites such as overflow pools, old flood channels, and pools with shallow margins on streams; otherwise found on sand or fine gravel bars adjacent to stable sandy terraces. Was historically found in the lower Santa Clara River watershed, but currently persists only along Sespe Creek, Piru Creek, and the upper watershed (Sweet 1992, USFWS 1999).
Mountain yellow-legged frog *(Rana muscosa)*	FE	--	CSC	Found in shallow waters of rocky and open foothill streams and lake edges with cool waters and a gentle slope. Documented in Sespe Canyon near the town of Fillmore.

Species	Status[1] Federal	State	Other	Habitat Associations and Occurrence in the Lower Santa Clara River Watershed[2]
REPTILES				
Coast (San Diego) horned lizard *(Phrynosoma coronatum (=blainvillii))*	--	--	CSC	Found in coastal sage scrub and chaparral habitats, with a preference for friable, rocky, or shallow sandy soils. Documented along the Santa Clara River southwest of Fillmore and in the vicinity of El Rio.
Western pond turtle *(Clemmys (=Emys; =Actinemys) marmorata)*	--	--	CSC	Found in ponds, lakes, ditches, perennially filled pools of intermittent streams, and backwater and low-flow areas of perennial streams and rivers. Nest are built in dry, fine soils, on gentle slopes, typically in open, grassy meadows less than 1,500 ft from water. Documented in both the lower and upper Santa Clara River watershed.
Two-striped garter snake *(Thamnophis hammondii)*	--	--	CSC	Found in or near permanent fresh water, often along streams with rocky beds and riparian vegetation. Documented along the mainstem lower Santa Clara River and along tributaries to Sespe Creek.
BIRDS				
Bank swallow *(Riparia riparia)*	--	ST	--	Found in riparian and other lowland habitats; require vertical banks/cliffs with fine-textured soils near streams, rivers, lakes, ocean for nesting. Documented along the coast at the Santa Clara River estuary.
Belding's savannah sparrow *(Passerculus sandwichensis beldingi)*	--	SE	--	Found in coastal salt marshes; nests in pickleweed (*Salicornia virginica)* along margins of tidal flats. Documented in marsh areas along the coastal just south of the Santa Clara River estuary near Ormond and McGrath beaches.
California least tern *(Sterna antillarum browni)*	FE	SE	FP	Found along the coast on bare or sparsely vegetated, flat substrates (sand beaches, alkali flats, land fills, or paved areas). Documented along the coastal strand area of the Santa Clara River.
Coastal California gnatcatcher *(Polioptila californica californica)*	FT	--	CSC	Found in coastal scrub habitats with a preference for sage scrub in arid washes, on mesas and slopes. Documented in the river corridor at Santa Paula.
Cooper's hawk *(Accipiter cooperii)*	--	--	CSC	Found nesting in riparian woodlands, primarily in open, interrupted or marginal sites. Documented along the lower Santa Clara River east of Piru.
Least Bell's vireo *(Vireo bellii pusillus)*	FE	SE	--	Found nesting in riparian scrub in the vicinity of water or in dry river bottoms. Documented to be relatively abundant throughout the lower Santa Clara River riparian corridor (Labinger and Greaves 2001).
Southwestern willow flycatcher (*Empidonax trailii extimus*)	FE	SE	--	Found in flood-prone riparian areas, where water is present and dense vegetation is present or expected to become established. Small numbers of nesting pairs and/or territorial individuals documented throughout the lower Santa Clara River riparian corridor (Labinger and Greaves 2001).

Species	Status[1] Federal	State	Other	Habitat Associations and Occurrence in the Lower Santa Clara River Watershed[2]
Western snowy plover *(Charadrius alexandrinus nivosus)*	FT	--	CSC	Found nesting on sandy beaches, salt pond levees and shores of alkali lakes in sandy, gravelly or friable soils. Documented at the mouth of the Santa Clara River.
Western yellow-billed cuckoo *(Coccyzus americanus occidentalis)*	FC	SE	--	Found in densely foliated riparian trees and shrubs, adjacent to slow-moving watercourses, backwaters, or seeps. Last documented in the lower Santa Clara River watershed in 1971; more recent sightings of migrants documented in the upper watershed (Labinger and Greaves 2001).
White-tailed kite *(Elanus leucurus)*	--	--	FP	Found in rolling foothills/valley margins with scattered oaks and river bottomlands or marshes next to deciduous woodlands; nest in isolated, dense-topped trees and forage in open grasslands, meadows, or marshes. Documented in the lower Santa Clara River watershed east of Santa Paula.
Yellow warbler *(Dendroica petechia brewsteri)*	--	--	CSC	Found nesting in riparian woodlands as well as montane shrub-scrub in open conifer forests. Documented along the lower Santa Clara River east of Piru.
Yellow-breasted chat *(Icteria virens)*	--	--	CSC	Found in riparian thickets of willow and other brushy tangles near watercourses; nest in low, dense riparian scrub. Documented along the lower Santa Clara River east of Piru.
MAMMALS				
Pallid bat (*Antrozous pallidus*)	--	--	CSC	Found in deserts, grasslands, shrublands, and woodlands; most common in open, dry habitats with rocky areas for roosting. Documented in the lower Santa Clara River watershed near Fillmore and Santa Paula.
PLANTS				
Coulter's goldfields *(Lasthenia glabrata* ssp. *coulteri)*	--	--	1B	Grows in coastal salt marshes, playas, valley and foothill grasslands, and vernal pools, typically on alkaline soils. Documented in salt marsh near Ormand Beach south of the Santa Clara River estuary.
Greata's aster *(Aster greatae)*	--	--	1B	Grows in mesic canyon in chaparral, cismontane woodland habitats. Documented in Hopper Canyon in the lower Santa Clara River watershed.
Nevin's barberry (*Berberis nevinii*)	FE	SE	1B	Grows in sandy/gravelly soils on steep, north facing slopes in coastal scrub and chaparral habitat or in low gradient sandy washes in alluvial and riparian scrub habitats. There is one extant occurrence in the upper Santa Clara River watershed.
Plummer's mariposa lily *(Calochortus plummerae)*	--	--	1B	Grows in rocky and sandy sites, usually of granitic or alluvial material in coastal scrub, chaparral, valley and foothill grassland, cismontane woodland, lower montane coniferous forest habitats. Can be very common after fire. Documented south of Fillmore in the lower Santa Clara River watershed.

Species	Status[1] Federal	State	Other	Habitat Associations and Occurrence in the Lower Santa Clara River Watershed[2]
Salt marsh bird's-beak *(Cordylanthus maritimus* ssp. *maritimus)*	FE	SE	1B	Grows in higher elevation zones of coastal salt marshes and in dunes. Documented along the coast at the mouth of the Santa Clara River near Oxnard.
Slender-horned spineflower *(Dodecahema leptoceras)*	FE	SE	1B	Grows in flood deposited terraces and washes in chaparral, coastal scrub, and alluvial fan sage scrub habitats. Three populations documented in the upper Santa Clara River watershed.
Ventura Marsh milk-vetch *(Astragalus pycnostachyus* var. *lanosissimus)*	FE	SE	1B	Typically grows in tidally inundated coastal salt marsh, and more rarely near seeps on sandy bluffs. Documented near the Santa Clara River estuary and McGrath State Beach.

1 FE = Federally listed as endangered
FT = Federally listed as threatened
FC = Candidate for federal listing
1B = listed by CNPS as rare, threatened, or endangered in California and elsewhere
SE = State listed as endangered (California)
ST = State listed as threatened (California)
CSC = listed by CDFG as a California species of special concern
FP = listed by CDFG as fully protected

2 Occurrence information from CDFG (2007), unless otherwise indicated.

Focal Species

A focal-species approach to developing a restoration strategy facilitates the exploration of linkages among ecosystem processes, resultant habitats, and biotic needs. It is based on the premise that maintaining and restoring physical and ecological processes will provide properly functioning habitat for well-distributed populations of native species, many of which have declined and may require habitat restoration to persist in the area. On the Santa Clara River, focal species and their habitat preferences and current potential habitat can be used to: 1) identify factors that are likely limiting the species population or distribution; 2) prioritize areas for conservation or restoration to maintain or improve populations; 3) design and select restoration actions that will create or maintain preferred habitat parameters or ameliorate a factor believed to be limiting a species population; and 4) evaluate the success of implemented management and restoration actions to increase or improve habitat conditions. For the restoration strategies recommended in Section 4, the focal species approach was used to identify high-priority areas for acquisition, active and passive revegetation, and non-native invasive species removal to conserve and restore focal species habitat. Once these restoration strategies begin to be implemented, monitoring of focal species' populations and habitat area can be compared to pre-project conditions and used to evaluate the success of implemented restoration actions. Additional site-specific population and/or habitat data would need to be collected for most focal species and restoration areas prior to project implementation.

Focal species for the Parkway project were selected from a list of candidate species that currently occur or historically occurred along the lower Santa Clara River. The focal species selection process is described in detail in Stillwater Sciences (2007c). They were selected based on their status under state and federal Endangered Species Acts, the occurrence of suitable habitat within the vicinity of the project area, and the ecological niche they represent. They cover a range of aquatic, riparian, and upland habitat requirements and represent various taxonomic groups and guilds within the river corridor ecosystem, ensuring that the focal species will function as indicators for the wide range of species and habitats that occur in the lower Santa Clara River. A few of the selected species no longer occur in the project area but were included because they might re-colonize or be reintroduced if habitat is restored. Arundo and tamarisk, both non-native invasive plant species that degrade riparian habitats, were also chosen as focal species because control of these species is a primary concern of restoration strategy development on the lower Santa Clara River, and the understanding their distribution will help prioritize and evaluate the success of control projects. These species are described in detail in Appendix A.

Potential habitat for focal species was mapped using information on current and historical distribution and life history requirements, and recently collected vegetation and geomorphic data (Stillwater Sciences 2007a, Stillwater Sciences 2007c, Stillwater Sciences and URS Corporation 2007) (Figure 2-18). Potential focal species habitat is based on existing riparian vegetation and geomorphic conditions; it is referred to as "potential" habitat because it is not certain whether focal species currently utilize this habitat. Potential habitat represents areas where, according to known habitat preferences and current vegetative cover, focal species are most likely to be found or establish themselves. This information is critical to identifying areas that are priorities for conservation, because they currently contain high-quality habitat or support focal species, as well as areas and habitat types that are priorities for restoration, because they are currently limited in distribution or degraded for some reason. The extent of focal species habitat could be much greater under restored conditions than illustrated in Figure 2-18, potentially increasing by 3,000 to 5,000 acres after completion of the Parkway project.

PARKWAY FLOODPLAIN RESTORATION FOCAL SPECIES

arroyo toad
Bufo californicus

western pond turtle
Clemmys marmarota

least Bell's vireo
Vireo bellii pusillus

southwestern willow flycatcher
Empidonax trailli extimus

western yellow-billed cuckoo
Coccyzus americanus occidentalis

steelhead trout
Oncorhynchus mykiss

tidewater goby
Eucyclogobius newberryi

Nevin's barberry
Berberis nevinii

slender-horned spineflower
Dodecahema leptoceras

arundo
Arundo donax

tamarisk
Tamarix spp.

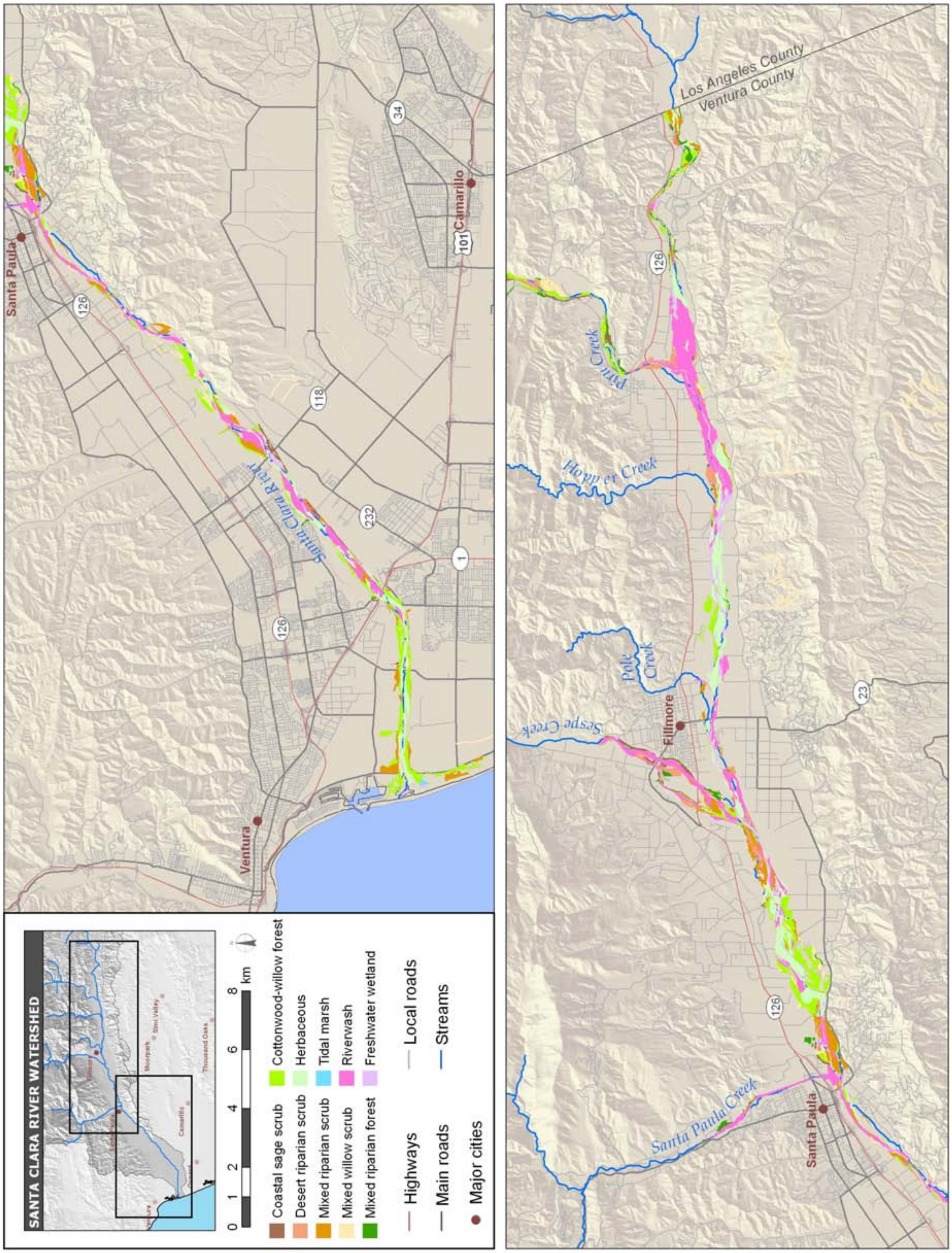

Figure 2-18. Extent of focal species potential habitat in the lower Santa Clara River (Stillwater Sciences 2007c).

Arroyo toad, a federal endangered species and a California species of special concern, was historically found in the upper and lower Santa Clara River basin and currently persists in large numbers along Sespe Creekfrom Hot Springs Canyon upstream to the mouth of Tule Creek (Sweet 1992, as cited in USFWS 1999b, USFWS 1994). They are habitat specialists that are primarily found on riverine floodplains shaped by dynamic fluvial processes, which scour vegetation and provide open riparian habitats (Sandburg 2004, as cited in USFWS 1999b). Arroyo toads require habitat near water. Their breeding habitat consists of open sites, such as pools and old flood channels that provide still water and have little emergent vegetation (Sweet 1992, as cited in USFWS 1999b). Juveniles and adults prefer to forage and burrow on terraces enclosed by dense riparian forest with little herbaceous cover. Many populations have been reduced or extirpated by extensive habitat loss from anthropogenic activities (*e.g.*, flood control, road building, agriculture, and recreation) (USFWS 1999b).

Western pond turtle, a California species of concern, has been observed throughout the lower Santa Clara River basin (CDFG 2007). Several known western pond turtle populations occur in the upper Santa Clara River watershed near Santa Clarita and in the vicinity of Piru Creek. The western pond turtle prefers nesting in grasslands and meadows away from trees and shrubs, and overwintering in upland areas in early- and late-stage riparian scrub and forest (Holland 1994, Reese 1996, Reese and Welsh 1997, Reese and Welsh 1998, Buskirk 2002). Juveniles and adults are generally found within lentic habitats (oxbows, side channels) near terrestrial areas used for basking and nesting (Holland 1994, Jennings and Hayes 1994, Ashton *et al.* 1997). Western pond turtle populations have experienced declines due to extensive conversion of wetland and riparian habitat for urban and agricultural use (Jennings and Hayes 1994, Germano and Bury 2001).

Least Bell's vireo, a state and federal endangered species, was reported as the most abundant and widely distributed endangered bird species within the lower Santa Clara River area (Labinger and Greaves 2001a). Least Bell's vireo prefers dense vegetative cover for nesting and a dense, stratified canopy for foraging (Goldwasser 1981, USFWS 1998a, Labinger and Greaves 2001a). Labinger and Greaves (2001a) observed least Bell's vireo within early successional cottonwood-willow forest, willow woodland, and mulefat scrub along the lower Santa Clara River. Least Bell's vireo was once abundant, but underwent sharp declines in abundance and range during the first half of the 20th century (USFWS 1998a, Labin-

Nesting least Bell's vireo
(photograph by Steve Maslowski, U.S. Fish and Wildlife Service)

ger and Greaves 2001a, Kus 2002). Habitat fragmentation from development within riparian areas and the establishment and spread of non-native plant species are primary factors in population decline. Habitat fragmentation can result in small populations that are spread out among remaining suitable patches. These smaller, more isolated populations are more vulnerable to habitat destruction, disease, low production years, and parasitism (USFWS 1998a, Labinger and Greaves 2001a).

Between 1990 and 2002, **southwestern willow flycatcher**, a federally and state endangered species, was recorded in locations along the Santa Clara River (CDFG 2007). They are generally found in riparian areas, preferring trees and shrubs with dense canopy for nesting and breeding, typically cottonwood, willow, mulefat, and saltcedar (USFWS 2002). Historical accounts suggest that willow flycatchers were once abundant in the inland valleys and coastal regions of central and northern California (Bombay *et al.* 2000). In the last five to six decades, however, southwestern willow flycatchers have been eliminated from most of the lower elevation habitat in California (Unitt 1987, Marshall 2000, Sogge *et al.* 2003). Water diversion and groundwater pumping, changes in flood and fire frequency, grazing, and establishment of invasive non-native plants have caused extensive loss of breeding habitat and reduced populations (USFWS 2002).

Western yellow-billed cuckoo, a state endangered species and a federal endangered species candidate, has been documented in the Santa Clara River watershed (where suitable habitat exists), although it is rare and some sightings may have been migrants (Labinger and Greaves 2001a, CDFG 2007). The bird has narrow habitat requirements, with field studies and habitat suitability modeling concluding that vegetation type (*i.e.*, cottonwood-willow forest), patch size, distance to water, and ratio of high to medium and low tree canopy height are critical factors determining the suitability of habitat for yellow-billed cuckoo breeding pairs (Laymon and Halterman 1989, Greco 1999). Western yellow-billed cuckoos typically inhabit densely foliated stands of deciduous trees and shrubs, particularly willows, with a dense understory, adjacent to slow-moving watercourses, backwaters, or seeps (CDFG 1983).

Adequate patch size and loss of habitat are the primary threats to western yellow-billed cuckoo populations. Loss of habitat is attributed to riparian and floodplain land conversion for agricultural and urban development, and to water management (*e.g.*, dams, channelization, ground water pumping and diversion) that alters the hydrologic regime and precludes the renewal and establishment of riparian trees and shrubs.

Steelhead, a federally threatened species, historically spawned and reared in tributaries of the lower Santa Clara River basin, downstream of the Santa Clara River and Piru Creek confluence (Kelley 2004, Harrison *et al.* 2006). Steelhead have specific habitat requirements for each life history stage (egg, fry, juvenile, smolt, and adult). The fish use the river as a migration corridor from the ocean to spawning and rearing habitats upstream in Santa Paula, Sespe, and Piru creeks (Stoecker and Kelley 2005). Currently, the mainstem supports low-quality steelhead habitat but historically may have provided important over-summering habitat for adult fish (Stoeker and Kelley 2005). The current distribution of anadromous steelhead in the Santa Clara River basin is influenced by several complete and partial migration barriers. The Vern Freeman Diversion Dam, approximately 10 mi upstream from the mouth of the mainstem, is likely a partial migration barrier (Stoecker and Kelley 2005). Since 1991, only 14 adult steelhead are known to have successfully passed through the diversion's fish ladder. Upstream of the Vern Freeman Diversion Dam, passage within Santa Paula Creek is limited by a fish ladder damaged during the 2005 floods[3], and Santa Felicia Dam has eliminated access to Piru Creek since 1955, leaving Sespe Creek as the only unregulated and potentially accessible spawning tributary available to upstream migrants.

Juvenile steelhead
(Photograph by Stillwater Sciences)

Tidewater goby, the Central California Coast Evolutionary Significant Unit (ESU) of which is a federal threatened species, has been observed in the Santa Clara River estuary as far as three miles upstream (AMEC 2005). Tidewater goby is an estuarine species that are an important part of estuarine food webs, as they provide prey for larger fish and piscivorous birds (Swenson and McCray 1996). The fish require shallow water (<3 ft) at the upper end of tidal lagoons and estuaries, sandy substrate for breeding, and velocity refuge during floods to prevent dispersal to the ocean or areas that are too saline (Moyle 2002, USFWS 2005). It is estimated that tidewater goby has disappeared from 74 percent of the coastal lagoons south of Morro Bay (USFWS 2005). The main threats to tidewater goby populations are changes in water

[3] Restoration and enhancement of fish passage at the Vern Freeman Diversion Dam and in Santa Paula Creek is currently being considered. The Vern Freeman Diversion Dam is undergoing formal Section 7 consultations under the federal Endangered Species Act, lead by the National Marine Fisheries Service. Barriers within the Santa Paula Creek sub-basin are being addressed through studies funded by the California Department of Fish and Game and the California Department of Transportation.

quality, degradation and loss of habitat due to urbanization (for example, the Santa Clara River estuary was approximately 300 ac, but is now closer to 30 ac [Stoeker and Kelley 2005]), and predation from invasive species such as piscivorous fish and African clawed frog (*Xenopus laevis*) (Lafferty *et al.* 1999, Lafferty and Page 1997). Conservation of tidewater goby habitat likely requires conserving the hydrologic regime and morphodynamics of the entire estuary system.

Nevin's barberry, a shrub in the barberry family, is a federal and state endangered species and listed by the California Native Plant Society as seriously endangered in California, with one extant occurrence in the Santa Clara River basin (CDFG 2007). Nevin's barberry generally grows within sandy, gravelly soil, on north facing slopes or low-gradient washes (Boyd 1987, Hickman 1993, CDFG 2006). On north facing slopes, it is associated with coastal scrub and chaparral habitat, while in low-gradient washes it is found in alluvial and riparian scrub (Boyd 1987, CDFG 2006). Population decline is likely related to low fecundity and habitat loss (Boyd1987, Mistretta 1989). Populations that occur in alluvial washes are threatened by urban and agricultural development, competition by non-native plant species, off-road vehicle activity, road maintenance, and vegetation clearing and channelization for flood control (Mistretta 1989, USFWS 1998b, CNPS 2006, NatureServe 2006).

Slender-horned spineflower
(photograph by U.S. Fish and Wildlife Service)

Slender-horned spineflower, a small annual in the buckwheat family, is federally and state endangered and a California Native Plant Society list 1B.1 species (seriously endangered in California), with three extant occurrences within the Santa Clara River basin (CDFG 2007). The flower is found on stabilized alluvial fans, floodplains, and terraces that are greater than 100 years in age (Wood and Wells 1996) and are inundated every 50 to 100 years (Prigge *et al.* 1993, as cited in Dudek and Associates 2000). In general, urbanization and stream channelization are the main causes of population decline (CNPS 2006). Preservation of older, stable alluvial surfaces in the historical range of slender-horned spineflower should be the primary focus for the protection of the species (Wood and Wells 1996).

2.4.4 Non-native Invasive Plant and Animal Species

The lower Santa Clara River riparian corridor, like most California landscapes, is host to many non-native invasive plant and animal species. These species can displace native plants and associated animals and disrupt food web dynamics and ecological processes. The most highly invasive species documented in the lower river and the locations where they were observed are shown in Table 2-5. More detailed accounts of these species are provided in Appendix A. The plant species listed in Table 2-5 have been documented as aggressive invaders that displace native plants and disrupt natural habitats (Cal-IPC 2007, DiTomoso and Healy 2007). Other non-native plants have been documented in the lower river (see Appendix C of Stillwater Sciences and URS Corporation [2007]), but these are primarily agricultural or landscape plants and are not considered to be serious threats to native ecosystems. The animal species listed in Table 2-5 have been documented to impact focal species populations (see Stillwater Sciences 2007c) or are known to significantly impact ecological processes in other river systems.

Table 2-5. Distribution of non-native invasive plant and animal species in the lower Santa Clara River.

Species Name	General Distribution in California and Lower Santa Clara River
Woody or Persistent Perennial Plant Species	
giant reed *(Arundo donax)*	Widespread, high-impact invader of riparian areas; found throughout the Santa Clara River watershed.
pampas grass *(Cortaderia jubata)*	Widespread, high-impact invader of coastal forests, grasslands, dunes and scrub, riparian areas, wetlands, and serpentine soils; limited distribution in the lower Santa Clara River.
cape ivy / German ivy *(Delairea odorata)*	Widespread, high-impact invader of coastal riparian areas; limited distribution in the lower Santa Clara River.
Spanish broom *(Spartium junceum)*	Widespread, high-impact invader of coastal scrub, grassland, wetland, oak woodland, and forest habitats; limited distribution in the lower Santa Clara River.
salt cedar/tamarisk *(Tamarix* spp.)	Widespread, high-impact invader of desert washes, riparian areas, seeps and springs; found primarily in the upper reaches of the lower Santa Clara River.
Herbaceous Plant Species	
yellow star thistle & tocalote *(Centaurea solstitialis & C. melitensis)*	Widespread, high-impact invaders of woodlands, grasslands, and some riparian areas; found in many disturbed herbaceous/grassland habitats along the lower Santa Clara River.
sweet fennel *(Foeniculum vulgare)*	High-impact invader of grasslands and scrub habitats; found primarily in disturbed, scrub vegetation along the lower Santa Clara River.
perennial pepperweed *(Lepidium latifolium)*	High-impact invader of coastal and inland marshes, riparian areas, wetlands, and grasslands; limited to the estuary area of the lower Santa Clara River.
Animal Species	
brown-headed cowbird (*Molothrus ater*)	Widespread brood-parasite of many native bird species, including least Bell's vireo, in riparian areas throughout California, especially those near agricultural lands; found throughout the lower Santa Clara River, particularly in upper- and lower-most reaches where cowbird trapping was not implemented.

Species Name	General Distribution in California and Lower Santa Clara River
African clawed frog (*Xenopus laevis*)	Likely widespread in California and elsewhere around the world, they are drought and saline tolerant and feed on a wide range of aquatic invertebrates and vertebrates, (*e.g.*, tad-pole and juvenile amphibians, arroyo chub, mosquito fish, unarmored three-spined stickleback, and tidewater gobies); currently found in muddy, slow-water areas throughout the upper and lower Santa Clara River, including the estuary and tributaries.
black bullhead (*Ameiurus melas)*	Widespread in California rivers and reservoirs, they compete with native fishes for space and food, are voracious predators of smaller fish, and have been found to be at least partially responsible for the decline of the native amphibian species in other states; observed in Sespe Creek in 2005 and believed to be widespread in the lower reaches of the Santa Clara River.
green sunfish (*Lepomis cyanellus)*	Likely found in all drainages in California, out-compete and prey on other native fishes and appear to be at least partially responsible for local extinctions of California roach (*Hespero-leucus symmetricus)*; observed in Sespe Creek in 2005, but be-lieved to be widespread in the lower reaches of the Santa Clara River.

Distribution sources: Labinger and Greaves (2001), Stoecker and Kelley (2005), Stillwater Sciences and URS Corporation (2007)

3 OPPORTUNITIES & CONSTRAINTS

To be successful, restoration efforts must work within the ecological as well as the social, institutional and infrastructural context of the river. This context includes the legacy of historical impacts, land use and zoning, water resource development and management, flood control requirements, physical structures (such as bridges), environmental regulations, and local policy and management. In addition, geomorphic functioning, water quality, and the presence of existing habitat are two important attributes of the river that influence the priority and long-term success of implemented restoration strategies. Each of these topics is discussed in the following sections to provide insight into potential opportunities and constraints for floodplain restoration. Recognizing these opportunities and constraints, acquisition and floodplain restoration strategies on the lower Santa Clara River can be designed to be implementable and functional within the current and foreseeable social, institutional, and infrastructural framework of the river.

3.1 Morphologic Legacy Effects

Restoration efforts have their best chance of succeeding if measures are set properly within their watershed historical context, as well as other social, institutional and infrastructural constraints. Central to the watershed historical context is the recognition that human impact on river systems means that they have changed from their pre-disturbance state, and that restoration measures that strive solely to "turn back the clock" are unlikely to be successful. Mindful of this fact, an extensive study of geomorphic processes in the Santa Clara River watershed (Stillwater Sciences 2007a) underpins these restoration plans.

It is apparent that, in general, the lower 38 miles of the Santa Clara River have undergone significant morphological transformation over the last approximately 70 years (*i.e.*, the length of time for which there is quantifiable historical data)(Stillwater Sciences 2007a). Based on analysis of repeat aerial photographs, the average width of the active channel bed became almost 50% narrower in the period 1938–2005 (from approximately 1,580 feet to 830 ft). Furthermore, the width of the active channel is, over large stretches of the river, no longer related to the magnitude of the last flood as is typical in a semi-arid river, suggesting the influence of human activities instead. Narrowing is most pronounced in the reaches below the Santa Paula Creek confluence (Reaches 1-4) whereas the channel retains its responsiveness in the reach upstream of the Santa Paula Creek confluence to the Sespe Creek confluence.

Repeat thalweg surveys of channel bed elevation, supplemented with 2005 LiDAR imagery, indicate that the entire lower Santa Clara River has also incised an average of 2.3 ft in recent history (1949–2005, see Figure 2-9). This change is also most pronounced in the reaches between Santa Paula Creek and the estuary (Reaches 1–4) where the average incision is nearly eight feet, with a single station maximum exceeding 25 ft of incision just downstream of the Vern Freeman Diversion Dam. Since the diversion dam was constructed in 1991, the Above Freeman and Below Santa Paula Reaches (3 and 4) have recovered their bed level significantly, as would be expected, and have shown an increase in sinuosity. The Below Freeman Reach (2) continues to incise just below the dam, as does the Hwy 101 Reach (1) near the mouth of the river. Conversely, in the reaches upstream of the Sespe Creek confluence, the channel bed has aggraded an average of just over two feet in recent history, with a single station maximum increase of just over 10 ft. Between the Santa Paula and Sespe Creek confluences, the bed level has remained fairly static.

The overall picture is one of significant functional change in parts of the lower Santa Clara River. Naturally, the river is transitional between braided and meandering river forms, but over the last 70 years it has incised to such an extent that it now operates increasingly like a low-sinuosity meandering channel with a compound cross-section. Sediment budget studies indicate that the large floods that drive the Santa Clara fluvial system will generally result in a net sediment loss, unless there is sustained high-magnitude flooding from Sespe Creek at the same time. This means that incision (especially in the lower reaches) is likely to continue in the foreseeable future without corrective measures.

Sediment budget studies also indicate that the primary force for change was instream aggregate mining for sand and gravel. As in many other rivers in California, aggregate mining was responsible for extracting from the bed of the river far more sediment than was supplied by flood events over the long-term average. Floods alone are only capable of explaining 0.4 ft of the average 2.3 ft incision of the lower Santa Clara River; the remaining 1.9 ft can be explained by material extracted for aggregate (Stillwater Sciences 2007a). However, instream aggregate mining is no longer permitted in the Ventura County portion of the Santa Clara River and, as the river has naturally very high rates of sediment supply from hillslopes in its headwater tributaries, there remains a question about why the river bed elevation, especially in the below Freeman Reach (2) which saw the majority of the mining effort, has not recovered in two decades after the cessation of instream mining. The answer appears to lie in the existence of levees that constrain the width of the river during flood at far less than natural extent. This width constraint imparts a very high capacity for sediment transport (with relatively high stream power) that enables the river to transport out more sediment than is transported in during almost all floods. Incision is thus inevitable.

Restoration efforts should recognize and understand the implications of these changes. In this regard, the lower Santa Clara River can be conveniently sub-divided into three sections. The legacy effects are greatest from the mouth to Santa Paula Creek, where the river is far narrower and deeper than it was 70 years ago, and where the river bed has been effectively disconnected from its floodplain by a combination of aggregate mining and the construction of reinforced levees. Partial bed level recovery in the Above Freeman and Below Santa Paula Reaches (3 and 4) was forced by the construction of the Vern Freeman Diversion Dam, which acts as a major grade control. The river is apparently becoming more sinuous in these reaches ,which suggests a priority on floodplain acquisition here to relive the potential future problems of bank erosion at the outside of meander bends. Downstream of this grade control, the river continues to incise; in numerous locations there are constraints on floodplain re-connection due to floodplain development and floodplain aggregate mining.

Between the confluence of Santa Paula and Sespe creeks, the river is functionally similar to 70 years ago. This is not necessarily equivalent to predisturbance conditions, as many changes may have occurred between Euro-American settlement of the watershed and the availability of quantitative historical data. However, the reaches are the most "natural" of those currently in existence in the lower Santa Clara River and, critically, the river bed still appears to respond naturally to flood events. The reasons for this condition seems to be three-fold: these reaches (*i.e.*, 5 and 6) were not subject to instream aggregate mining, are largely unconstrained by levees, and are the first to receive flood flows and sediment from the unregulated Sespe Creek (which frequently exceed flows from the upper watershed of the Santa Clara River). As such, restoration efforts should focus on preserving the current river-floodplain as much as possible, and releasing constraints where they exist. This includes, for example, setting back bank-edge levees where feasible.

Upstream of Sespe Creek, in reaches 7–10, the active river bed has both narrowed and aggraded slightly, suggesting that there has been a change in the balance between flood flows and sediment supply in the reach. Narrowing of the active river bed width during floods may be related to the extreme regulation of flood flows from Piru Creek since 1955, which has reduced the overall magnitude of flow flows in this portion of the Santa Clara River. In concert, there are three possible episodic causes for increased sediment load to the reach including (1) the increased frequency of ENSO-generated large flood flows since 1969, potentially delivering more than "normal" amounts of sediment to the reach; (2) incidents of landsliding associated with the 1994

Northridge earthquake and/or fire-related sediment production that has increased sediment supply to the lower Santa Clara River in flood events: or (3) a pulse of construction-related sediment resulting from the rapid upstream growth of the city of Santa Clarita. Whatever the true cause, there appears to be now relatively more sediment supplied than can be carried by the flood flows. Restoration efforts in these reaches should focus on floodplain and river bed acquisition as a basis for enhancing conservation values. Restoration activities should be planned cognizant of the fact that urban expansion generally results in a decrease in sediment supply per unit discharge in the long term, and so these reaches may begin to incise in future years if they are indeed responding to the expansion of Santa Clarita.

3.2 Land Use

The lower 33 miles of the river within the 500-year floodplain are currently dominated by agricultural and developed land uses (Table 3-1; Figure 3-1), although 7,214 ac of riparian vegetation is still supported (Stillwater Sciences and URS Corporation 2007).

Table 3-1. Land use-land cover types within in the 500-year floodplain of the lower Santa Clara River.

Land Use - Cover Type	Acres	Hectares	Percent of Mapped Area
Agriculture	8,141	3,295	33%
Developed	6,484	2,624	26%
Riparian Vegetation	7,214	2,919	29%
Riverwash	2,096	848	8%
Open Water	857	347	3%
Total Mapped Area	**24,791**	**10,033**	**100%**

Agriculture (orchards, vineyards, croplands, and pasture) is the primary developed land use in the lower river corridor, accounting for 33% of the land use in the 500-year floodplain (Table 3-1). Golf courses, mining, urban development, and municipal infrastructure are other important land uses in the lower Santa Clara River watershed, and continued population growth in both Ventura (*e.g.*, Oxnard, Ventura, Santa Paula, Fillmore, and El Rio) and Los Angeles counties (*e.g.*, Santa Clarita and the Newhall Ranch Development) is resulting in the continued and rapid expansion of these land uses.

The 10,167 ac of open water, riverwash, and riparian vegetation (Table 3-1) present an obvious minimum goal for Parkway project acquisition. In addition, vacant, undeveloped lands and flood-prone agricultural lands present clear opportunities for acquisition and restoration implementation. Property owners are more likely to sell or place conservation easements on relatively unproductive lands; these types of land uses are generally free of infrastructure that might complicate the implementation or compromise the effectiveness of restoration actions; and they can provide immediate benefits, even if funding for restoration or maintenance are not available. In fact, 3,250 ac of these land types have already been acquired within the 500-year floodplain of the lower Santa Clara River for public access and/or conservation and res toration purposes (see Section 3.5). While parcels of vacant, undeveloped lands occur throughout the lower river, the upper reaches (approximately Reaches 8 through 11) present particular opportunities for conservation and passive restoration strategies.

The large extent of developed land in the lower Santa Clara River watershed is a constraint to restoration. Large-scale restoration actions would not be appropriate on lands zoned for urban or residential uses. This is a particular issue near the towns of Santa Paula and Fillmore, where Ventura County growth boundaries currently allow for urban development within the 500-year floodplain (but see further discussion below). These areas have or could potentially have intensive development and concentrated populations, factors that limit the ecological effectiveness of restoration activities. Furthermore, developed property constrains the types of restoration actions that are appropriate on adjacent property: implemented restoration actions cannot compromise nearby land uses and must be done with concern for increased public access, vandalism, and trespassing on adjacent private property. Where appropriate, however, small-scale urban-oriented restoration projects, such as parks and interpretive areas, could be implemented in urban and residential areas.

Ventura County's current urban development restrictions provide an opportunity for restoration that should be capitalized upon as soon as possible to protect ecologically sensitive areas in perpetuity before land-use laws potentially change. Ventura County's Save Open space and Agricultural Resources (SOAR) boundaries limit urban growth to existing urban centers, such as the cities of Ventura, Santa Paula, and Fillmore, unless approved by a County vote (Fulton *et al.* 2003). While some agricultural and open space lands are within the growth boundaries, the vast majority of these land uses are located outside of the boundaries. Acquisition of these lands should be a priority while the SOAR boundaries are in place (current SOAR boundaries will expire between 2013 and 2018). Conversely, acquisition of agricultural or open space areas *within* SOAR boundaries, particularly those areas within the 500-year floodplain near the towns of Santa Paula and Fillmore (Reaches 3, 4 and 5 and Reach 7, respectively), should be top priorities to protect the floodway from urban development.

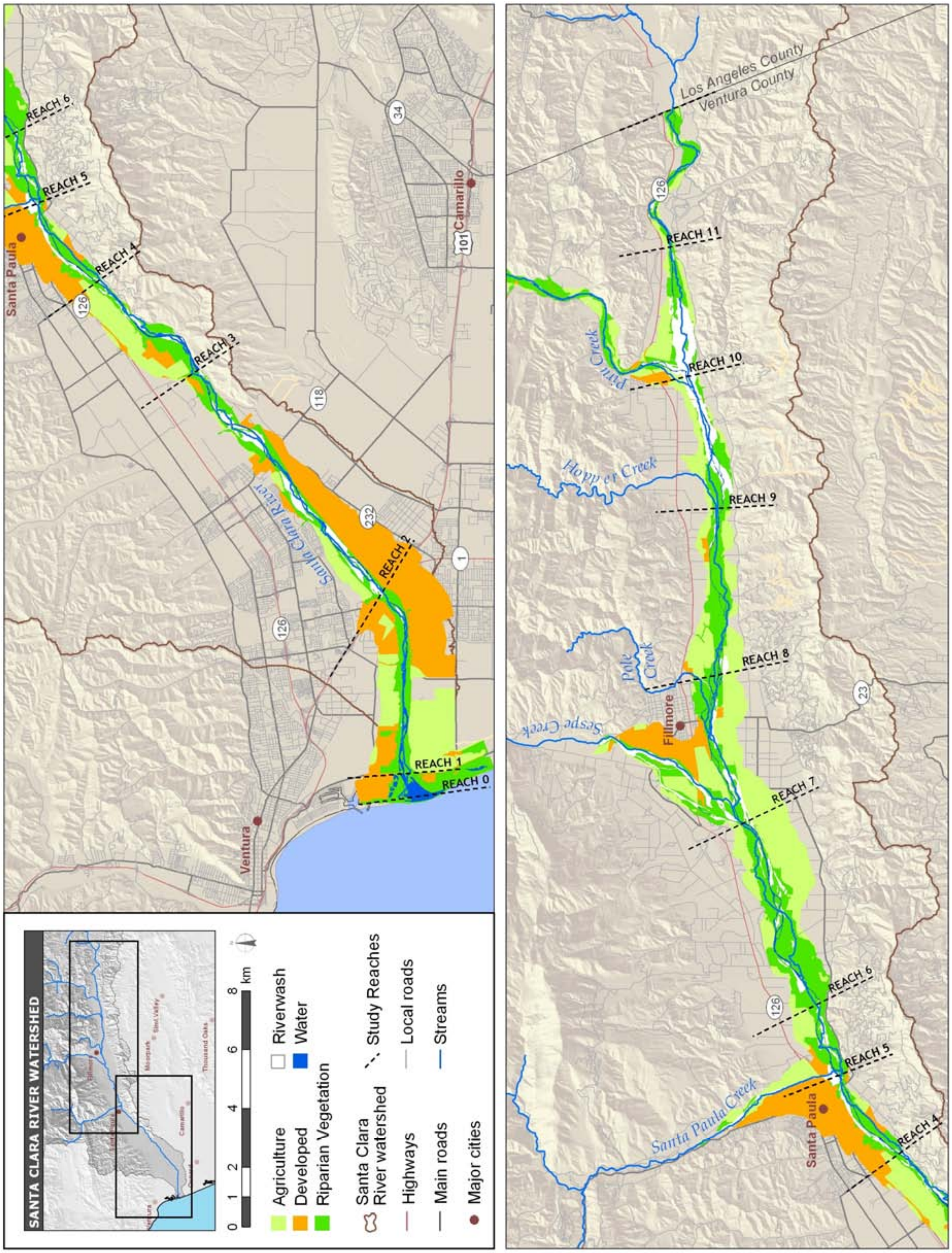

Figure 3-1. Land use-land cover types within the 500-year floodplain of the lower Santa Clara River.

As the population of Ventura County grows, however, there will be increasing pressure to convert agricultural and other open space to urban and suburban land uses. Fulton *et al.* (2003) indicates that urban areas in Ventura County have increased 20%, with a corresponding decline in farmland by 14% between 1986 and 2000. Because only 20,800 ac of unconstrained land occurs within the SOAR growth boundaries, any additional growth in the area would necessitate urbanization of either agricultural lands or important natural habitats (Fulton *et al.* 2003). This pressure to urbanize agricultural and natural areas, as seen in the town of Fillmore, presents a clear constraint to future restoration: urban land uses are far less compatible with natural river functioning and Parkway objectives than agriculture, and conversion of natural areas may result in there being no riparian corridor or river processes worth conserving or restoring.

3.3 Water Management & Flood Control

Water resource management (*i.e.*, flow diversion and flow regulation) has been affecting in-channel and floodplain geomorphic and ecological condition within the lower Santa Clara River since the early 1800's (Stillwater Sciences 2007a). Major water diversions for irrigation and groundwater recharge have occurred in the lower Santa Clara River since the early 1930's. The most significant diversion of water occurs at the Vern Freeman Diversion Dam (river mile 10.8), where 69,000 ac-ft (approximately 28% of the total annual runoff from the Santa Clara River) of water is diverted annually from the Santa Clara River to groundwater recharge spreading grounds in El Rio and Saticoy (URS 2005) (Figure 3-2). A portion of this diverted water can return to the mainstem below the diversion through groundwater discharge and agricultural return flow. Dams regulate flow in over one-third of the Santa Clara River watershed and have reduced flow to the mainstem by over 25% (Warrick 2002). Major attempts at flow regulation in the watershed began with the construction of ill-fated St. Francis Dam in San Francisquito Canyon in 1924 and in the lower Santa Clara River in 1955 with the completion of Santa Felicia Dam on Piru Creek (Figure 3-2). Reservoir releases in Piru Creek are currently the main source of flow in the lower Santa Clara River during the dry season, providing potentially unnaturally high summer season flows (URS 2005, Stillwater Sciences 2007a).

In addition to water resource management, flood control has also had a profound effect on geomorphic and ecological conditions within the lower Santa Clara River (Stillwater Sciences 2007a). Historically, flow spread out on the Oxnard Plain before reaching the Pacific Ocean. Settlement in the lower watershed resulted in the establishment of an extensive levee system to protect floodplain agriculture and commercial and residential developments. Over 33% of the lower Santa Clara River has levees on the adjacent banks (URS 2005), totaling 31.2 mi in length. The levee system includes those maintained by the U.S. Army Corp of Engineers and the Ventura County Watershed Protection District (total length of 14.1 mi [22.6 km]) as well as private property owners (total length of 17.1 mi [27.5 km]) (Figure 3-2). Privately maintained levees are generally designed to protect agricultural fields and many need to be rebuilt after flood events.

Levees represent the most dramatic loss of floodplain habitat restoration opportunities, but development in the floodplain will continue to reduce the amount of natural floodplain area. It will also continue to raise the risk to existing floodplain infrastructure and flood-protection structures, because current rules allow structures or filling in the floodplain that result in as much as a one-foot rise in water-surface elevation. Alternative, zero-rise floodplain regulations that would significantly reduce not only the amount of floodplain disturbance but also the risk of future damage to existing structures and property have been applied in several other U.S. jurisdictions, although not to date in any Southern California communities. Zero-rise floodplain regulations require developers to show that proposed developments do not increase flood elevations at the site and/or downstream. Developments within the floodplain that increase floodplain water surface elevations are prohibited.

Recently, a comprehensive regional water resource management plan (or Integrated Regional Watershed Management Plan [IRWMP]) that includes the lower Santa Clara River was developed by the Watershed Coalition of Ventura County (WCVC 2006). The purpose of the IRWMP is to integrate watershed restoration planning and implementation efforts with the goal of improving water supply reliability, water recycling, water conservation, flood control, wetlands enhancement and creation, and environmental habitat and protection. Watershed-specific plans will eventually be developed, with opportunities for local stakeholder review. A similar plan is currently being developed for the upper Santa Clara River in Los Angeles County.

Existing water resource management and flood control practices, as well as the recent IRWMP, represent constraints on the restoration scenarios devised for lower Santa Clara River as part of this project. Restoration strategies will have to be carefully designed to avoid impacts to water management infrastructure (*e.g.*, diversions, levees adjacent to the Ventura Water Reclamation Facility and other developed land uses) and prevent any increase in flood risk to nearby development. In addition, restoration activities implemented as a part of the Parkway project will need to be coordinated with the recently developed IRWMP, which could potentially represent a constraint on the options available for restoration implementation.

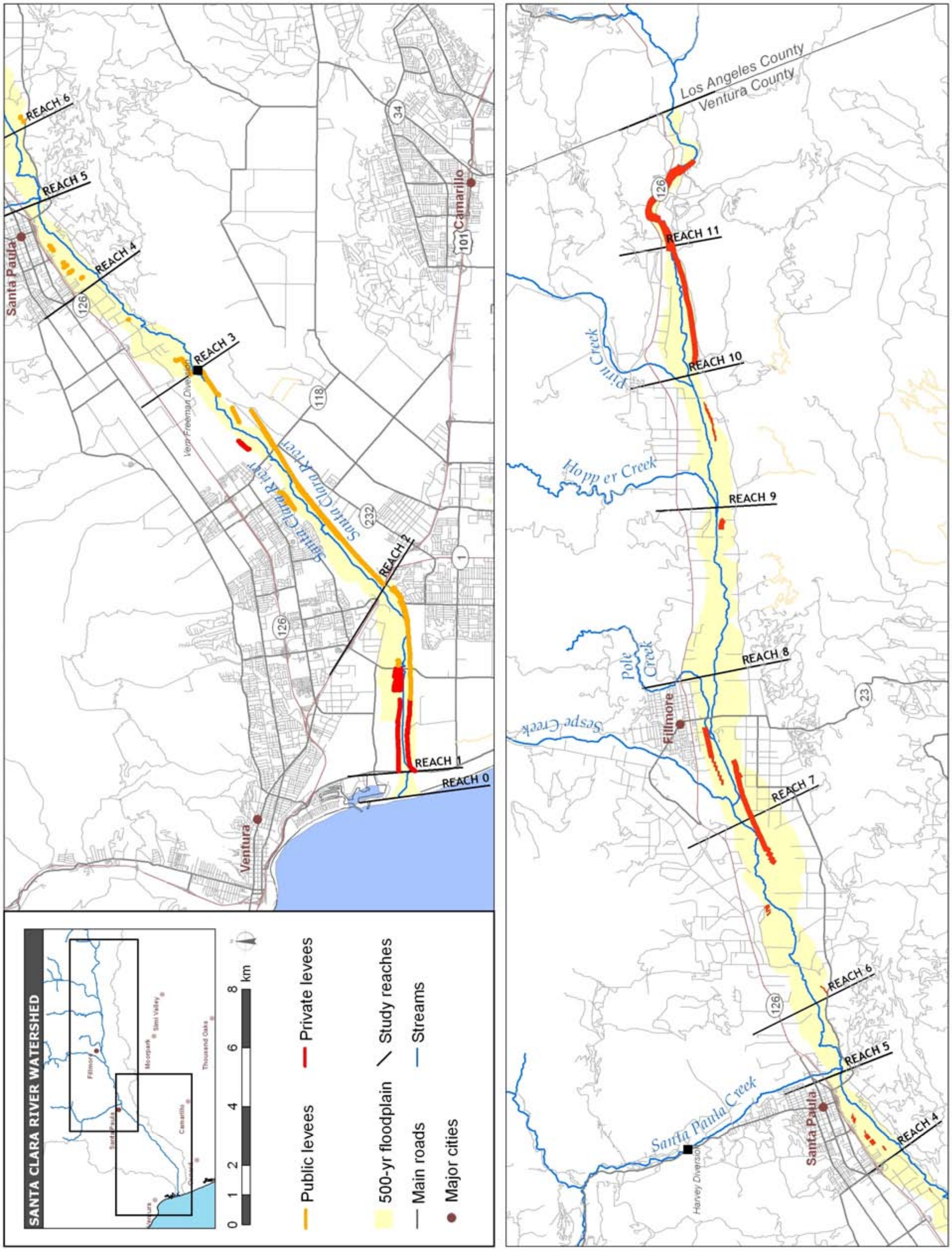

Figure 3-2. Public dams, diversions, groins and levees in the lower Santa Clara River.

Despite the considerable design constraints that water resource management and flood control practices will present to restoration implementation, there are several restoration opportunities related to these structures. First, there is considerable momentum in replacing or redesigning fish ladders at both Vern Freeman Diversion Dam and Harvey Diversion Dam on Santa Paula Creek to improve aquatic habitat connectivity, particularly for southern California coast steelhead which spawn in several sub-basins in the upper watershed. As discussed in more detail in Section 4.7, increasing fish passage is a necessary first step to improving aquatic habitat conditions in the lower Santa Clara River and, quite possibly, to sustaining southern California coast steelhead populations in the watershed.

The extensive network of privately maintained levees also presents an opportunity for restoration. These agricultural levees are far less engineered than those constructed and maintained by the U.S. Army Corp of Engineers and the Ventura County Watershed Protection District and, as a result, are frequently damaged by high flows (URS 2005). Purchasing flood-prone agricultural lands with these types of levees, such as in Reaches 6 and 8 through 11, from willing sellers reduces maintenance costs on less productive farmland and presents a technically feasible and cost effective opportunity to passively or actively remove and/or set back these levees.

3.4 Infrastructure

Infrastructure in the channel and floodplain of the Santa Clara River has impacted physical and biological process in the lower Santa Clara River since European settlement and has contributed to several contemporary challenges for river management and restoration. Infrastructure building began in the watershed in the 1800's with the establishment of permanent settlements and introduction of agriculture, and has increased rapidly since the 1960's with a five-fold increase in population within the watershed. Major in-channel infrastructure within the lower Santa Clara River includes eight bridges (Harbor Blvd., Victoria Ave., Southern Pacific Rail Road, Highway 101, Highway 118, 12th Street, Highway 123, and Newhall), levees protecting gravel mining operations (approximately one mile in length downstream of Freeman Diversion Dam), flood protection levees (discussed in Section 3.3), and rock groins installed for levee protection (approximately eight miles in length) (URS 2005). Major infrastructure within the 500-year floodplain is concentrated in urban areas (Oxnard, Ventura, Santa Paula, Fillmore, and El Rio) and includes the Ventura marina, Ventura Water Reclamation Facility, McGrath State Beach, and Santa Paula Airport (URS 2005).

The existing in-channel and floodplain infrastructure represent significant constraints on the restoration scenarios devised for lower Santa Clara River as part of this project. Given the permanence and importance of the infrastructure discussed above, restoration activities will have to be carefully designed to avoid negative impacts, such as increased risk of flooding, sediment deposition, or woody debris accumulation, to existing or planned infrastructure that will remain intact following restoration. As opportunities arise, restoration strategies that incorporate the relocation, removal, or modification of flood-prone, high-risk and/or highly constraining infrastructure should be pursued. These opportunities are discussed in more detail in Section 4.2. For example, while any modification to the recently and expensively widened Highway 101 bridge is unlikely in the next several decades, there may be opportunities to widen or modify smaller, high-maintenance bridges farther upstream during or in addition to normal maintenance to improve flood conveyance and minimize the risk of damage from flooding and channel changes is minimized.

3.5 Water Quality

Segments of the lower Santa Clara River are impaired by several point and non-point source pollutants, including TDS (total dissolved solids), chloride, coliform, sulfate, ammonia, pH, toxaphene, and ChemA[1] (CRWQCB 2006, 2007). Section 303(d) of the Clean Water Act requires states to report to the Environmental Protection Agency (EPA) a list of waters that do not meet water quality standards and therefore require implementation of Total Maximum Daily Load (TMDL) requirements. Several reaches of the lower Santa Clara River (including the estuary) were listed on the 2006 303(d) list of impaired waters (Table 3-2, Figure 3-3) by the California Regional Water Quality Control Board – Los Angeles Region[2] (CRWQCB 2007). In addition, several pollutants of concern have been identified in stormwater discharge to the river, including total and fecal coliform, mercury, polyaromatic hydrocarbons (PAHs), DDT and their by-products, diazinon, sediment/total suspended solids (TSS), chlorpyrifos, copper, lead, thallium, bis(2-ethylhexyl) phthalate, and phosphorous (VCSQMP 2000).

[1] Chem A (Group A Pesticides) includes: aldrin, dieldrin, chlordane, endrin, heptachlor, heptachlor epoxide, hexachlorocyclohexane (including lindane), endosulfan, and toxaphene
[2] The Los Angeles Region of the California Regional Quarter Quality Control Board has jurisdiction over all coastal drainages flowing to the Pacific Ocean between Rincon Point (on the coast in western Ventura County) and the eastern Los Angeles County line.

Table 3-2. CWA 303(d) water quality limited segments of the lower Santa Clara River (including tributaries).

Location[1]	Pollutant /stressor[2]
Santa Clara River – Reach 0 (Estuary)	Chem A[3]
	Coliform bacteria
	Toxaphene
Santa Clara River - Reach 1 (Estuary to Hwy 101 Bridge)	Toxicity
Santa Clara River – Reach 3 (Freeman Diversion to A Street)	TDS
	Ammonia[4]
	Chloride[5]
Santa Clara River – Reach 5 (Blue Cut gaging station to West Pier Hwy 99 Bridge)	Chloride[4]
	Coliform bacteria
Santa Clara River – Reach 6 (W Pier Hwy 99 to Bouquet Cyn Rd)	Chlorpyrifos
	Coliform bacteria
	Diazinon
	Toxicity
	Chloride[3]
Santa Clara River - Reach 7 (Bouquet Canyon Rd to above Lang Gaging Station)	Coliform bacteria
Hopper Creek	Sulfates
	TDS
Wheeler Canyon/ Todd Barranca	Sulfates
	TDS
	Nitrate and Nitrite[6]
Pole Creek	Sulfates
	TDS
Santa Clara River – Reach 11 (Piru Creek, from confluence with Santa Clara River Reach 4 to gaging station below Santa Felicia Dam)	Boron
	Sulfates

Source: CRWQCB (2007)

1 Reaches delineated as per CRWQCB 2007

2 All pollutants are from nonpoint or unknown sources

3 Chem A (Group A Pesticides) includes: aldrin, dieldrin, chlordane, endrin, heptachlor, heptachlor epoxide, hexachlorocyclohexane (including lindane), endosulfan, and toxaphene

4 TMDL approved by USEPA in 2005

5 TMDL approved by USEPA in 2002

6 TMDL approved by USEPA in 2004

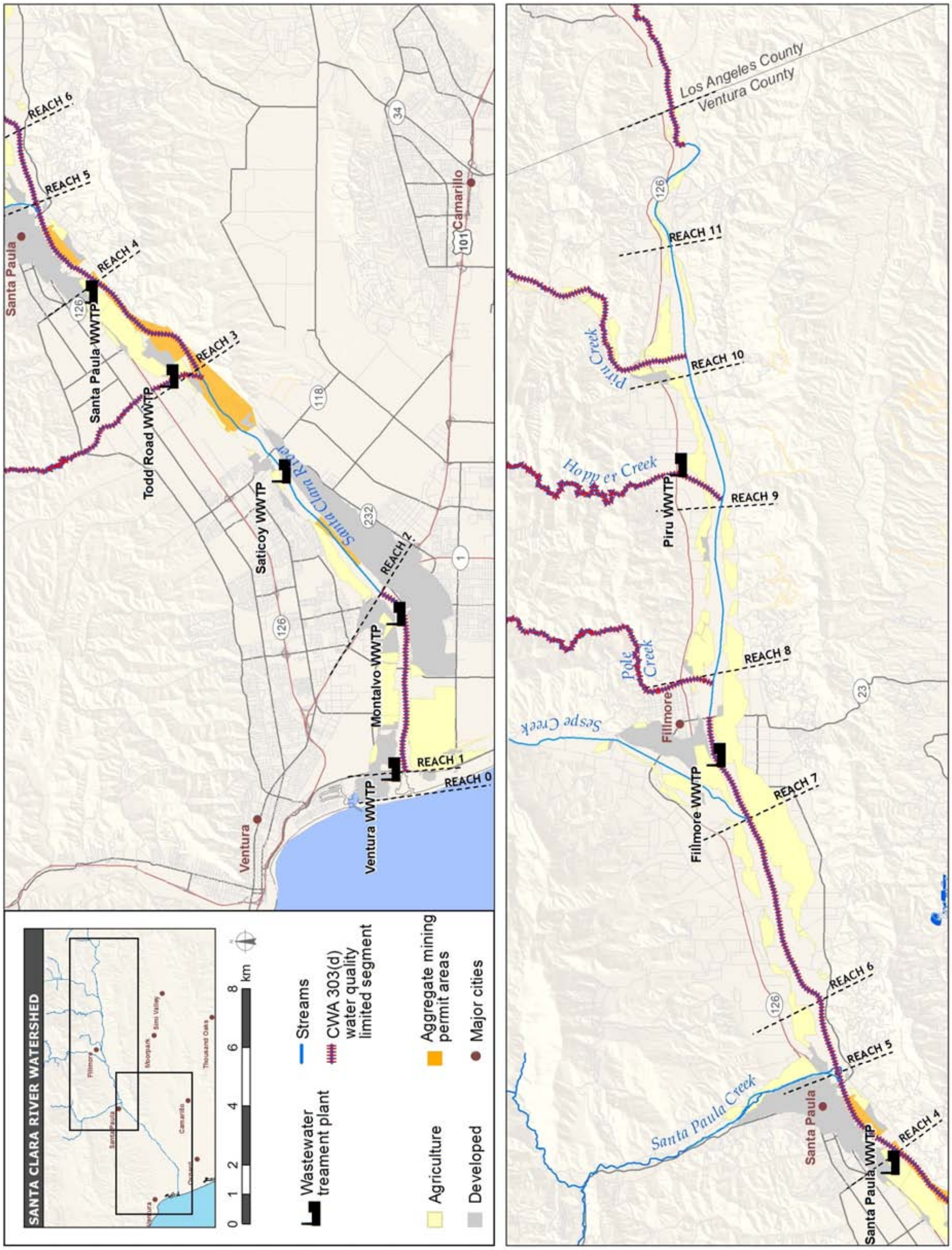

Figure 3-3. CWA 303(d) water quality limited segments relative to point and non-point sources for pollutants (Source: USEPA 2006).

Depending on the level of the pollutant and its effect on aquatic organisms, water quality impairment can constrain restoration on the lower Santa Clara River by potentially compromising the ecological benefits and effectiveness of implemented restoration strategies, particularly in the reaches and downstream of the tributaries listed in Table 3-2. Excess nutrients can lead to eutrophication, which can lower dissolved oxygen concentrations below those needed to support healthy fisheries. Excess nutrients are also believed to promote the widespread infestation of arundo, which appears better able to take advantage of anthropogenically enriched N levels in riparian ecosystems, allowing it to out-compete native riparian species (Coffman 2007). Excess bacteria can result in incidences of pathogenic outbreaks to aquatic organisms and people who contact the water during recreation. Salts (TDS and chloride) can damage agricultural crops, impact aquatic species, and impair drinking water.

While the specific impacts of poor water quality on biota in the lower Santa Clara River are currently not well-understood, the level of impairment and types of pollutants found in the lower Santa Clara River (see Table 3-2) imply that water quality potentially limits at least some life stages of many aquatic organisms (Kelley 2004, AMEC 2005). Effects of poor water quality on aquatic and terrestrial biota can be direct or indirect and, depending on the level of the pollutant, chronic (*i.e.*, reproductive interference and/or decreased vitality) or acute (*i.e.*, lethal). Indirect effects of toxicity due to poor water quality may be a significant factor influencing the manner in which ecosystems respond to other anthropogenic stressors, including deviations from natural temperature and flow regimes and response to resource competition from introduced species (Preston 2002, Fleeger et al. 2003). Additionally, certain pollutants can bioaccumulate in the food web, resulting in concentrations in biota that are orders of magnitude greater than in ambient water concentrations (Weiner *et al.* 2003). If water quality impairments are limiting aquatic species populations in the lower Santa Clara River, many process- or engineering-based restoration strategies will be unable to fully meet their objectives to improve habitat quality conditions for native aquatic species.

Fortunately, monitoring and improving water quality for multiple beneficial uses is already a priority of several organizations. The ultimate goal of the TMDL process is to develop and implement a plan to restore healthy water quality conditions. As a part of the TMDL process, the CRWQCB (Los Angeles Region) has initiated studies of, and intends to reduce the discharge of, those constituents listed in Table 3-2 with approved TMDLs by implementing Best Management Practices (BMPs) for new developments within municipal stormwater discharge systems (VSQMP 2000). BMPs typically include post-implementation monitoring to ensure the desired water quality standards are attained (VSQMP 2000). Los Angeles County Sanitation Districts and LAWQCB have initiated agriculture/chloride threshold, ground/surface-water interaction, and endangered species/chloride threshold studies as a part of the upper Santa Clara River chloride TMDL (CH2MHill 2006). In 2007, the House of Representatives granted $1 million to improve water quality in the upper Santa Clara River related to wastewater treatment and hazardous waste contamination of groundwater (Ryan 2007). The Friends of the Santa Clara River organization is monitoring temperature, pH, dissolved oxygen, turbidity, flow, and several nutrient parameters at six sites along the river in support of the Nitrogen TMDL (FSCR 2007). These efforts to assess and improve water quality in the Santa Clara River should benefit native aquatic species and help other restoration strategies to maximize their ecological benefits.

3.6 Existing Habitat and Protected Property

Despite the degradation of the lower Santa Clara River ecosystem as a result of water and flood management, aggregate mining, and encroaching urban development, the fact that the river is not entirely channelized (as so many other coastal southern California rivers are) presents one of the greatest opportunities for implementing effective process-based restoration strategies.

Specifically, the comparatively intact floodway and riparian corridor of the lower river present critical opportunities to conserve existing habitat or conduct habitat enhancement activities, such as revegetation and non-native species removal, to both enhance ecosystem functions and protect sensitive species populations. In addition, the growing extent of publicly-owned, protected property within the 500-year floodplain presents opportunities to fulfill the goal of the Parkway project to create a continuous 25-mile long corridor that provides habitat and movement corridors for wildlife and multiple ecosystem and human benefits (Figure 3-4).

Figure 2-18 illustrates the extent of currently available habitat for Parkway focal species (see Section 2.4.2). There are 7,894 ac of existing habitat suitable for use by multiple focal species. The Below Sespe and County Line Reaches (6 and 11) and lower Piru Creek provide potential habitat for the greatest number of focal species and the greatest current potential habitat areas (Stillwater Sciences 2007c). These reaches also contain the greatest areas of mixed riparian and mixed willow scrub and cottonwood-willow forest, which support the greatest number of focal species. These areas are opportunities to conserve existing high-quality habitat patches that are known to be critical to native species populations (Stillwater Sciences 2007c). In addition, these areas provide focal points for implementing terrestrial restoration strategies, such as revegetation and non-native invasive species removal, to enhance the quality of these existing habitats. For example, building from conservation in the Below Sespe and County Line Reaches (6 and 11) and

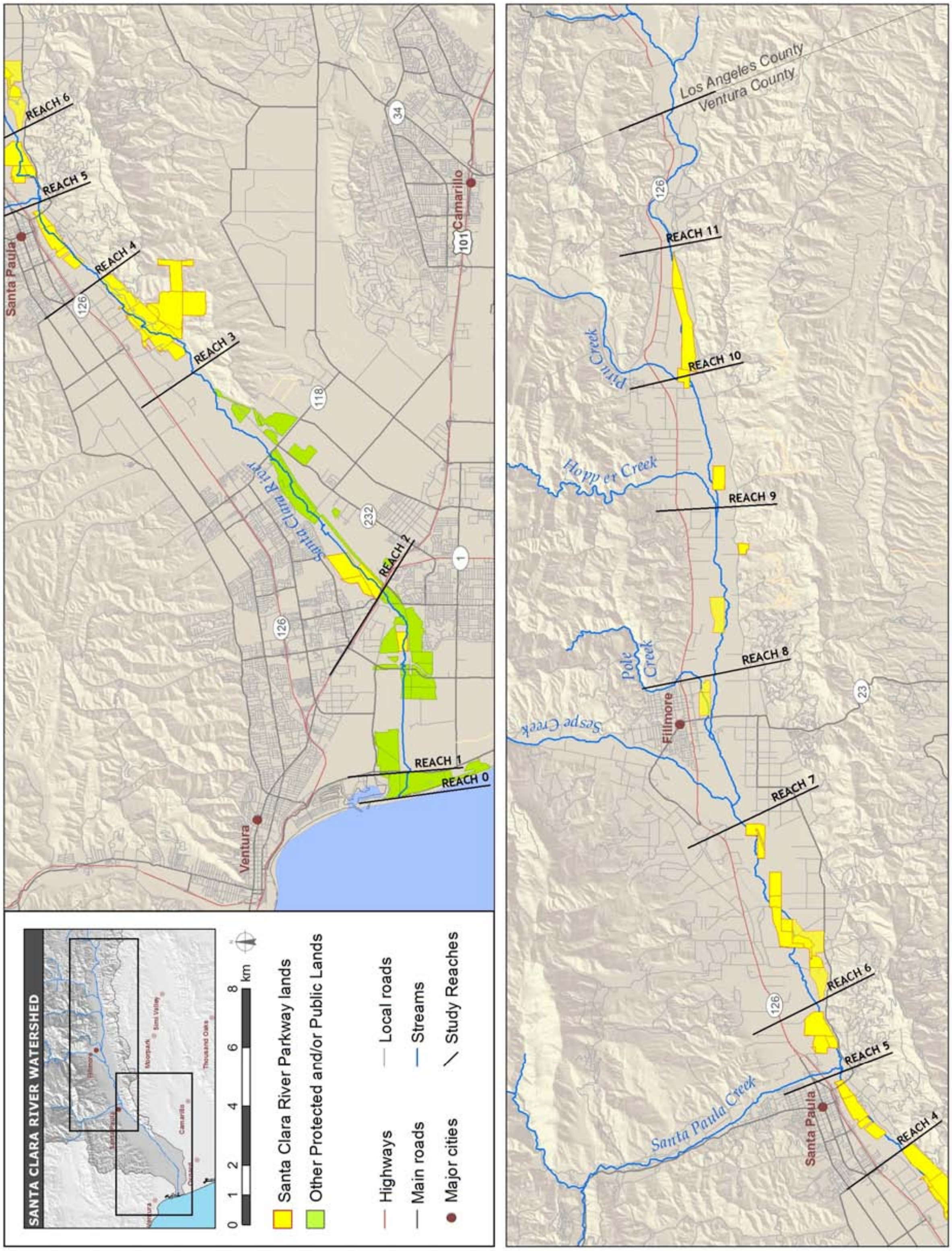

Figure 3-4. Public and/or protected property in the lower Santa Clara River (Source: TNC, unpublished data).

lower Piru Creek, there are restoration opportunities for non-native species eradication along the Above Sespe, Hopper and County Line Reaches (7, 8, and 11), that are highly infested by arundo and tamarisk. Restoration and conservation in these reaches would allow formation of habitat corridors along the Santa Clara River and along Santa Paula Creek to the Sierra Madre Range, which were identified in Penrod *et al.* (2001) as severely threatened habitat corridors. The restoration strategies developed for this report, particularly land acquisition, revegetation, and non-native species removal (see Sections 4.1, 4.3 and 4.4), have been designed to take advantage of the obvious opportunities presented by existing habitat within the lower Santa Clara River.

The existing, and growing, extent of public protected lands in the Santa Clara River watershed provides clear opportunities for implementing and maximizing the ecological benefits of restoration strategies. There is currently a total of 5,530 acres of publicly-owned, protected land within the 500-year floodplain of the lower Santa Clara River (Figure 3-4). This land includes approximately 326 acres of California State Parks and 3,250 acres of land owned and/or managed by the Coastal Conservancy, The Nature Conservancy and the Friends of the Santa Clara River. The Below Sespe and Above Piru Reaches (6 and 10), in particular, present opportunities to implement restoration strategies in protected areas where the ecological benefits of the actions can be optimized. In addition, they provide centers upon which additional property acquisition can build, eventually helping to achieve the goals of the Parkway project, providing movement corridors for wildlife and recreational opportunities for the public.

3.7 Regulatory Considerations

Implementation of the non-acquisition restoration strategies described in this report (levee removal or setback, floodplain re-contouring, non-native invasive plant removal, and active revegetation) will have to be done in compliance with all applicable federal, state, and local regulations and permit requirements. These regulations and permits require that certain measures be incorporated into the project design and implementation to minimize direct and indirect impacts on the environment, project neighbors, and nearby communities. The primary implications for restoration presented by most environmental regulations and permits include: 1) the time necessary to develop the required documents and navigate the permit process; and 2) particular measures that may have to be incorporated into the restoration design and actions and/or areas that may have to be avoided to minimize short-term impacts. For example, compliance with California Environmental Quality Act (CEQA) and National Environmental Protection Act (NEPA) will require significant interaction with the regulating agencies, development of an Initial Study and one of several environmental review documents, and a lengthy public review and approval process, all prior to restoration implementation. Acquiring a Streambed Alteration Agreement and Clean Water Act Section 401 permit will likely require that particular actions be taken or avoided during project implementation; the Streambed Alteration Agreement may specify work windows for sensitive species in the area, and the Section 401 permit may specify maximum increases in turbidity allowed during project activities.

The long-term ecological benefits provided by the restoration strategies will help mitigate any short-term adverse impacts of project implementation and facilitate regulatory compliance. It is likely, however, that required regulatory measures will affect the design and implementation of most restoration strategies and must be considered carefully when developing final restoration designs. Appendix B of this report presents: 1) the required governmental reviews and permits that will likely be triggered by particular restoration strategies; 2) a summary of the environmental regulations and permits that the restoration strategies will likely have to comply with and/or acquire; and 3) a discussion of programmatic permitting approaches, as an alternative to piece-meal permit acquisition. Together, these discussions should assist future restoration strategy planners in developing appropriate schedules and approaches to permit acquisition.

4 RESTORATION STRATEGIES & FEASIBILITY

4.1 Restoration Overview & Objectives

For the purposes of this study, acquisition and restoration strategies that are feasible and appropriate for implementation on the lower Santa Clara River must:

- be considered a practical and effective method to achieve the ecological objectives of the Parkway project (see Section 1);
- be technically appropriate given the physical and biological attributes and human uses of the river corridor (see Section 2);
- work within current and foreseeable constraints and build from opportunities for acquisition and restoration in the lower river corridor, including legacy effects (see Section 3); and
- work toward the flood control objectives of the Parkway project.

These criteria were used jointly to screen potential acquisition and restoration efforts and resulted in six restoration strategies, as discussed below.

Restoration Strategies:

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.

These strategies seek to restore physical functioning and improve ecological conditions, recognizing that watershed-wide impacts of grazing, urban development, instream mining, infrastructure, and surface and groundwater regulation preclude a complete return to presumed historical conditions (see Section 2). The objectives of the restoration strategies are as follows:

- the land acquisition strategy will provide long-term, protected and sustainable venues for restoration strategies to be implemented in a cost-effective and environmentally-maximized condition;
- the levee removal and setback and infrastructure modification strategy will improve physical functioning of the river to the extent feasi-

ble given existing flow and infrastructure conditions, to naturally create and sustain riparian habitats;

- revegetation will increase riparian habitat quantity and quality in currently degraded or newly restored areas and contribute to ecosystem functions;
- non-native species removal will help improve riparian habitat quality for native species, as well as remove limitations to some special-status species populations;
- ecosystem-based placement of water quality treatment wetlands will maintain a range of chemical parameters that support healthy native assemblages of aquatic species and meet water quality criteria; and
- aquatic habitat enhancements will increase instream habitat quantity and quality and help maximize the benefits provided by other restoration strategies.

These strategies are defined broadly to provide guidance to the Coastal Conservancy and other organizations involved in the lower Santa Clara River and serve as a means of prioritizing future funding, planning, design, and implementation efforts. These strategies are also process-based, in that they focus on conserving and/or restoring rates and magnitudes of geomorphological, hydrological, and biological processes that sustain natural habitat quality and quantity and so support biological productivity and a diverse assemblage of native species. The implementation of conservation and process-based restoration strategies should provide multiple ecosystem benefits and reduce the types and number of piecemeal restoration actions that need to be implemented. For example, land acquisition will conserve tracts of riparian-floodplain habitats and stands of existing native plant assemblages that already exist within the 500-year floodplain (Section 4.1). Levee removal and setback will increase the floodplain area and restore the process of floodplain inundation that is critical to meeting substrate and water requirements for the recruitment and survival of native riparian vegetation (Section 4.2). Non-native invasive plant removal will provide the opportunity for native vegetation to become established in place of non-natives and improve the quality of riparian habitat for various wildlife species (Section 4.3). Improvements to water quality will occur through the use of treatment wetlands to remove excess nutrients from the river, helping to discourage the recruitment and growth of arundo and restoring aquatic habitat conditions more conducive to natural assemblages of freshwater organisms (Section 4.5).

4.2 Land Acquisition

As the population of Ventura County grows, the pressure to convert agricultural and natural areas to urban and suburban land uses will increase (Fulton *et al*. 2003). When converted to urban land uses, not only are agricultural and natural areas lost permanently, but remaining adjacent habitats become increasingly degraded and fragmented. The value of preserved natural oases in a mosaic of urban land uses are limited by their connectivity to other natural landscapes, particular for those species requiring large areas for habitat and gene flow between populations. Urban development in and near the lower Santa Clara River floodway will also result in increased flood risk to nearby developments and greater dependence on large-scale levees for flood control.

Public acquisition of floodway property by conservation organizations protects these parcels of land in perpetuity. Conservation easements can also be used to protect floodway lands for a wide range of timeframes, as well as preserve agricultural land uses that are more consistent with ecological objectives for the lower river than urban development. Strategic location of acquired or easement parcels protects valuable natural resources, provides connectivity between locally- and regionally-important landscapes for terrestrial and aquatic species (such as those identified by Penrod *et al.* 2006), protects populations of sensitive species, and provides technically appropriate, long-term venues for implementing restoration actions.

4.2.1 Strategy Concept & Feasibility

The general approach is to acquire, or to a lesser extent place under long-term conservation easement, properties within and adjacent to the 500-year floodplain of the lower Santa Clara River that: 1) conserve important habitat (*e.g.,* rare, threatened, or focal species habitat); 2) allow natural fluvial processes; 3) provide flood control benefits; and 4) are geographically, hydrologically, geomorphically, and ecologically appropriate to implement restoration strategies. Several investigations conducted as part of this Feasibility Study informed development of this restoration strategy, including riparian vegetation mapping (Stillwater Sciences and URS Corporation 2007), geomorphic assessment (Stillwater Sciences 2007a), riparian vegetation dynamics analysis (Stillwater Sciences 2007b), and focal species habitat assessment (Stillwater Sciences 2007c). In addition to the Coastal Conservancy, strategic land acquisition for the purposes of conserving existing high-quality habitat areas, providing connectivity between protected areas, and protecting native species populations is also the focus of extensive planning, acquisition and management efforts by TNC and the Friends of Santa Clara River. The concepts and strategies described in TNC's planning documents for the lower Santa Clara River (TNC 2006 and 2007) were integrated into this Feasibility Report in order to maintain consistency between Coastal Conservancy and TNC acquisition efforts. It should be noted that the term "acquisition" is used to indicate both fee-title purchase and conservation easement of entire or portions of parcels.

In addition to providing the benefits described below, the Coastal Conservancy has established the goal of acquiring a *continuous* corridor (rather than scattered parcels), because of the recreational benefit of a continuous river trail system and the practical problems created by intermittent gaps in the corridor. Intermittent gaps in the Parkway corridor would compromise (although not prevent) the Conservancies' ability to restore the river by:

- limiting biological connectivity;
- limiting flood management continuity;
- threatening the Parkway with potentially conflicting land uses in the future; and
- requiring additional publicly-funded construction and management costs.

Moreover, no undeveloped property in the floodway is so compromised by past use that it would not provide substantial benefits to the overall process-based restoration strategy; all of the non-urbanized property in the Parkway area meets some of the proposed criteria for acquisition (see Table 4-1). Nevertheless, given currently available funds and currently willing sellers, the

Table 4-1. Criteria for acquiring property for restoration strategy implementation purposes in the lower Santa Clara River.

Category	Criteria
Conservation	• Property contains high-quality and/or a large-extent of aquatic or terrestrial habitat that is used by focal species.
	• Property contains rare or threatened habitat type.
	• Property would provide connectivity to, or synergistic effects with, other preservation or restoration projects.
	• Acquisition of property would protect floodplain from urban encroachment.
Fluvial Processes	• Property, and upstream and downstream parcels, are of adequate size and set in landscapes suitable to support channel changes and potential increase in channel meander width.
	• Removal of levees, floodplain recontouring, or infrastructure modification on property would provide fluvial process and ecological improvements.
Flood Management	• Acquisition of property would reduce flood risk and/or reduce maintenance costs following floods.
	• Existing infrastructure on property can be modified or removed to reduce risk of damage from natural river processes or to be more compatible with ecological processes.
Implementation	• Property is of adequate size to provide balance between ecological benefits and negotiation effort and cost.
	• Property lacks infrastructure that would require maintenance or protection or that is incompatible with natural physical and ecological processes.
	• Groundwater levels are sufficient to eliminate or minimize the need for long-term irrigation of restoration plantings.
	• Bank-edge levees on property can be passively (via flood breaches) or actively (via heavy equipment) removed or set back without increasing flood risk to upstream or downstream developed parcels.
	• Land uses adjacent to the property do not compromise the integrity or objectives of implemented restoration.

Conservancies will choose, with the assistance of this study, to pursue acquisition of those reaches and properties first that will provide the greatest benefits.

The criteria listed in Table 4-1 can be used to identify and prioritize the acquisition of parcels falling within the four categories described above. They were selected to be compatible with criteria that might be used to prioritize property acquisition for habitat preservation purposes (see Cox *et al.* [2001] for specific examples). Of course, identifying and working with willing sellers is the top priority, and necessary precursor, for any acquisition effort.

Significant thought and consideration must be given to how best to apply and measure each criterion, and how much weight each holds in light of achieving restoration objectives. These criteria were used develop reach-specific recommendations for restoration strategy implementation (Section 4.8).

4.2.2 Anticipated Benefits

Acquiring land in the riparian corridor of the lower Santa Clara River for conservation and restoration purposes provides myriad ecological benefits in perpetuity. In general, protected parcels act as buffers between river processes and wildlife habitat and incompatible adjacent land uses. This allows the river to function more naturally (*e.g.*, inundate the floodplain and scour and deposit sediments) and wildlife to colonize and utilize patches of riparian habitat without risking flood damage to nearby land uses or compromising the ecological benefits of conservation and restoration actions. Specific to the other restoration strategies described in this report, acquired lands provide technically appropriate and protected venues for implementing restoration actions.

Obtaining conservation easements for agricultural areas within the 500-year floodplain can also provide benefits to the lower river. Ventura County has some of the most productive farmland in the world, but it is threatened by the increasing demand for housing and urban development (Ventura County Agricultural Land Trust and Conservancy 1996). Keeping lands within the 500-year floodplain in agricultural production through conservation easements not only preserves a valuable economic resource for the County, but also is far more compatible with the ecological objectives of the Parkway project than more developed land uses. Frequently, agricultural conservation easements have conditions limiting the extent of maintenance done following flood damage. In this way, less productive flood-prone lands can be naturally reclaimed by the riparian corridor, while allowing agricultural practices to continue.

4.2.3 Uncertainties

Several issues affect the feasibility of acquiring land within the 500-year floodplain of the lower Santa Clara River or the effectiveness of a purchased property in achieving desired ecological benefits. As stated previously, there must be a willing seller for land acquisition to be feasible. Property values, crop productivity, land maintenance costs, and prevailing attitudes towards restoration all contribute to a landowner's willingness to sell and cannot be easily controlled.

Given the high cost of land in coastal Ventura County, significant funding is necessary to purchase property for conservation and restoration. The fiscal feasibility of acquiring property in the Parkway will depend largely on available funding mechanisms and the cost of land at the time.

Land use conversions are dictated by county zoning ordinances, which can change over time. While current Ventura County zoning and growth ordinances provide clear opportunities for riparian conservation (see Section 3.2), it is difficult to anticipate what future administrations will write into legislation or how residents will vote as urban growth pressure increases after the current growth boundaries expire in 2013–2018.

4.3 Levee Removal & Setback

As discussed in Section 2, channel confinement by privately and publicly maintained levees and channel alteration by aggregate mining are two of the most severe impacts limiting geomorphic and hydrologic functioning of the lower Santa Clara River, especially below the confluence of Santa Paula Creek (Simons, Li & Associates 1983, Stillwater Sciences 2007a). In addition to altering the river's morphology, the levees have reduced floodplain habitat use opportunities for a variety of species within the lower watershed. Bozkurt *et al.* (2000) outlined levee impacts on ecological systems whereby a decrease in floodplain inundation and channel migration generally leads to reductions in habitat formation and maintenance, and ultimately to loss of biodiversity with a potential decline of many species populations. Although the levee system is an integral part of the flood control efforts along the river, its integrity is regularly threatened by winter high flow events, which, in conjunction with alterations to the channel morphology, has led to significant levee failures requiring costly repairs (Simons, Li & Associates 1983, URS 2005). Levee damage occurred both in the 1969 and 2005 flood events. As a result, there is a strong need to improve the effectiveness of the current flood control system to reduce maintenance costs, in addition to restoring geomorphic and ecological processes that have been adversely affected by the channel-constraining levees. This need is underscored by the recently published Federal Emergency Management Agency (FEMA) floodplain maps of the Santa Clara River, which concluded that significant lengths of the existing levee system, particularly near Fillmore and Oxnard, do not meet FEMA certification standards (Sullivan 2008).

4.3.1 Strategy Concept & Feasibility

This restoration strategy involves some combination of the following actions either singularly or in combination: the active or passive removal of existing channel-confining levees, construction of setback levees away from the river channel, re-contouring of the restored floodplain area where there have been impacts by aggregate mining and other land uses, and removal or modification of infrastructure.

On properties acquired for conservation uses, passive or active levee removal may be feasible. Passive removal would be appropriate primarily for privately maintained agricultural levees that are not highly engineered, as are common along the lower Santa Clara River, particularly in the upper reaches. Passive removal implies allowing failure or breaching to occur naturally during large flood events but without subsequent repair. Active removal requires heavy equipment to dismantle the levee. In locations where levees are allowed to fail or breach, consideration should be given to whether restoration would benefit from the subsequent removal of the remaining levee structure.

In areas that require continued flood protection of development or agriculture on the floodplain, bank-edge levees could be replaced by setback levees constructed to provide the same level or better flood protection while still providing lateral connection between the river and its floodplain, thus encouraging natural fluvial processes and habitat development. A setback levee is placed landward some distance away from the active channel margin, which allows the restored floodplain area between the setback levee and the river's edge to be occasionally inundated during seasonal high flow events (Mount 1995, USACE 2002) (Figure 4-1). Levee setback strategies should be focused on the Hwy 101, Below Freeman, and Above Freeman Reaches (1, 2, and 3), where existing levees severely constrain the floodplain

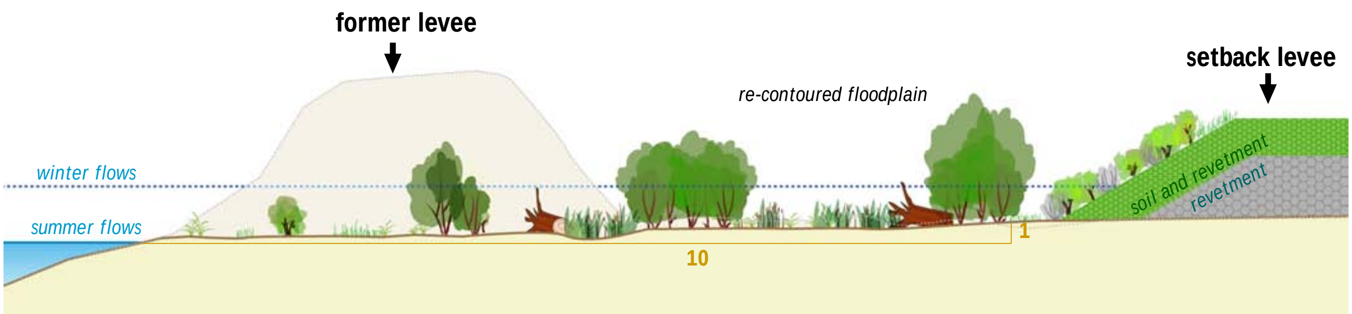

Figure 4-1. Diagram of setback levee strategy.

width and opportunities for setback exist. Some opportunities also exist in the upper reaches. The recent FEMA floodplain mapping of the Santa Clara River presents a strategic opportunity for setting back levees: when levees are reconstructed to meet FEMA certification standards, they can be simultaneously setback. Because they increase the floodway width and so inherently increase the river's flood conveyance capacity, setback levees need not be as high as bank-edge levees and are much less disruptive to high-flow processes.

Following removal of existing levees or construction of setback levees, some areas may require re-grading of the floodplain surface that is now part of the active floodway. This procedure, also called floodplain re-contouring, may involve filling in any abandoned gravel-mining pits, or other man-made depressions that could present stranding issues for salmonids and increased predation by avian or fish species (CDWR 2006). Lowering or sloping of the floodplain towards the river channel may also be required to increase the potential for seasonal inundation, especially along incised reaches where the elevation of the floodplain in relation to the channel bed has dramatically changed from pre-development conditions (*i.e.*, especially in reaches 1-4). Similar to other restoration projects involving floodplain re-contouring, such as on the Merced River (CDWR 2006), the restored riparian corridor would be re-vegetated with native plant species to provide habitat for wildlife. Floodplain re-contouring may also be necessary in the few areas where levee removal or setback would connect former mining or industrial areas with the floodplain.

Another activity associated with levee removal and/or setback is the modification or removal of infrastructure in the floodway. As the floodplain is widened and the channel is allowed to migrate, existing infrastructure may have an increased risk of damage by bank erosion or flood flows. In most cases, infrastructure is modest, consisting primarily of fencing, concrete debris, power lines, and pumping facilities. In other cases, such as McGrath State Beach, it would be prudent to relocate camping and day use facilities farther away from the river mouth to allow the river to move away from the Ventura Water Reclamation Facility and reduce maintenance costs following high flows. In more extreme cases, modifying bridges or relocating wastewater treatment facilities would be necessary to improve fluvial processes and reduce flood risk to these structures.

4.3.2 Anticipated Benefits

Implementation of this restoration strategy would potentially provide numerous benefits to riparian habitat conditions and geomorphic processes that have been substantially altered due to the presence of the existing channel-confining levees. These myriad benefits provide justification for process-based restoration strategies. The primary ecological benefit of this restoration strategy is the re-establishment of a seasonally inundated floodplain. The river's re-connection to its floodplain will allow for an exchange of water, sediment, and nutrients between the river and its floodplain, and an increase in riparian habitat patch size and quality. Constructing setback levees would, where necessary, maintain flood protection for the surrounding developments outside of the Parkway area. An enlarged river corridor would enhance landscape linkages, providing movement corridors for wildlife between protected lands. Additionally, a wider floodway should increase the residence time of flood waters on the floodplain and so increase groundwater recharge (Poole *et al.* 2002, Kazama *et al.* 2007). It should be noted that while levee setback and removal may need to be implemented in a parcel-by-parcel fashion due to land acquisition and funding constraints, the larger benefits of this restoration strategy, particularly flood control and landscape linkages, as well as cost efficiencies, will not be fully realized until larger extents of levees are setback or removed.

Re-initiation of fluvial processes, such as bank erosion, bar growth, channel migration and width increases to the active channel bed, would be an expected outcome following implementation of this restoration strategy. During flood events in a braided-meandering river similar to the Santa Clara River, bank erosion naturally occurs at the outer banks of a river bend where velocities are greatest, or near perturbations on the channel bed, such as mid-channel bars, that can topographically steer the flow against the adjacent bed or banks causing higher shear stresses to scour the channel boundaries (Leopold *et al.* 1964). Deposition of sediment occurs in slower portions of the channel and contributes to the formation of point bars, mid-channel bars, and natural sedimentation processes. The re-initiation of this process would not only restore a dynamic physical characteristic of the Santa Clara River but also would benefit in-channel and riparian habitat diversity (see Section 4.7) (Bozkurt *et al.* 2000).

The long-term trend of channel incision within the downstream-most reaches could potentially slow or cease following implementation of this restoration strategy, because the flood waters would be allowed to spread out upon the reconnected floodplain, thus increasing the river's flood capacity and effective flood width. Also, because floodplain discharge has low velocities due to frictional resistance from vegetation and other roughness features on the floodplain, sufficiently broad floodways can attenuate flood flows, thus diffusing the potential for deep, high velocity flows to scour the channel bed. An additional benefit from the seasonal inundation of the restored floodplain is recharge of groundwater into the basin's aquifers, which are a major source of fresh water for the many land-use activities in the valley, especially agriculture. The amount of groundwater recharge by inundated floodplains depends on several factors, the most critical of which are the residence time of the water on the floodplain, the permeability of the floodplain substrates, and depth to the water table. For these reasons, arid-region rivers dominated by sporadic high flow events such as the lower Santa Clara River, have greater potential for groundwater recharge because their floodplains are often composed of coarse sediments with high permeability, and the groundwater table is usually well below the channel (G. Wallace, Pacific Groundwater Group, pers. comm., 2008). Short residence time, low porosity, and a shallow groundwater table inhibit groundwater recharge. For example, the Oxnard Plain groundwater basin has several clay strata that inhibit effective infiltration of floodwater. However, the majority of the groundwater basins underlying the lower Santa Clara River (see Section 2.3.8) occur in recent and relatively deep alluvial deposits that are very porous and allow easy infiltration of floodwater.

A final benefit from this action is improved flood protection for the various developments located throughout the lower Santa Clara River valley. Hydraulic modeling of levee setback scenarios in the lowest reaches of the river suggests that water surface elevations and velocities for high-magnitude flow events could be greatly reduced. A simple simulation showed that setting back south bank levees between Victoria Ave Bridge and Harbor Blvd Bridge decreased water surface elevation by approximately 6 to 7 ft and decreased flow velocity by approximately 3 to 7 ft/sec for the 10- , 50- and 100-year flood events when compared to existing conditions (Stillwater Sciences 2007f). Flood protection can be further enhanced by new setback levees by building them according to the latest engineering and FEMA certification standards. Setback and properly constructed levees should also reduce levee maintenance and other public works and private property costs associated with flood damage.

4.3.3 Uncertainties

One of the uncertainties involved with this restoration strategy is the local change in channel hydraulics and sedimentation resulting from a parcel-based strategy of levee removal or setback. Depending on land uses surrounding the conservation parcel, it may be necessary to model flood flows (and resultant shear stresses as a guide to erosion and deposition trends) to ascertain any potentially negative upstream or downstream effects. Maximizing the levee setback distance from the river would be expected to offer the greatest number of benefits to re-establishing dynamic channel processes, attenuating flood flows, and improving habitat conditions (Bozkurt *et al.* 2000) without generating potentially negative effects A regional-level evaluation using hydraulic models should be conducted for the Parkway area to assess the overall potential flood management benefit of this restoration strategy.

Related to the hydraulic uncertainties discussed above is the effort to acquire required environmental compliance documents and permits. Restoration actions that have the potential to impact the river channel, banks, floodplain, and wetland areas within the floodplain are subject to considerable scrutiny under a number of environmental statutes (see Section 3.7 for more details). Restoration planners will have to work within regulatory constraints and secure all necessary permits and approvals prior to implementation which could increase the cost and timeframe of restoration significantly. Fortunately, flood conveyance improvements and ecological benefits of this restoration strategy should facilitate the acquisition of necessary environmental documentation and permits.

Another significant uncertainty related to levee setback is the cost of implementation. Additional Parkway acquisition would be necessary to provide a sufficient amount of land for the successful restoration of a functional, seasonally inundated floodplain and riparian corridor. Costs associated with the removal of existing levees, construction of setback levees, and floodplain re-contouring can be significant. For example, a cost estimate for a proposed setback levee project on the Sacramento River was at $2,000 per linear foot ($10.5 million per mile) (M. Dietl, USACOE, pers. comm., 2007). This estimate included all associated project costs, including engineering, permitting, removal of the existing levee section, and construction of a setback levee. Costs associated with setting back agriculture levees on the Santa Clara River are likely to be far lower, and passive removal of agricultural levees would require almost no cost. At numerous locations on the Santa Clara River, natural terrace formations or a perceptible lateral floodplain gradient may mitigate against the need to replace a bank-edge agricultural levee.

While an increasing number of levee setback projects in California can provide some guidance and insight, the specific outcomes of levee removal and setback along the lower Santa Clara River are still uncertain. To date, there have been proposed setback levee projects for several California streams, including the American River (Jones & Stokes 2005), Deer Creek (DCWC 2002, Jones & Stokes 2005), Berryessa and Coyote creeks (urban watershed) in Santa Clara County (SCVWD 2005), Lower Calleguas Creek (Coastal Conservancy 2007), and Ventura River (Coastal Conservancy 2004). However, because none of these projects occur in analogous settings, and long-term monitoring has yet to be carried out, detailed understanding of how the lower Santa Clara River might change as a result of setback levee and floodplain recontouring is limited.

4.4 Passive & Active Revegetation

The significant loss of riparian vegetation in the lower Santa Clara River equates with a similarly significant loss in habitat quality, quantity and ecosystem functioning. Conservation is particularly important for regionally or locally rare vegetation types, such as coastal sage scrub and desert riparian scrub, and species, such as Nevin's barberry (*Berberis nevinii)* and Slender-horned spineflower (*Dodecahema leptoceras)*. Used in conjunction with other proposed restoration strategies, active and passive revegetation of native riparian plant species can increase the extent and improve the quality of riparian habitat and contribute to ecosystem functioning.

4.4.1 Strategy Concept & Feasibility

Other process-based restoration strategies described in this chapter are integral to a successful revegetation strategy. In a survey of revegetation projects in semi-arid river systems, Briggs (1992 as cited in Briggs 1996) found that successful revegetation projects nearly always incorporated the implementation of process-based restoration strategies in addition to, or in lieu of, active revegetation (*e.g.*, replanting native species using horticultural techniques). Where improvements to riparian vegetation composition and extent are desired but not necessarily expected by implementing other process-based restoration strategies (see discussion under Section 4.1), active revegetation should be considered.

In areas where floodplain inundation occurs across a wide area and/or groundwater levels are high, revegetation should rely primarily on natural recruitment, although lower cost active revegtation actions (*e.g.*, planting cuttings without irrigation in areas of high groundwater) might also be appropriate in some of these areas. Vegetation mapping of the lower Santa Clara River in 2005 and 2006 documented a large number of willow and cottonwood seedlings in the river corridor (Stillwater Sciences and URS Corporation 2007). Clearly, natural seed sources are adequate for natural recruitment in many reaches, although physical conditions may not support the continued growth and survival of those seedlings (as evidenced by the Below and Above Piru Reaches [9 and 10] that are largely devoid of vegetation). Natural recruitment generally should not be presumed where flood flows do not inundate at least once every year or two, or where groundwater levels are documented or suspected of being inadequate to sustain plants during the growing season. Levee removal and setback should increase the area of the lower Santa Clara River that is appropriate for passive revegetation strategies by increasing the available floodplain area and facilitating inundation of floodplains by slow-moving floodwaters during high flow events (see Section 4.2).

Correlations between physical variables and vegetation types can be used to predict what species are likely to naturally recruit in an area based on physical information from a site (Stillwater Sciences 2007b). Revegetation in the most active or dynamic portions of the floodway (*i.e.*, those portions of the river that are scoured by floods every one to two years), should generally not be a high priority for restoration actions. Natural recruitment of vegetation is likely to occur in these areas without any intervention, although removal of newly established vegetation through scour during subsequent floods is also likely to occur. The most appropriate restoration action in such active areas would most likely be removal of arundo propagules following a major flood (both to control the spread of arundo density and to facilitate establishment of seedlings of native riparian species by removing a potentially dominant competitor).

Where natural recruitment or seedling survival is not expected to achieve revegetation goals, perhaps because of a lack of upslope or upstream seed supply, less reliable surface inundation, or shallow groundwater levels, active revegetation should be implemented. Active revegetation consists of planting, and potentially irrigating, native species seedlings, cuttings and/or seeds.

Priorities for active revegetation projects should use the following guidelines:

- For willow, cottonwood, and mixed riparian forest and scrub habitat types, focus on areas outside the active floodway (*i.e.*, where significant and frequent scouring would not be expected) and in gaining reaches of the river (Reaches 1, 2, 3, 5, 8, and 11; see Table 1.1), where active revegetation is most likely to be successful (Briggs 1996).
- For desert riparian scrub habitats (*e.g.*, *Artemisia tridentata* and *Lepidospartum squamatum* alliances), focus on areas outside the active floodway and in drier, losing reaches (Reaches 7, 9, and 10 and lower Sespe Creek).
- When restoring acquired parcels that were former agricultural areas or that are disturbed (see Figure 2.4-5), use active revegetation to accelerate the recruitment of native species and the establishment of a dense canopy of vegetation.
- Following large-scale arundo removal projects (except if in the active floodway), use active revegetation to replace lost nesting habitat. Least Bell's vireo and southwestern willow flycatcher, both endangered bird species found in the lower Santa Clara River, nest in arundo now that it has largely replaced the willow scrub that they typically nest in (Labinger and Greaves 2001). Large-scale arundo removal should be followed by revegetation of native scrub species in order to replace the structural habitat needed for these birds during breeding season (Labinger and Greaves 2001). Planting cuttings of willow and cottonwood, which are relatively inexpensive, is more appropriate in areas that receive intermediate levels of scour from flood flows to replace the loss of structure following arundo removal and to help compete with arundo regeneration.

Planting just prior to the rainy season can reduce the need for irrigation (although it may increase the chances for scour by winter floods), but given the semi-arid climate and lowered groundwater table in some portions of the lower Santa Clara River corridor, irrigation should be anticipated for most upland surfaces that are not inundated frequently or do not have groundwater conditions that support the germination or early growth of restoration plantings. In these instances, drip irrigation should be considered as it helps conserve water and limit the establishment of weedy species that can compete with planted seedlings, cuttings, and seeds (Stillwater Sciences 2007e).

Determining the suite of native species to plant and the conditions under which planting is most likely to be successful are critical parts of revegetation planning (Briggs 1996). Regionally or locally rare vegetation types, such as desert riparian scrub and coastal sage scrub, and those that provide habitat for multiple species, such as mixed riparian and mixed willow scrub and forest, should be priorities for revegetation projects on the lower Santa Clara River (Stillwater Sciences 2007c, Stillwater Sciences and URS Corporation 2007). Finding locations suitable for restoration of these plant communities generally depends on the ecological requirements of the dominant species. Appendix C lists a selection of native dominant tree and shrub species that are currently found in the lower Santa Clara River and that are appropriate for active revegetation projects. Appendix C also identifies the ecological requirements of the species to provide guidance for revegetation planning.

4.4.2 Anticipated Benefits

Acquiring land, setting back levees, and allowing passive revegetation or actively replanting former agricultural areas or disturbed areas will increase the extent and density of the riparian vegetation, improve habitat conditions for native species, and increase the buffer between the river and adjacent land uses.

Intact corridors of riparian vegetation have been demonstrated to provide the following benefits to native species:

- breeding, foraging, and refuge habitat for numerous native terrestrial species, particularly neotropical migrant birds (Gaines 1974, Laymon *et al.* 1997, RHJV 2004);
- corridors through which wildlife can migrate over long distances (Penrod *et al.* 2006);
- noise and odor reduction from nearby land uses that might discourage native species from inhabiting the riparian corridor (Corbett and Lynch 1985);
- habitat heterogeneity, habitat structure and cover in the form of large woody debris, and lower late-summer water temperatures (McDade *et al.* 1990, Opperman and Merenlender 2004);
- shade and cover in near-bank aquatic habitats, which is important for some species of fish (Beschta 1991, Johnson and Ryba 1992); and

- a natural food source to the river in the form of leaf litter and terrestrial insects (Vannotte *et al.* 1980).

In addition, riparian buffers of adequate width can provide the following ecosystem services:

- trapping and removing up to 75% of sediment from runoff (Trimble and Sartz 1957, Doyle *et al.* 1977, Gough 1988, NRCS 2000) (see Figure 4-2);
- trapping and removing up to 50% of nutrients and pesticides and 60% of pathogens from runoff (Petersen *et al.* 1992, NRCS 2000) (see Figure 4-2); and
- stabilizing streambanks and reducing erosion (NRCS 2000).

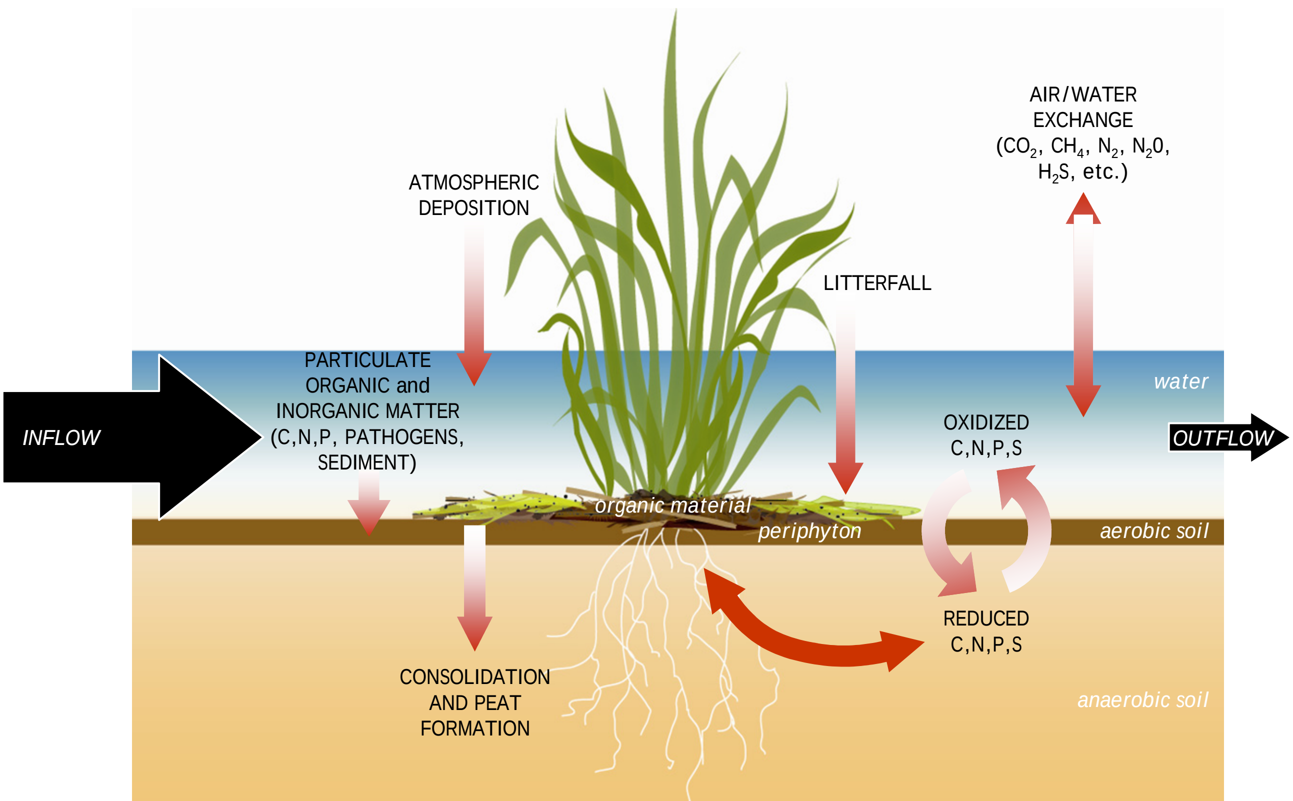

Figure 4-2. Simplified nutrient and sediment cycling diagram illustrating the various processes that can filter runoff.

4.4.3 Uncertainties

There are two primary uncertainties related to the successful implementation of both passive and active revegetation projects on the lower Santa Clara River: groundwater levels and non-native invasive species. Available groundwater data from the 500-year floodplain of the lower river is so variable, in terms of both period of record and recorded water-table depths, that it is difficult to identify any spatial or seasonal patterns in groundwater levels, particularly at a level of detail suitable for restoration planning. This lack of understanding makes it difficult to predict whether plant roots will be able to reach groundwater within a year or two, a key to long-term successful revegetation. The best clue of where groundwater levels are suitable for revegetation comes from mapping of gaining and losing reaches of the river (*i.e.*, reaches where groundwater moves toward and contributes to surface flows versus reaches where surface flow infiltrates the channel bed and contributes to groundwater), but this is largely based on the quantity and quality of existing vegetation rather than groundwater monitoring data (USGS 1999, SCREMP 2005). SCREMP (2005) mapping indicates that Reaches 1, 2, 3, 5, 8, and 11 are primarily gaining reaches, suggesting that approximately 21 mi, or 60%, of the lower river is potentially suitable to sustain restoration of more water-loving riparian vegetation types (*e.g.*, cottonwood and willow forest and scrub, floodplain wetlands) over the long term. The rest of the river corridor may be more suitable for vegetation types that can tolerate drier conditions (*e.g.*, desert riparian scrub). In areas where large active revegetation efforts are being considered, installing and monitoring shallow groundwater wells can guide restoration planning and improve the success rate of replanting efforts.

The continued introduction, spread, and growth of non-native invasive plant species, particularly arundo, is another uncertainty to the long-term success of revegetation in the lower Santa Clara River. In passive revegetation areas, arundo propagules (vegetative fragments) and tamarisk seedlings may be just as likely to recruit as native willows and cottonwoods (Stillwater Sciences and URS Corporation 2007). While tamarisk survival past the seedling stage appears to be limited in most parts of the lower river corridor, arundo propagules often grow faster and out-compete seedlings of native trees and shrubs, particularly in nutrient-rich areas (Coffman 2007, Stillwater Sciences and URS Corporation 2007). The risk of arundo and tamarisk invasion in passively revegetated areas will continue to be an issue for revegetation planners until sufficient amounts of arundo and tamarisk are removed, and upslope and upstream propagule sources become diminished. In actively revegetated areas, non-native plant propagules could be introduced from upslope or from upstream sources during occasional floods. The use of irrigation could encourage the recruitment and growth of weed species, particularly in former agricultural areas. While drip irrigation should minimize this problem, in more fertile areas, unless active control measures are implemented, agricultural weeds could grow faster and out-compete planted seeds, seedlings, cuttings, and container stock.

4.5 Non-native Invasive Species Removal

Non-native invasive plant and animal species can contribute to the degradation of native ecosystems by preying upon or out-competing native species in environments where they have few, if any, natural predators. Human disturbances to the ecosystem typically provide the opportunities for non-native invasive species to establish and invade native habitats. In the lower Santa Clara River, increased nutrient supply from adjacent land uses, changes in the natural fire regime and development adjacent to the riparian corridor have encouraged the spread of several non-native invasive plant and animal species that are threatening native species populations and habitats. This restoration strategy primarily addresses two non-native invasive species that are considered to have the greatest impact in the lower Santa Clara River—arundo and tamarisk—although other non-native plants, brown-headed cowbird (*Molothrus ater*), and African clawed frog (*Xenopus laevis*) are also discussed. These species are discussed in more detail in Appendix B. By creating larger buffers between riparian habitat and adjacent development and enhancing natural riverine processes and habitat development, it is expected that land acquisition and the implementation of process-based restoration strategies by the Parkway project will partly remedy the conditions that currently encourage these non-native species. Direct removal of some of these species is expected to be necessary however, given their level of establishment in the lower Santa Clara River, and this is the focus of the recommended restoration strategy.

4.5.1 Strategy Concept & Feasibility

Arundo and Tamarisk

Their wide distribution in the Santa Clara River watershed, rate of spread, and impacts to the ecology of riparian areas have made arundo and tamarisk the focus of a large-scale eradication effort in the upper and lower watersheds (VCRCD 2006b, N. Cabanting, Wildscape Restoration, *pers. comm.*, 2007). A primary focus of this restoration strategy is to support the Ventura County Resource Conservation District in their large-scale eradication efforts, as they have already identified many priority areas for removal and appropriate removal methods (see Section 1.5). However, recent research by Coffman (2007) on the ecology and impact of arundo on the lower Santa Clara River specifically provides guidelines for prioritizing arundo removal projects that should be incorporated to the extent feasible in arundo and tamarisk removal projects supported by the Parkway project.

- Removal projects should generally be conducted from upstream to downstream and in tributaries. These areas have lower risk of re-infestation and reduce the supply of propagules to downstream areas.
- Upland or transition zones between riparian areas and upland areas should be priority areas for removal projects to reduce the supply of propagules to lower areas and to reduce the fire risk to the riparian corridor and adjacent vegetation types.

- Riparian areas that are adjacent to fire-prone shrub lands should be priority areas for removal projects to reduce the risk of arundo infestations serving as a corridor for transmission of fires from adjacent vegetation types into or through the riparian habitats.
- Watersheds with low nutrients should be priority areas for removal projects, as these areas would be less likely to favor the reestablishment of arundo over native species.
- Removal projects should be conducted in the summer following flood event when biomass has already been washed downstream and it is easier to access, cut and treat the plants. This would provide a cost-effective means of controlling arundo and is likely to facilitate natural recolonization by native species.
- Removal projects should be conducted after fires to take advantage of the loss of biomass and to suppress rapid arundo regrowth following fires (see Section 2.3.3). Without such action, arundo is likely to re-establish rapidly and out-compete native riparian species which are typically slower to recover after fire (Coffman 2007).

While arundo and tamarisk removal is considered a priority action to enhance endangered avian habitat conditions in the lower Santa Clara River, it should be done outside the breeding season (mid-March to late September) of species, such as least Bell's vireo and southwest willow flycatcher, that may use arundo and tamarisk as nesting habitat (Labinger and Greaves 2001). In addition, where large tracts of arundo or tamarisk are to be removed, projects should be immediately followed by revegetation with native riparian species to quickly replace structural habitat for scrub-nesting species of bird (Labinger and Greaves 2001). Administratively, the Parkway project should encourage and/or fund longer-term contracts for arundo and tamarisk removal projects. Successful removal and eradication projects require pre- and post-project monitoring and typically involve multiple treatments (DiTomoso and Healy 2007). One- to three-year contracts are not generally long enough to allow for pre-project monitoring, treatment, post-project monitoring, and subsequent maintenance or retreatment, given that removal projects in riparian areas with sensitive species can only be conducted during particular seasons.

Other Non-native Invasive Plant Species

A wide variety of non-native herbaceous species occur in the lower Santa Clara River (Stillwater Sciences and URS Corporation 2007). These range from low-impact agricultural or horticultural weeds to high-impact yellow starthistle, sweet fennel, and perennial pepperweed (see Section 2.4.2). Many of these species do not present significant threats to native riparian habitats, where they are shaded out by native shrubs and trees. However, in open or disturbed habitats these species can quickly dominate the vegetation and displace native species that provide foraging or structural habitat for native species (DiTomoso and Healy 2007). Removal projects focused on non-native herbaceous species should be prioritized in sensitive open to shrub-dominated habitats, particularly if those habitats support threatened, endangered, or sensitive plant or animal species. For example, non-native herbaceous plant removal projects could be implemented, using appropriate techniques, in open sandy areas that are used by the San Diego horned lizard. Care would need to be taken that removal methods and project timing do not impact non-target species.

Non-native invasive plant removal projects should also be prioritized for higher-impact species that currently have limited distributions. For example, only small patches of perennial pepperweed currently occur in the tidal marsh habitat at the mouth of the lower Santa Clara River. This member of the mustard family is an aggressive invader that forms dense monospecific stands and changes soil conditions to inhibit the growth of native plant species (DiTomoso and Healy 2007). Eradication of this species while its distribution is still small is much more likely to be successful and will require less effort. This same strategy would also be appropriate for pampas grass, cape-ivy, Spanish broom, and tree tobacco, which all currently have fairly limited distributions within the 500-year floodplain of the lower Santa Clara River (Stillwater Sciences and URS Corporation 2007).

African Clawed Frog

Originally discovered in the upper watershed in 1974 and in the estuary in 1995, African clawed frogs are now present throughout the Santa Clara River and its small tributaries and barrancas (Lafferty and Page 1997; Lannoo 2005; B. Orr, Stillwater Sciences, *pers. obs.*, 2005; S. Sweet, UCSB, *pers. comm.*, 2006). Most efforts to eradicate clawed frogs in California have not been successful, although a number of control methods exist, including poisoning, draining ponds, seining, gill netting, gigging, and electrofishing (Lannoo 2005). Little has been published comparing control effort methodologies, which may be to due difficulties in comparing control efforts in different geographic locations. The single successful eradication effort was located on the University of California Davis campus, where the colonized habitat was a discrete, limited body of water where frogs were restricted to an area they could be poisoned effectively (Lannoo 2005). African clawed frogs left the water during unsuccessful attempts to use Rotenone poison at Vasquez Rock, the site of one of the first populations detected in the upper Santa Clara River (Lannoo 2005). Additional efforts to develop effective protocols for poisoning clawed frogs in the Santa Clara River were unsuccessful (Lannoo 2005).

Acquiring and enhancing riparian habitat in the lower Santa Clara River and implementing process-based restoration actions should assist in reducing African clawed frog populations. Increasing the extent of protected riparian habitat will increase the number of native predators of African clawed frogs, including two-striped garter snakes, great blue herons, green herons, black-crowned night herons, common ravens, and western gulls (Stebbins 2003, Lannoo 2005). Bullfrogs, bass, and sunfish, all non-native species in Santa Clara River, are also predators of African clawed frogs (Stebbins 2003, Lannoo 2005). Improvements in water quality, temperature, and aquatic habitat diversity resulting from process-based restoration actions (see Section 4.5), should reduce the extent of suitable habitat for African clawed frogs, which prefer warm, slow-moving water, although the estuary is always likely to provide suitable habitat, as this species is salt tolerant (Lafferty and Page 1997, Lannoo 2005). Active eradication projects should be implemented from upstream to downstream, as this is how African clawed frog has been demonstrated to disperse in the lower Santa Clara River (Lanoo 2005), and should focus on isolated areas to increase the chances of success.

Brown-headed Cowbird

Cowbird parasitism in the lower Santa Clara River was more common in areas where no cowbird trapping was being conducted (Labinger and Greaves 2001). Cowbird removal is believed to be one of the factors responsible for increases in several southern California vireo populations (USFWS 1998). An annual cowbird control program on the lower Santa Clara River implemented by the California Department of Fish and Game, which includes the trapping and killing of adults and removal of eggs from host nests, appears to be increasing least Bell's vireo productivity (Labinger and Greaves 2001).

Parkway project efforts to acquire, protect, and restore riparian habitat in the lower Santa Clara River should assist in decreasing brood parasitism by brown-head cowbirds by increasing the extent of continuous riparian habitat (*i.e.*, increasing the distance between cowbird foraging and breeding areas). The Parkway project should also support and/or fund cowbird control programs, such as those implemented by CDFG in the lower watershed and by California Department of Transportation (Caltrans) in the upper watershed, to protect populations of endangered bird species.

4.5.2 Anticipated Benefits

Habitat conservation and enhancement, process-based restoration, and removal of non-native invasive species will provide multiple, synergistic benefits. Property acquisition and enhancement of existing habitats, and removal of non-native species, particularly arundo, will conserve and restore continuous tracts of riparian habitat in the lower Santa Clara River. This, in turn, should decrease the rate of brood parasitism by brown-headed cowbird and improve native bird productivity, particularly endangered least Bell's vireo.

Implementation of process-based restoration projects, such as levee removal and setback, will enhance riverine processes such as floodplain inundation, channel meandering, and sediment transport. These processes will create and sustain aquatic habitats that should discourage African clawed frog, which prefer warmer, lentic or low velocity lotic habitats.

Direct removal of arundo will decrease the risk of fire in the riparian corridor and to adjacent habitat types. Direct removal of African clawed frog will protect populations of native prey species, such as tadpoles and juveniles of multiple amphibians, arroyo chub, unarmored three-spined stickleback, and tidewater goby. Direct removal of brown-headed cowbird adults and eggs will improve the productivity of host species, including least Bell's vireo.

4.5.3 Uncertainties

There are several uncertainties related to the removal and eradication of non-native invasive species. The primary uncertainty related to all non-native species is whether the timing and extent of control efforts are sufficient to overcome the rate of expansion of existing infestations or introduction of new non-native species. Control projects require several years to acquire permits, implement, monitor, and re-treat if necessary and are typically very expensive. Budget or schedule delays allow time for infestations to grow, becoming increasingly more expensive to control. The VCRCD's coordinated permits for multiple arundo and a tamarisk control project are good examples of ways to decrease the time to implementation. Treating infestations while the species is still fairly limited in distribution is another way to decrease the effort and cost associated with control projects.

The lack of success in eradicating African clawed frog from the lower Santa Clara River is an example of when the extent of the project may not be adequate to achieve successful control. When one area is treated, the species simply moves to a nearby area (Lanoo 2005). However, given the negative impacts of potentially poisoning the entire lower Santa Clara River to eradicate African clawed frog, the impacts of the non-native species must clearly be carefully weighed against the impacts of the control effort. This is also true for arundo control projects; while fewer large projects may be more effective and efficient than a large number of smaller projects, removal of large tracts of arundo in a single season results in a lack of structural habitat needed for nesting bird species during the subsequent breeding season (Labinger and Greaves 2001). Minimizing or mitigating for impacts to non-target species is critical to implementing large-scale control projects that are successful in both removing the non-native species and benefiting native species.

Sources and treatment of excess nutrients that encourage the invasion of arundo are just one of the uncertainties related to its successful control. If excess nutrient sources go untreated, arundo growth and colonization will continue to be encouraged over that of native species (Coffman 2007). Whether or not native species have the competitive abilities to colonize quickly after arundo control project is another uncertainty. If site conditions (*e.g.*, low groundwater table or excess nutrients) limit the recruitment and growth of native species, they may not be able to provide the structural habitat needed for breeding birds or suppress subsequent introductions or regrowth of arundo.

The lack of understanding of what is currently limiting tamarisk in the lower river corridor is another uncertainty related to successful control. Cohorts of newly recruited tamarisk seedlings were observed in both summer 2005 and 2006, suggesting a strong recruitment potential downstream of the few mature stands of tamarisk currently established in the County Line Reach (11) (Stillwater Sciences and URS Corporation 2007). Monitoring is necessary to determine how many of these seedlings survive to maturity and identify what may or may not be limiting their survival. If groundwater levels or channel scour patterns are currently limiting the survival of tamarisk, and these physical variables change as a result of development or restoration in the watershed, tamarisk could become a much larger problem for the river ecosystem and a challenge to control efforts.

4.6 Treatment Wetlands for Water Quality Improvement

As discussed in Section 3.4, point and nonpoint source pollution in the lower Santa Clara River watershed has resulted in a number of water quality limited segments of the river (Figure 3-3). The following strategy describes the use of water quality treatment wetlands in the 500-year floodplain of the lower Santa Clara River to help maintain a range of instream and floodplain chemical parameters that meet water quality criteria and support healthy native assemblages of aquatic and riparian biota.

4.6.1 Strategy Concept & Feasibility

The overall strategy for improving water quality in the lower Santa Clara River is two-fold. First, the water quality strategy will utilize the combined effects of land acquisition and the process-based restoration strategies of levee setback or removal and active and passive revegetation of the floodplain (see Table 4-3) to increase the potential for attenuation and treatment of a wide range of nonpoint source pollutants. However, while the re-establishment of natural wetlands and riparian vegetation in the floodplain is expected to help increase instream and estuary water quality through their general functioning as environmental biogeochemical transformers, river segments that are currently 303(d)-listed for regular exceedances of contaminants such as ammonia, coliform, TDS, sulfate, and trace organics are expected to require more targeted strategies to remove constituents of concern.

Therefore, a second water-quality improvement strategy is recommended, one that actively complements the ongoing TMDL process (see Section 3.4) by creating water quality treatment wetlands, strategically placed at the confluence of barrancas with the mainstem Santa Clara River to remove non-point source pollutants before they enter the mainstem itself. While treatment wetlands offer a low-cost alternative to large-scale treatment of non-point source pollution in particular (Horne and Fleming-Singer 2006), they also can successfully treat a variety of point sources. Functioning at rates one to two orders of magnitude greater than natural riparian buffer strips and floodplain vegetation (Fleming-Singer and Horne 2005, Hill 1996, Horne 1995, Bilby 1988, Lowrance *et al.* 1984), treatment wetlands are a proven technology for ameliorating a wide range of pollutants including TDS, nutrients (*e.g.*, nitrogen and phosphorous; Mitsch et al. 2000), metals (*e.g.*, chromium, copper, selenium), trace organic compounds (pesticides such as atrazine, chlorpyrifos, and endosulfan; Rodgers and Dunn 1992, Alvord and Kadlec 1996, Moore 2000, Schulz and Peall 2001) and pathogens (total and fecal coliform, bacteriophages, and protozoans; Kadlec and Knight 1996, Karpiscak *et al.* 1996, Quinonez *et al.* 1997).

In a recent study funded by the Los Angeles Regional Water Quality Control Board and the Coastal Conservancy, eight southern California treatment wetlands were included among a total of 40 freshwater urban wetlands in an evaluation of wildlife benefits, toxicity exposure, and water quality treatment effectiveness (Sutula *et al.* 2008). While none of the eight treatment wetlands evaluated are located in the Santa Clara River watershed, all experience a semi-arid to arid climate, similar to that of the Santa Clara River basin, as well as potentially higher concentrations of urban runoff contaminants as compared with that of temperate climates (Schiff and Sutula 2004, Sutula and Stein 2003, Caraco 2000 as cited in Sutula *et al.* 2008). Although determination of actual treatment effectiveness for the eight wetlands was not uniformly possible due to lack available flow data, results indicated that, averaged across wet and dry weather and season, the eight southern California treatment wetlands reduced concentrations of total and dissolved metals (e.g., copper, lead, zinc, selenium), nutrients (e.g., nitrate, ortho-phosphorous), total suspended solids (TSS), and bacteria (e.g., *Enterococccus, Eschericha coli*, fecal and total coliform) ($p<0.01$ for each constituent) (Sutula et al. 2008). Additionally, while sediment contaminant concentrations were found to be elevated above probable effects concentrations (PECs) in some instances, as a group the southern California treatment wetland sediments were not significantly elevated compared with sediments in either habitat wetlands or multi-purpose wetlands (used for both habitat and water quality treatment) throughout the 40 wetlands surveyed (Sutula et al. 2008). The same was true for aquatic toxicity of the amphipod *Hyalella azteca* and the larval midge *Chironomus tentans* (Sutula *et al.* 2008).

In the lower Santa Clara River, treatment wetlands could be integrated with the overall process-based Parkway restoration design by locating facilities outside the active floodway to avoid significant and frequent scouring. Similar to plans developed for the San Diego Creek watershed in southern California (GeoSyntec 2005), the wetlands can be designed to treat storm flows and summer runoff from both urban and agricultural areas. Preliminary review of regional conditions suggests that application of treatment wetlands would be particularly useful in gaining reaches of the lower Santa Clara River (Table 1-1) where groundwater quality is also of concern.

Individual treatment wetland designs must be tailored to local conditions and constraints; however, general design criteria may include:

- plug flow configuration,
- gradual slope for maintaining low water velocity,
- varied depth to support a variety of vegetation types and related treatment functions,
- multiple cells to prevent short circuiting, and
- inlet and outlet structures.

Development of water quality models prior to installation would allow for estimation of the performance of individual and collective treatment wetland facilities. Evaluation of alternative configurations and operation periods would be carried out to discern to what extent the facilities would contribute to load reductions of water quality pollutants to the Santa Clara River. For example, a research and demonstration project at the Hedrick Ranch Nature Area (HNRA) is currently ongoing along the Santa Clara River between Santa Paula and Fillmore, in Ventura County (URS 2003). The demonstration project is being carried out to investigate the potential for nutrient and pesticide removal from agricultural runoff using a slightly different type of non-point source pollution natural treatment system termed a bioswale. Bioswales function in a manner similar to typical surface-flow treatment wetlands, however they are more shallow (approximately 1 ft deep) and have a generally shorter residence time as compared with most wetland designs. The HNRA bioswales contain a mixture of summer and winter variety grasses selected to withstand the wet and dry conditions of the Santa Paula climate and to be tolerant to high salinity conditions (Keller and Clark 2008). Deeper (> 2 m) bioactive trenches are also included in the HNRA project, which are natural treatment facilities configured, in this instance, to intercept groundwater as it moves from upslope fields towards the Santa Clara River in both anaerobic and aerobic test cells (Keller and Clark 2008). Alternative designs, such as those implemented at HRNA, would be considered along with strategic placement of treatment wetlands within the lower Santa Clara River floodplain to best address water quality challenges.

4.6.2 Anticipated Benefits

Treatment wetlands are a type of natural treatment system, and as such offer secondary benefits including habitat creation and enhancement, aesthetics, recreation, and education (GeoSyntec 2005). The primary benefit of the wetland treatment units will be improved water quality. As discussed in Section 3.4, benefits of improved water quality for aquatic species include direct and indirect effects (Preston 2002) and depending on the level of the pollutant, may be localized and dramatic (*e.g.*, acute effects) or geographically broad and more subtle (*e.g.*, long-term, chronic effects). Although the specific impacts of poor water quality resulting from point and nonpoint source contaminants on biota in the lower Santa Clara River and estuary are not well-understood (Kelley 2004, AMEC 2005), the overall health of all aquatic organisms is expected to benefit from improved water quality.

As an example, tidewater gobies spend their entire lifecycle in the estuarine environment (Swift *et al.* 1989, Lafferty *et al.* 1999), feeding on a variety of small invertebrate organisms such as mysid shrimp, gamarid amphipods, and chironomid midge larvae (Swift *et al.* 1989, Swenson 1999, Moyle 2002), and providing prey for a variety of larger fish and piscivorous birds (Swenson and McCray 1996). Their wide range of food sources, foraging techniques, and broad function as prey to multiple predator species leaves them well-positioned to transfer toxicants between trophic levels and contribute to bioaccumulation of particular contaminants. Thus, benefits to the tidewater goby from improved water quality have the potential to positively affect multiple species in the aquatic food web. Lessening indirect effects of toxicant exposure will also potentially improve the ability of tidewater goby populations to recover from heavy predation by introduced piscivorous fish, particularly sunfishes (*Lepomis* spp.) and basses (*Micropterus* spp.) which have been have been introduced in or near coastal lagoons and estuaries throughout California (USFWS 2005).

Upstream of the estuary, aquatic species are expected to benefit from decreased total ammonia concentrations in the lower Santa Clara River, which currently exceed Basin Plan water quality objectives (CRWQCB 2006). Ammonia toxicity to fish is temperature and pH dependent, with recommended water quality criteria for acute (1-hr average) exposure in reaches having a salmonid presence at roughly 24 mg N/L, assuming pH 7.0 (CRWQCB 2005). Prolonged exposure to sub-lethal levels can lead to skin and gill hyperplasia, respiratory problems, stress, and conditions which support proliferation of opportunistic bacteria and parasites, thus chronic (30-day average) water quality criteria for ammonia is lower. For example, for reaches with early life stages of fish present, assuming pH 7.0 and ambient water temperature at 20 C, the chronic criterion is 4.15 mg N/L (CRWQCB 2005). Improved water quality is also expected to benefit organisms by decreasing chronic or episodic acute exposure to pesticides (*e.g.*, chlorpyrifos and diazinon) and general toxicity, which currently occurs in several reaches of the lower Santa Clara River (Figure 3-3). Identification of species-specific benefits to improved water quality requires further study (see Section 4.9).

4.6.3 Uncertainties

The primary uncertainty related to the successful implementation of treatment wetlands for water quality improvement is the availability of suitable locations at or near the confluence of barrancas with the mainstem lower Santa Clara River. While uncertainties involving general land acquisition (Section 4.3.3) apply to potential sites for treatment wetlands, choosing appropriate sites for the proposed treatment facilities must also include consideration of topography that allows gravity flow into and out of the wetland, sufficient acreage to achieve reasonable detention times, and (where possible) locations within existing or planned water quality detention basins.

The magnitude of dry-weather flows in barrancas, or other strategically identified locations for treatment wetlands, that could be potentially treated by the wetland facilities is also uncertain. While initial review of regional conditions indicates that locating these facilities in gaining reaches is most likely to supply year-round water (including low-quality groundwater, where applicable) and highest treatment efficiencies, the magnitude of off-channel summertime flows requires further investigation.

Additionally, further study is needed to help reduce the uncertainty in assessing the habitat value of treatment wetlands or multipurpose wetlands, and to determine whether habitat value can be improved through changes in physical structure or management approach. As discussed in the Sutula *et al.* (2008) review of 40 southern California freshwater urban wetlands, multipurpose wetlands, or those wetlands and riparian areas created to serve the dual objectives of habitat and water quality improvement, exhibited significantly higher plant species richness and diversity than did exclusively habitat or treatment wetlands. However, it was noted that the higher plant richness and diversity observed was being artificially maintained at these sites, because the majority of multipurpose wetlands are also mitigation wetlands which require native plants as a component of permit conditions. The California Rapid Assessment Method (CRAM) physical structure scores at the multipurpose wetlands were lower than at the habitat wetlands (Sutula *et al.* 2008), suggesting that habitat quality may actually be lower at the multipurpose wetlands.

The San Joaquin Wildlife Sanctuary (SJWS) is one example of a treatment wetland located in southern California that has been actively managed for both habitat value and water quality treatment effectiveness. While classified in the Sutula *et al.* (2008) review as a treatment wetland, the SJWS was conceived of as a multipurpose facility, and as such includes design elements and management specifications for promoting nitrate removal from inflowing San Deigo Creek water as well as maximization of avian habitat. Design elements such as 90% open water area, bulrush stands limited to pond perimeters by deep predator trenches, and bi-weekly drawdown of ponds on a rotating basis provide habitat for waterfowl and foraging sites for shorebirds, while differing carbon amendments promote high rates of denitrification. Fleming-Singer and Horne (2006) report high nitrogen removal efficiency (60% total nitrogen, 80% total inorganic nitrogen), seasonal nitrate removal rates of 350-500 $mg/m^2/d$ (April-May), and high avian species richness (65-76 species/mo) and avian species abundance (65-83 birds/ha/mo) for the SJWS during 1999-2002. Overall, results indicate that SJWS avian habitat design features did not appear to inhibit high rates of denitrification during the study period.

Finally, implementation of certain rehabilitation actions (*e.g.*, removal and/or construction of setback levees, removal of barriers to fish passage) will be constrained by state and federal regulations designed to protect Basin Plan Beneficial Uses and associated Water Quality Objectives (CRWQCB 2006). Potential detrimental effects on water quality, long-term or temporary, caused by rehabilitation construction activities will require appropriate permitting (see Section 3.7) and implementation of Best Management Practices (BMPs) to contain and minimize the extent of contamination. Although the permitting process will be a non-trivial component in the overall cost of rehabilitation, the ultimate protection of Basin Plan Beneficial Uses will result in a net benefit to the ecosystem.

4.7 Passive and Active Aquatic Habitat Enhancements

As previously discussed, while many large coastal southern California rivers have been confined to concrete channels in their lower reaches, the Santa Clara River riparian corridor has retained patches of high-quality aquatic and riparian habitat and currently supports, to varying degrees, several threatened and endangered native aquatic species (CDFG 2005, Stillwater Sciences 2007c). Despite its relatively intact status compared with other coastal rivers in the region, flood protection infrastructure, roads, agriculture, aggregate mining, and urbanization on the Santa Clara River have resulted in riparian and aquatic habitat loss or degradation (Section 1.4). Inclusion of aquatic habitat enhancements in the overall restoration approach for the lower Santa Clara River will ultimately support the long-term preservation or, in some cases, recovery of sensitive species populations.

4.7.1 Strategy Concept & Feasibility

Based on reviews of existing habitat availability for sensitive aquatic species on the lower Santa Clara River and its tributaries (Court *et al.* 2000,AMEC 2005, Stillwater Sciences 2007c), the restoration strategy for aquatic habitat enhancements, like that of floodplain revegetation (Section 4.3), includes both passive and active components. Passive aquatic habitat enhancements are those improvements to connectivity and instream, floodplain, and estuarine habitat availability that are expected to arise from the process-based restoration approach (Section 1.4). The strategy is founded upon the premise that dynamic habitat formation will occur within a floodplain sustained by natural rates and magnitudes of geomorphologic and hydrologic processes.

The strategy for active aquatic habitat enhancements involves primarily improving instream passage for native anadromous and resident fish species through the redesign of the fish ladders at Vern Freeman Diversion Dam and Harvey Diversion Dam. While the active amelioration of water quality degradation is necessary to achieve significant enhancements in aquatic habitat for species in the lower Santa Clara River and estuary, it is a strategy in its own right and is therefore addressed more specifically in Section 4.6. The remainder of this section presents a general discussion of the feasibility of facilitating instream passage and passive improvements to aquatic habitat.

(top) Looking upstream, and (bottom) downstream at the at the Vern Freeman Diversion Dam fish ladder (2003).
(photograph by Stillwater Sciences)

Improve Instream Passage

The National Marine Fisheries Service has stated that improvement of fish passage in the lower Santa Clara River requires the re-operation, and potentially re-design, of the denil fish ladder at Vern Freeman Diversion Dam. This is to accommodate the timing, duration, and magnitude of flow events that anadromous fish require for upstream migration (Stoecker and Kelley 2005). Additionally, the fish ladder at Harvey Diversion Dam on Santa Paula Creek needs to be repaired, reconfigured or removed to assure continuous passage for anadromous fish species from the mainstem Santa Clara River to the headwaters of Santa Paula Creek. The modification of these two complete or partial fish passage barriers is expected to be a feasible, albeit lengthy and expensive, approach for improving connectivity in the Above Freeman and Above Santa Paula Reaches (3 and 5) and to improve steelhead access to spawning grounds in tributaries. In addition, there is the potential to improve fish passage and/or aquatic habitat connectivity by modifying other potential barriers in the major tributaries (Sespe and Santa Paula creeks, in particular) (Stoecker and Kelley 2005).

Improve Aquatic Habitat Availability and Diversity

In the lower river, allowing floodplain inundation, bed scour, bank erosion and sediment deposition to occur at natural rates in an expanded floodway is expected to be a feasible approach to supporting the creation and maintenance of aquatic habitat for native plants and animals with minimal human intervention. For example, in the lower Santa Clara River, where watershed conditions such as erodible banks, abundant supply of sediment, and rapid and frequent variations in stream discharge promote the formation of a low-flow, braided channel system (Stillwater Sciences 2007a), the network of small channels and islands in an expanded floodway will offer seasonally abundant, shallow, low-velocity flow conditions with vegetative cover and a riparian buffer for water quality improvement. Under higher flow scenarios (*e.g.*, rainy season high flows) when the mainstem switches to a single-thread meandering channel (Stillwater Sciences 2007a), higher velocity main channel conditions will prevail and a better-defined sequence of contiguously wetted and connected deep and shallow water features can be supported.

In the estuary, the predominant strategy for accomplishing the self-sustaining formation of aquatic habitat is upstream levee setback or removal with floodplain re-contouring where needed, as in the case of abandoned floodplain aggregate mining pits or other potential landscape features that may cause channel incision.

4.7.2 Anticipated Benefits

The modification of the two identified migration barriers on the Santa Clara River (*i.e.*, Vern Freeman and Harvey Diversion Dams) will improve access by southern California coast steelhead and Pacific lamprey to upstream spawning habitats (but see Section 4.7.3) and also benefit resident fish such as Santa Ana sucker, Arroyo chub, and unarmored threespine stickleback, which might also be currently prohibited from longitudinal movement along the lower river corridor and certain tributaries.

Passive aquatic habitat enhancements supported by the proposed restoration activities are expected to benefit several sensitive species residing in the 500-year floodplain of the Santa Clara River and/or the estuary. For example, increasing riverine habitat availability and connectivity is anticipated to benefit adult migrating steelhead by providing deep pools for resting and holding to minimize their energetic outputs (Puckett 1975, Roelofs 1983, as cited in Moyle *et al.* 1989, Stoecker and Kelly 2005). These benefits could be expected during ENSO years in particular (which are predicted to increase as a result of global climate change), when the Santa Clara River experiences higher peak flows (see Section 2.3.2).

The estuarine aquatic community is also expected to realize benefits from passive upstream restoration actions. For example, successful tidewater goby reproduction requires relatively unconsolidated, clean, coarse sand in shallow waters (USFWS 2005) for burrow construction and egg deposition. The availability and quality of spawning habitat for tidewater gobies could improve through a general increase in recently deposited sediments due to upstream levee removal and decreased hyperpycnal flows (see Section 2.3.6).

Adult and juvenile tidewater gobies in the estuary may be adversely affected by early seasonal breaching of the estuary mouth. Early breaching of the estuary due to freshwater discharges from the Ventura Water Reclamation Facility could prevent access to preferred habitat but would generally not be expected to affect reproductive success. Even if early breaching events occur, salinity is generally expected to remain within the preferred range for spawning (≤15 ppt [Swenson 1999, USFWS 2005]) and the timing of these events is not expected to coincide with the peak spawning period. The highest intensity of spawning activity occurs early in the summer (April to June, [USFWS 2005]), whereas discharges from the wastewater treatment facility predominantly occur during late summer and fall (August to October). However, because tidewater gobies are not marine-adapted, early estuary breaching could be problematic if the fish are not able to seek refuge in brackish estuarine habitats and are instead displaced into the ocean where they are not likely to survive (Swift *et al.* 1989, Lafferty *et al.* 1999). Expanding available estuarine habitat diversity may offer a refuge for tidewater gobies if continued early breaching events occur. Southern California coast steelhead smolts are also expected to benefit from increased habitat availability in the estuary, as they require time to gain size and adjust to increased salinity in tidal lagoons or estuaries before migrating to the ocean. Examples of anticipated benefits to aquatic species from improved water quality are discussed in Section 4.6.2.

Table 4-2 presents the variety of aquatic habitats, using a hierarchical classification scheme (Cowardin *et al.* 1979, Hawkins *et al.* 1993), that are expected to be sustained by the proposed restoration efforts and that will support multiple instream aquatic species at different life-history stages. A variety of obligate and facultative aquatic birds as well as river-riparian species will also benefit from proposed aquatic habitat enhancements.

Table 4-2. Aquatic habitat classes and associated instream species expected to benefit from Santa Clara River Parkway Project restoration strategies.

Aquatic habitat class[1] to be supported following rehabilitation activities: Level I	Level II (Level III examples)	Sensitive aquatic species expected to benefit from habitat enhancements (A=adult, J=juvenile)
ESTUARINE[2]		
Subtidal[2]	Unconsolidated bottom	Arroyo chub (A, J) Southern California coast steelhead (A, J-smolt)
	Aquatic bed (algal, seagrasses)	
Intertidal[2]	Unconsolidated shore (boulder, cobble, mud, sand)	Tidewater goby (A, J)
	Unconsolidated bottom (tidal pond, slackwater sloughs)	Arroyo chub (A, J) Tidewater goby (A, J) Southern California coast steelhead (J-smolt)
	Emergent wetland (fresh water marsh, salt marsh)	Arroyo chub (A, J) Tidewater goby (A, J) Southern California coast steelhead (J-smolt)
RIVERINE		
Fast water	Turbulent (chute, rapid, riffle)	Pacific lamprey (A) Southern California coast steelhead (A, J) Santa Ana sucker (A)
	Non-turbulent (sheet run)	Pacific lamprey (A) Southern California coast steelhead (A, J) Santa Ana sucker (A, J) Arroyo chub (A, J)
Slow water	Scour pool (bank eddy, mid-channel scour pool, lateral scour pool)	Pacific lamprey (ammocoetes) Southern California coast steelhead (A, J) Arroyo chub (A, J)
	Dammed pool (backwater, abandoned or slow-moving side channel, oxbow)	Pacific lamprey (ammocoetes) Unarmored threespine stickleback (A, J) Western pond turtle (A, J) Arroyo toad (A, J) California red-legged frog(A, J) Two-striped garter snake (A, J)
Riparian	Open, non-vegetated gravel/sand bars inside meander bend, point bar	Arroyo toad (A, J-larval)

[1] Applicable estuarine habitat classes from Cowardin *et al.* 1979 and riverine habitat classes from Hawkins *et al.* 1993.
[2] The estuary functions as a muted tidal lagoon rather than a traditional estuary (Stillwater Sciences 2007a), thus Level I habitat estuarine classifications may not strictly hold.

4.7.3 Uncertainties

The strategy for passive aquatic habitat enhancements relies on the process-based rehabilitation approach, and it is therefore largely dependent on the successful implementation of the other five rehabilitation strategies. In general, uncertainties for the other five strategies also apply to passive aquatic habitat enhancement, but in particular levee setback or removal (Section

4.3.3), active and passive revegetation of the floodplain (Section 4.4.3), and treatment wetlands for water quality (Section 4.6.3) must be broadly successful to significantly improve aquatic habitat and water quality in the river and estuary. Without improvements in water quality, the ecological benefits and effectiveness of increased passage and connectivity in the lower river and improvements to the estuary will be limited (see Section 3.4). Additionally, the success of improvements to the fish ladders at Freeman and Harvey Diversion Dams is critical to improving overall connectivity and passage for instream aquatic species.

The timetable for aquatic habitat formation and maintenance under the process-based design is uncertain, as large floods are required to induce the channel changes and erosion/sedimentation required for aquatic habitat formation (Stillwater Sciences 2007a). While creation of riparian habitat through active revegetation of the floodplain will provide shading and complexity of edge habitats within a more certain timeline (*i.e.*, three to five years following successful planting), the location and degree of instream aquatic habitat formation via channel morphologic change is dependent on the occurrence of large floods. Analysis of ENSO patterns indicates that these large flood events typically take place every three to seven years, but future frequency is unknown. Better estimates of long-term coarse sediment load would also assist in the prediction of timing for habitat forming processes such as beach replenishment and littoral transport (Stillwater Sciences 2007a).

One of the most significant uncertainties associated with aquatic habitat enhancements is how and when biota will respond to improvements in physical habitat conditions. For example, modifications to the fish ladders at the Vern Freeman and Harvey Diversion dams may not contribute to increases in the southern California coast steelhead population if the fish are not entering the Santa Clara River from the ocean. If lack of access to high-quality spawning habitat is not one of the factors most limiting southern California coast steelhead populations, then passage improvements may not be expected to result in significant increases in the steelhead population. Even if lack of spawning habitat is a critical limiting factor, it may take several steelhead generations to begin seeing population benefits associated with fish passage improvements, as progressively greater numbers of adult steelhead are able to reach high-quality spawning habitats in upstream reaches. Interactions with non-native fish and other invasive species may also interfere with, to varying degrees, the ability of native fish species to take advantage of improved or restored habitat. These uncertainties are beginning to be addressed through a variety of fisheries, flow, and temperature studies being conducted or planned by United Water Conservation District and others on the river (UWCD 2007).

4.8 Reach-Specific Recommendations for Strategy Implementation

The reach-specific recommendations described below are intended to provide guidance for the next phase of implementing strategic restoration actions along the lower Santa Clara River corridor. Table 4-3 summarizes the recommended restoration strategies and identifies particular reaches where each of these strategies would be most appropriate, feasible, and expected to be effective (*i.e.*, restoration strategies correspond to reach-specific geomorphic functions and habitat conditions). For example, levee setback strategies are focused on the lowest reaches where the floodway is most constrained, while passive levee removal is emphasized in the middle reaches. Land acquisition, revegetation, and invasive species removal strategies dominate in those reaches with the greatest amount of existing focal species habitat or with the greatest threat of development. (Arundo and tamarisk are the only non-native species identified for removal at this time as they are the only species for which spatially-explicit data is available.)

The following descriptions for each reach are intended to expand on the information presented in Table 4-3 by briefly describing the general strategy for restoration in each reach.

Table 4-3. Recommended restoration strategies for the lower Santa Clara River.

Reach	Primary reach issues	Recommended restoration strategy: Land acquisition	Levee removal or setback	Revegetation	Non-native, invasive species removal	Treatment wetlands	Aquatic habitat enhancement	Other
0	• Right bank and upstream levees increase occurrence of hyperpycnal flow and estuary scouring. • Wastewater treatment facility presents physical constraint to restoration, may impair water quality, and increases the duration and frequency of summer and fall sandbar breaching. • Facilities at McGrath State Beach occur in the historic estuary zone and constraint southward migration of the river mouth.		✓ (infrastructure modification)					
1	• Levees eliminate or reduce lateral channel migration and aquatic habitat diversity, and contribute to channel incision. • Victoria Ave and Harbor Blvd bridges and left bank landfills present physical constraints to restoration.	✓ (to implement strategies)	✓ (levee setback and floodplain re-contouring)	✓ (following levee setback)		✓ (to treat agricultural and urban runoff)		
2	• Levees eliminate or reduce lateral channel migration and aquatic habitat diversity • Aggregate mining pits on floodplain and Hwy 101 bridge present physical constraint to restoration. • Freeman Diversion Dam contributes to channel incision.	✓ (to implement strategies and conserve habitat)	✓ (levee setback and floodplain re-contouring)	✓ (following levee setback)		✓ (to treat agricultural and urban runoff)		✓ (mining reclamation planning)
3	• Individual homes present physical constraint to restoration. • Freeman Diversion Dam impedes upstream fish passage to this reach. • Low groundwater decreases habitat connectivity in low flow years and may limit effectiveness of revegetation efforts without irrigation.	✓ (to implement strategies and conserve habitat)	✓ (levee setback and passive levee removal)	✓ (following levee setback)	✓ (arundo)	✓ (to treat agricultural runoff)	✓ (fish passage improvement)	
4	• Floodplain aggregate mining pits, airport, and left bank geology present physical constraints to restoration. • Low groundwater decreases habitat connectivity in low flow years and may limit effectiveness of revegetation efforts without irrigation.	✓ (to implement strategies and conserve habitat)	✓ (passive levee removal)	✓ (following levee removal)	✓ (arundo)	✓ (to treat agricultural and urban runoff)		

Reach	Primary reach issues	Recommended restoration strategy						
		Land acquisition	Levee removal or setback	Revegetation	Non-native, invasive species removal	Treatment wetlands	Aquatic habitat enhancement	Other
5	• Levees at confluence with Santa Paula Creek eliminate or reduce lateral channel migration and aquatic habitat diversity. • Damaged fish passage structure at Harvey Diversion Dam does not allow fish passage.	✓ (to conserve habitat)	✓ (floodplain recontouring)	✓ (in degraded habitats)	✓ (arundo)	✓ (to treat agricultural runoff)	✓ (fish passage improvement)	
6	• Lack of channel incision, gaining groundwater, and unregulated flows result in the highest-levels of natural fluvial processes and existing focal species habitat in the study area.	✓ (to conserve habitat)	✓ (passive levee removal)	✓ (following levee removal)	✓ (arundo)	✓ (to treat agricultural runoff)		
7	• Levees on Sespe Creek and the mainstem Santa Clara River, particularly in the vicinity of Fillmore, eliminate or reduce lateral channel migration and aquatic habitat diversity. • Bridge presents physical constraint to restoration.	✓ (to implement strategies and conserve habitat)	✓ (passive levee removal and infrastructure modification)	✓ (following levee removal)	✓ (arundo)	✓ (to treat agricultural runoff)		
8	• Relatively small, privately-owned agricultural levees confine the channel in some locations • Sediment input from Piru Creek contributes to channel aggradation. • Flow regulation in Piru Creek impacts hydrology. • Fish hatchery presents physical (infrastructure) constraint to restoration on the northern edge of the floodplain	✓ (to implement strategies and conserve habitat)	✓ (passive levee removal and infrastructure modification)	✓ (following levee removal)				
9	• Low groundwater contributes to the limited extent of riparian vegetation in this reach.	✓ (to conserve habitat)		✓ (in degraded habitats)	✓ (arundo)	✓ (to treat agricultural runoff)		
10	• Low groundwater contributes to the limited extent of riparian vegetation in this reach.	✓ (to conserve habitat)		✓ (in degraded habitats)	✓ (arundo)			
11	• Higher groundwater supports increasing extent of riparian vegetation, especially cottonwood forest (compared with reaches 9 and 10) • Narrow canyon morphology is significantly different from lower reaches.	✓ (to conserve habitat)		✓ (in degraded habitats)	✓ (arundo and tamarisk)			

Estuary Reach (0)

Restoration should be fairly limited in the Estuary Reach, as it is expected to benefit from upstream actions. The geomorphic functioning and habitat quality of the reach is expected to benefit from upstream implementation of levee setback and treatment wetland strategies. While removal of arundo and other non-native, invasive species would be beneficial, reintroduction of arundo from upstream sources is likely during moderate to large floods. Therefore, arundo removal or control in the estuary is a low priority until upstream control efforts are successful in reducing the sources of propagules likely to reinvade the Estuary Reach. Modification or relocation of key infrastructure at McGrath State Beach would allow the river mouth to migrate southward, away from the Ventura Water Reclamation Facility.

Hwy 101 Reach (1)

The Highway 101 Reach is a critical reach for implementing the levee setback strategy due to constrained channel migration, channel incision, and reduced riparian habitat that now result from the narrow configuration of levees. Property would be acquired primarily to secure areas for setting back levees. By focusing these actions on the right bank, the left floodplain could largely be left alone, decreasing costs and effort. Areas that are reconnected to the floodplain following levee removal, but that are not expected to experience significant flood inundation and scour, should be actively revegetated. Hwy 101 Reach has a barranca on the right bank that would be a potentially suitable site for construction of a treatment wetland to retain and filter agricultural and urban runoff. Removal of non-native invasive species is generally a low priority in this reach until upstream control efforts are successful.

Below Freeman Reach (2)

Below Freeman Reach is severely impacted by both levee confinement and channel incision downstream of Freeman Diversion Dam. Property acquisition would be conducted both to secure areas for implementing levee setbacks and to expand conservation areas beyond the existing TNC parcels in the reach. Levee setback would be prohibitively expensive on the left bank of the river in this reach due to floodplain aggregate mining and urban development; therefore, as in the Hwy 101 Reach, levee setbacks should focus on the right bank. Areas that are reconnected to the floodplain, but not expected to experience significant flood inundation and scour, should be actively revegetated. This reach presents an opportunity to integrate mining reclamation with riparian restoration efforts: aggregate mining reclamation projects should incorporate floodplain re-contouring and revegetation to improve riparian habitat conditions. Below Freeman Reach has several barrancas along the right bank that are potentially suitable to construct treatment wetlands to retain and filter agricultural and urban runoff. Removal of non-native invasive species is a low priority in this reach until upstream control efforts are successful.

Above Freeman Reach (3)

Access to Above Freeman Reach, and upstream reaches, by anadromous fish has been impaired by Freeman Diversion Dam. As a result, improving fish passage facilities at the dam (such as those improvements currently being considered by United Water Conservation District in consultation with the National Marine Fisheries Service) should be the highest priority restoration action for this reach. In addition, property acquisition in this reach should focus on securing areas for implementing levee setback and fish passage improvement projects. At the upstream end of the reach, property acquisition could be used to expand the extent of protected parcels that conserve existing agricultural land uses and habitat. In addition, preserving wildland connections with South Mountain should be considered a priority to maintain potential landscape corridors for wildlife movement. Levee setback strategies should focus on the right bank, where physical constraints to restoring connectivity to historical floodplain areas are less of an issue. Active revegetation should follow. Above Freeman Reach has several barrancas along the right bank that are potentially suitable to construct treatment wetlands to retain and filter agricultural and urban runoff. Removal of non-native, invasive arundo should be implemented at the base of South Mountain in the reach to eliminate upslope propagule sources in the riparian-upland transition zone and reduce the risk of arundo serving as a conduit for fire transmission within the riparian corridor.

Below Santa Paula Reach (4)

Below Santa Paula Reach is constrained by floodplain mining, an airport located along the right bank, and naturally hard geology on the left bank. In this reach, property acquisition should be focused on the left bank to conserve existing habitat and allow the channel to migrate away from the airport (acquiring and removing the airport would be prohibitively expensive and would not secure a significant amount of floodplain). Property acquisition could be used to expand the extent of protected parcels that conserve existing land uses and habitat. Active revegetation should be implemented in former agricultural areas and in disturbed areas of acquired parcels. The mouth of Fagan Canyon, along the right bank, is potentially suitable site for construction of a treatment wetland to retain and filter agricultural and urban runoff. As in the Above Freeman Reach, removal of non-native, invasive arundo should be implemented at the base of South Mountain to eliminate upslope propagule sources in the riparian-upland transition zone and reduce fire risk.

Above Santa Paula Reach (5)

Above Santa Paula Reach, which includes the confluence with Santa Paula Creek, provides an opportunity to expand the relatively high-quality geomorphic functioning and habitat conditions in Below Sespe Reach (6). In this reach, property acquisition should be focused on conserving existing habitat, protecting the floodplain from development, and linking existing protected parcels that conserve existing land uses and habitat. In addition, preserving wildland connections with South Mountain and with Santa Paula Creek should be considered a priority to maintain potential landscape corridors for wildlife movement. Active revegetation should be implemented in former agricultural areas and in disturbed areas of acquired parcels. The mouth of Orcutt Canyon, along the right bank, is a potentially suitable site for construction of a treatment wetland to retain and filter agricultural runoff. Removal of non-native, invasive arundo should be implemented at the base of South Mountain to eliminate upslope propagule sources in the riparian-upland transition zone and reduce fire risk. Fish passage improvements should be made to Harvey Diversion Dam on lower Santa Paula Creek to allow fish access to the high-quality habitats located upstream.

Below Sespe Reach (6)

Below Sespe Reach is the most naturally functioning, least incised, and largely unregulated reach in the lower Santa Clara River. Property acquisition should be focused on conserving existing habitat, protecting the floodplain from development, and linking existing protected parcels by acquiring the numerous large parcels that span both the active channel and sensitive floodplain habitats. There are patches of scalebroom vegetation in this reach that particularly important to conserve. Revegetation should be implemented in former agricultural areas and in disturbed areas of acquired parcels. Several barrancas occur on the right bank of this reach are potentially suitable to construct treatment wetlands to retain and filter agricultural runoff. Removal of non-native invasive arundo should be implemented at the base of South Mountain to eliminate upslope propagule sources and reduce fire risk.

Above Sespe Reach (7)

Like the Above Santa Paula Reach, Above Sespe Reach, which includes the confluence with Sespe Creek, provides an opportunity to expand the relatively high-quality geomorphic functioning and habitat conditions in Below Sespe Reach. Property acquisition in this reach should focus on protecting sensitive habitats and flood-prone areas along both the mainstem and Sespe Creek from floodplain development as the town of Fillmore expands and so reduce the pressure to construct more levees along lower Sespe Creek. In addition, preserving existing riparian-floodplain habitats and connectivity with Sespe Creek should be a priority to maintain potential landscape corridors for wildlife movement. Active revegetation should be implemented in former agricultural areas and in disturbed areas of acquired parcels. A barranca on the left bank of this reach is potentially suitable site for constructing a treatment wetland to retain and filter agricultural runoff. Removal of non-native invasive arundo should be implemented along Sespe Creek where arundo is relatively limited in distribution, to eliminate upstream propagule sources.

Hopper Reach (8)

Hopper Reach is impacted by flow regulation on Piru Creek. Property acquisition in Hopper Reach should focus on protecting floodplain habitats from floodplain development upstream of the town of Fillmore. In addition, property acquisition in this reach can be used to conserve or enhance wildlife migration linkages between upland habitats and conserved areas in the river corridor. Opportunities to allow passive levee removal and modify or relocate fish hatchery and farming infrastructure in this reach should be pursued to improve geomorphic functions. Active revegetation should be implemented in former agricultural areas and in disturbed areas of acquired parcels. Removal of non-native, invasive species is a low priority in this reach until upstream control efforts are successful.

Below Piru Reach (9)

Below Piru Reach is a losing reach and supports almost no riparian vegetation as a result. Property acquisition should focus on acquiring flood-prone parcels to reduce flood damage, and conserving upland and desert riparian scrub vegetation types. In addition, preserving wildland connections with the Santa Susana Mountains and with Hopper Creek should be considered priorities to maintain potential landscape corridors for wildlife movement. Active revegetation with upland (rather than riparian) vegetation types should be implemented in former agricultural areas and in disturbed areas of acquired parcels. Several barrancas along the right bank of this reach would be potentially suitable sites for constructing treatment wetlands to retain and filter agricultural runoff. Removal of non-native invasive arundo should be implemented to eradicate the relatively small patches that occur in this reach.

Above Piru Reach (10)

Like Below Piru, Above Piru is a losing reach and supports very little riparian vegetation. Property acquisition should focus on acquiring flood-prone parcels to reduce flood damage, and conserving upland and desert riparian scrub vegetation types. In addition, property acquisition in this reach can be used to conserve or enhance wildlife migration linkages between upland habitats and conserved riparian areas, and should include maintaining good connectivity with riparian habitats along Piru Creek. Active revegetation with upland vegetation should be implemented in former agricultural areas and in disturbed areas of acquired parcels, and following arundo removal. Removal of non-native invasive arundo should be implemented to eradicate the relatively small patches that occur in this reach.

County Line Reach (11)

County Line Reach occurs in a narrow canyon, more similar to the upper watershed than to the rest of the reaches in the lower river. Property acquisition should focus on conserving existing habitat and wildlife migration linkages between upland habitats and conserved riparian areas. Active revegetation should be implemented in former agricultural areas and in disturbed areas of acquired parcels, and following arundo removal. Removal of non-native invasive arundo should be implemented to eradicate the relatively small patches that occur in this reach. In addition, the isolated patches of tamarisk in this reach should be eradicated promptly.

4.9 Information Gaps & Potential Future Studies

While describing the conditions of the lower river and developing feasible restoration strategies for this report, gaps in information or lack of understanding of the river system became evident. The following additional studies are recommended to increase the understanding of the lower Santa Clara River system and assist in developing more detailed restoration plans:

- Groundwater monitoring in reaches of planned large-scale revegetation, conducted for long enough and over a broad enough area to characterize groundwater levels at scales suitable to evaluate project suitability.
- Hydraulic modeling of levee removal and setback scenarios to estimate the likely flood attenuation of different restoration actions.
- Water quality monitoring to characterize existing threats to the conservation of native biota.
- Water quality and quantity monitoring at the Ventura Water Reclamation Facility to identify the magnitude and timing of water quality impacts to native biota, and to identify effects of treated effluent on seasonal patterns of salinity in the estuary and the timing of breaching.
- Water quality monitoring in the Estuary Reach (1) to identify the magnitude and chemical composition of discharge from landfills.
- Long-term monitoring of selected restoration sites and high-quality reference sites for both aquatic and riparian habitat. In particular, monitoring of the effectiveness of different types of restoration and revegetation strategies relative to environmental conditions in the parkway area (*e.g.*, gaining versus losing reaches, time since last disturbance from flood or fire) would help guide and increase the success rate of future restoration efforts.

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APPENDIX A
Non-native Invasive Plant and Animal Species in the Lower Santa Clara River

The lower Santa Clara River riparian corridor, like most California landscapes, is host to many non-native, invasive plant and animal species. Invasive plants and animals can threaten natural habitat value by displacing native plant species and associated animal species, and disrupting food web dynamics and ecological processes. The most highly invasive species documented in the lower Santa Clara River corridor and the locations where they were observed are described below (Sections A.1–A.8), along with some less invasive but widely distributed plant species (Sections A.9–A.12), and two invasive animal species (Sections A.13–A.14).

A.1 Arundo (*Arundo donax*)

Arundo is a highly aggressive, naturalized landscape plant that invades riparian zones by establishing dense, monospecific clonal stands (DiTomoso and Healy 2007). This species is drought- and fire-tolerant (its foliage is highly flammable) and re-sprouts vigorously after fire by quickly exploiting released nutrients (Coffman 2007). Arundo is also shade-tolerant, establishing under established canopies and exposing the dominant trees to increased fire threat. The species does not propagate by seed (all plants in the U.S. have been found to be sterile), and establishment occurs exclusively by vegetative propagules — most often rhizomes that wash downstream from eroded banks (DiTomoso and Healy 2007). Giant reed is a strong competitor in systems with increased nutrient supply, and heave fertilizer use may be an important factor aiding its dominance in many California riparian areas (Coffman 2007). Most commonly, the plant colonizes disturbed areas such as roads, revetted banks and bridge abutments where native vegetation has been cleared. Along the Santa Clara River, arundo occurs primarily in dense monocultures typically 2-5 meters tall (Stillwater Sciences and URS Corporation 2007). It also occurs in a co-dominant role with mulefat (*Baccharis salicifolia)*, narrowleaf willow *(Salix exigua)*, myoporum *(Myoporum laetum)*, red willow (*S. laevigata)*, and arroyo willow *(S. lasiolepis)*. Arundo is found, to some extent, in 5,242 ac, or 73%, of the total mapped vegetation of the lower Santa Clara River corridor (Stillwater Sciences and URS Corporation 2007). Arundo removal is a priority restoration action for the lower Santa Clara River specifically, and the coastal southern California region.

A.2 Pampas grass (*Cortaderia jubata*)

Pampas grass is a large, densely tufted perennial grass with wind dispersed seeds that may spread up to 20 miles from the host population (DiTomoso and Healy 2007). Viable seeds can develop without fertilization and seedlings will readily establish on bare, disturbed soil, although seeds are not long lived in the field (less than 6 months) and a persistent seedbank does no accumulate. Individual plants can survive up to 15–20 years (DiTomoso and Healy 2007). Its habitat includes disturbed areas, dunes, bluffs, roadsides, road cuts and logged forests (CalIPC 2007). Populations can be controlled by hand pulling seedlings, manually cutting or chopping out mature plants from below the crown or planting desirable vegetation on bare sites to reduce seedling establishment. Along the lower Santa Clara River corridor, pampas grass was found growing in low density in one patch along with *Salix lasiolepis* (Stillwater Sciences and URS Corporation 2007).

A.3 Cape-ivy (*Delairea odorata*)

Cape-ivy is a vigorous perennial vine that is especially noxious in riparian areas though it can also invade coastal bluffs and scrubs, seasonal wetlands, moist canyons, oak woodlands, coastal grasslands and various forests (CalIPC 2007). Vines can form dense mats over trees and shrubs and smother underlying vegetation. Cape ivy reproduces vegetatively from rhizomes, stolons and fragments of rhizomes, stolons and stems. Manual removal with follow-up to remove resprouts can control infestations (DiTomaso and Healy 2007). Along the lower Santa Clara River corridor, Cape Ivy was found growing in low density in one patch along with *Salix laevigata* (Stillwater Sciences and URS Corporation 2007).

A.4 Spanish broom (*Spartium junceum*)

Spanish broom was originally introduced into North America in the 1900's as an ornamental for soil stability along highways (DiTomaso and Healy 2007). Its habitat includes open, disturbed sites (logged or burned areas, roadsides and pastures), undisturbed grasslands, coastal scrub, oak woodlands, riparian forests and open forests (CalIPC 2007). Infestations of Spanish broom can increase fire hazard and decrease the use of rangeland (DiTomaso and Healy 2007). Its seeds are long lived in the field and can distribute over large areas by water, soil movement, vehicles, animals and human activities (DiTomaso and Healy 2007). Spanish broom will resprout when it is cut so mechanical treatment alone is generally not effective. Chemical treatment can successfully control large infestations with several years of follow-up treatment (chemical or manual pulling) (DiTomaso and Healy 2007). Spanish broom is found in small numbers in coastal sage scrub communities of the lower Santa Clara River corridor (Stillwater Sciences and URS Corporation 2007).

A.5 Tamarisk (*Tamarix ramosissima*)

Tamarisk is an aggressive invader that disperses seeds by wind and water. It can spread quickly in riparian areas and often develops into dense monoculture stands. It has a deep, extensive root system and a high evapotranspiration rate which, when present in large stands, can greatly reduce underground water tables along riparian corridors (DiTomaso and Healy 2007). Tamarisk leaves excrete salts which increases local soil salinity and inhibits the growth, survival and recruitment of desired, native vegetation. Chemical treatment is required to control infestations with follow-up seedling removal in successive years to prevent regrowth (DiTomaso and Healy 2007). Its extent in the upper Santa Clara River watershed, rate of spread and impacts to the ecology of riparian areas have made it the focus of a large-scale eradication effort, along with giant reed, in the upper watershed (VCRCD 2006b). Currently, mature tamarisk is sparsely distributed in the lower watershed. It is most abundant in County Line Reach (11), the upstream-most reach in the riparian vegetation mapping area, presenting a great risk of further infestation in downstream reaches (Stillwater Sciences and URS Corporation 2007). Cohorts of newly recruited tamarisk seedlings were observed in both summer 2005 and 2006, suggesting a strong recruitment potential downstream of the few mature stands of tamarisk currently established in County Line Reach (11), although future monitoring would be required to determine how many of these seedlings survive to maturity (Stillwater Sciences and URS Corporation 2007).

A.6 Tocalote and yellow starthistle (*Centaurea melitensis and C. solstitialis*)

Ubiquitous in southern California grasslands, tocalote and yellow starthistle are low-growing, small-flowered herbaceous species which invade disturbed areas, pastures, and roadside clearings (CalIPC 2007). Yellow starthistle is considered one of the most serious rangeland weeds in the western United States (CalIPC 2007). Natives of southern Europe, tocalote and yellow starthistle were introduced in California between 1848 and 1869. As of 1995, yellow starthistle it is estimated to have invaded 10–12 million acres in California (Bossard *et al*. 2000). Infestations of tocalote and yellow starthistle can displace native plants and animals, deplete soil moisture reserves in annual grasslands, interfere with grazing, and reduce land values (DiTomaso and Healy 2007). Infestations can be controlled with grazing, mowing, burning and cultivation over a period of at least 2-3 years. Tocalote was common in disturbed areas and herbaceous vegetation types thought the lower Santa Clara River corridor, while a small amount of yellow star thistle was observed growing with *Populus balsamifera* and other non-native herbaceous species (Stillwater Sciences and URS Coprporation 2007).

A.7 Sweet fennel (*Fooniculum vulgare*)

Sweet fennel is common along roadsides and disturbed areas, particularly in coastal regions of central and southern California (CalIPC 2007). It also invades grasslands, riparian areas and other natural communities. It is a prolific seed producer and seeds can be dispersed with water, soil movement, animal, and human activities (DiTomaso and Healy 2007). Small population can be controlled by manually removing individual plants, although larger populations may require a more integrative management scheme including repeated mowing, burning, and chemical applications (DiTomaso and Healy 2007). Sweet fennel was found in several locations along the lower Santa Clara River corridor, primarily in disturbed, scrub vegetation in the lower reaches of the river (Stillwater Sciences and URS Corporation 2007).

A.8 Perennial pepperweed (*Lepidium latifolium*)

Perennial pepperweed is a highly competitive plant that often forms dense patches and can displace native vegetation and wildlife (DiTomaso and Healy 2007). Its habitat includes wetlands, riparian areas, meadows, vernal pools, salt marshes, floodplains, sand dunes, roadsides and irrigation ditches as well as alfalfa fields, orchards, vineyards and irrigated pastures (CalIPC 2007). It reproduces vegetatively from creeping roots and root fragments and by seeds (DiTomaso and Healy 2007). Both the root fragments and seeds float and the plant can disperse across great distances by flooding, soil movement, agricultural practices and other human activities (DiTomaso and Healy 2007). A small stand of perennial pepperweed was observed in 2005 in the tidal marsh habitat in Estuary Reach (0) (Stillwater Sciences and URS Corporation 2007).

Other, lower impact non-native invasive plant species but that are relatively widely distributed in the lower Santa Clara River corridor include eucalyptus (*Eucalyptus* spp.), tree tobacco (*Nicotiana glauca*), Peruvian peppertree (*Schinus molle*), and castor bean (*Ricinus communis*). These species may be easier to eradicate from the watershed than the aggressive invaders described above, since they currently have limited distributions or low rates of infestation.

A.9 Eucalyptus (*Eucalyptus* spp.)

Eucalyptus species have become slow, though widespread, invaders throughout California. Once established, the trees can make their microenvironment hostile to native species by altering soil chemistry and reducing the availability of light, water, and nutrients (DiTomaso and Healy 2007). Blue gum (*Eucalyptus globulus*) is the most common eucalyptus species in California and is widely planted as an ornamental or as a wind break. It habitat includes disturbed areas, especially riparian areas, coastal grasslands, and forests (CalIPC 2007). Blue gum reproduces from seeds and can disperse great distances by water and soil movement and human activities (DiTomaso and Healy 2007). Eradication of eucalyptus is straightforward given adequate incentive and funding, though its fast growth and clonal root sprouting often necessitate multiple treatments (DiTomaso and Healy 2007). In the lower Santa Clara River corridor, eucalyptus is generally found in disturbed areas and occurs as small, but widely distributed patches (Stillwater Sciences and URS Corporation 2007).

A.10 Tree tobacco (*Nicotiana glauca*)

Tree tobacco is rated as a moderately invasive species in coastal scrub, grasslands and riparian areas in California (CalIPC 2007). All parts of this plant are highly toxic to humans and livestock when ingested. It grows in open, sandy or gravelly sites, especially along roadsides and in fields, disturbed areas, washes, and riparian areas. Tree tobacco reproduces by seeds which disperse with water, soil movement, and human activities (DiTomaso and Healy 2007). Stands of tree tobacco are currently found along Sespe Creek, Piru Creek and downstream of Piru Creek on the mainstem Santa Clara River in Above Piru Reach (10) (Stillwater Sciences and URS Corporation 2007). The presence of tree tobacco in these upstream areas presents a potential risk for downstream invasion.

A.11 Peruvian peppertree (*Schinus molle*)

Peruvian peppertree is listed as a limited invasive species that occurs generally in washes, on slopes, and in dry fields (CalIPC 2007). Peruvian peppertree is found throughout the lower Santa Clara River corridor as a co- or subdominant canopy species with cottonwood, eucalyptus species, western sycamore, California black walnut, arroyo willow, red willow, blue elderberry (*Sambucus mexicana*), and coast live oak (*Quercus agrifolia*) (Stillwater Sciences and URS Corporation 2007).

A.12 Castor bean (*Ricinus communis*)

Castor bean is a widespread summer annual or perennial shrub in coastal scrub and riparian areas in southern California (Cal-IPC 2007). Its habitat includes roadsides, fields, riparian areas and disturbed waste places (CalIPC 2007). Castor bean reproduces by seed and populations can be spread across large distances by human activities, soil, and water movement (DiTomaso and Healy 2007). The seeds and foliage of castor bean are highly toxic to humans and animals when ingested. Castor bean infestations can be controlled with periodic removal of seedlings or with systemic herbicides (DiTomaso and Healy 2007). Castor bean is found in disturbed sites throughout the lower Santa Clara River corridor, including many of the barrancas (small tributary streams) that cross agricultural zones, and is often found growing with shortpod mustard (*Hirschfeldia incana*) and ripgut grass (*Bromus diandrus*) (Stillwater Sciences and URS Corporation 2007).

A.13 African clawed frog (*Xenopus laevis*)

African clawed frogs are native to southern Africa, and were introduced in California and other places as laboratory animals (Nieukoop and Faber 1994, Lannoo 2005). Because African clawed frogs can easily adapt to a variety of habitats and locations, they have been able to successfully establish populations on multiple continents (Lannoo 2005). African clawed frogs are able to locate living prey easily, even when prey are concealed in mud and detritus (Lafferty and Page 1997, Beck and Slack 2001). Because they prefer warm stagnant ponds that are highly muddy, or turbid, and often covered in green algae, African clawed frogs have also evolved the ability to locate prey by smell. As a "sit and wait" predator, adult African clawed frogs in introduced areas feed on essentially whatever prey/food items are available. This may include a wide range of aquatic invertebrates and vertebrates, (*e.g.*, tadpoles and juveniles of multiple amphibians, arroyo chub, mosquito fish, unarmored three-spined stickleback, and tidewater gobies) (Lafferty and Page 1997, Stebbins 2003, Lannoo 2005). Additionally, African clawed frogs can live off of non-living food items as scavengers—a rare adaptation in frogs—and one which often gives this species a significant advantage when transplanted to other parts of the globe (Lafferty and Page 1997, Beck and Slack 2001, Lannoo 2005). Because they breathe through highly developed lungs and can survive up to a year burrowed in deep mud, African clawed frogs are able to survive drought conditions much more successfully than native frog species (Simmonds 1985, Kaplan 1995, Lannoo 2005). Originally discovered in the upper watershed in 1974 and in the estuary in 1995, African clawed frogs are now present throughout the lower Santa Clara River corridor and its small tributaries and barrancas (Lafferty and Page 1997; Lannoo 2005; B. Orr, Stillwater Sciences, pers. obs., 2005; S. Sweet, UCSB, pers. comm., 2006).

A.14 Brown-headed cowbird (*Molothrus ater*)

Brown-headed cowbirds are native to North America, although they are fairly recent arrivals in the western United States, where they are believed to have increased in population following the development of the west in the early 20th century (Morrison *et al.* 1999, Friedmann 1963 as cited in Labinger and Greaves 2001). The brown-headed cowbird is one of North America's most notorious nest parasites. Cowbirds use other bird species as nest hosts, laying their eggs in host nests and having the host bird incubate and feed the cowbird chicks (Morrison *et al.* 1999). Female cowbirds are capable of laying up to 30 eggs in one breeding season (Morrison *et al.* 1999). The young cowbirds often out-compete the other nestlings and may lower the reproductive success of the host bird species (Halterman and Laymon 1997, Morrison *et al.* 1999). Cowbird chicks have been successfully reared by over 150 host species, with songbirds comprising the majority of the hosts (Morrison *et al.* 1999, Friedmann *et al.* 1977 as cited in Labinger and Greaves 2001). Rates of parasitism depend on the proximity of cowbird foraging areas (grasslands, agricultural lands, pastures, grazing yards, and grain silos) to the host breeding sites (Rothstein *et al.* 1984 as cited in Labinger and Greaves 2001, Halterman and Laymon 1997). Partners in Flights (1997) found that large, contiguous forests sustained lower rates of cowbird parasitism that fragmented forests, suggesting the cowbirds search for hosts along forest edges. Fragmented forests have more edge habitat, often alongside agricultural or pasture areas, and species within these areas are more susceptible to cowbird parasitism (Partners in Flight 1997).

Cowbird parasitism has been documented throughout the lower Santa Clara River corridor in least Bell's vireo, Hutton's vireo, yellow warbler, common yellowthroat, yellow-breasted chat, and song sparrow nests (Labinger and Greaves 2001). Parasitism was more common in areas where no cowbird trapping was being conducted, and cowbird host species were less abundant in areas of high cowbird abundance (although this may also be related to habitat quality and land use patterns) (Labinger and Greaves 2001). Cowbird removal is believed to be one of the factors responsible for increases in several southern California vireo populations (USFWS 1998). An annual cowbird control program on the lower Santa Clara River corridor implemented by the California Department of Fish and Game, which includes the trapping and killing of adults and removal of eggs from host nests, appears to be increasing least Bell's vireo productivity (Labinger and Greaves 2001).

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APPENDIX B

Regulatory Considerations and Permitting Requirements

Implementation of the non-acquisition restoration strategies presented in this report will trigger multiple, yet slightly different sets of environmental review and permit requirements. Potential jurisdictional agencies for the four restoration strategies include: the U.S. Army Corp of Engineers (USACE), U.S. Fish and Wildlife Service (USFWS), NOAA Fisheries Service (also known as the National Marine Fisheries Service, or NMFS), California Department of Fish and Game (CDFG), Regional Water Quality Control Board (RWQCB), Ventura County Watershed Protection District (VCWPD), and California Coastal Commission (CCC) (the jurisdictional areas and activities of these agencies are discussed in Section B.4). This section, modified from examples provided in the Ventura County Planning Division's (2006) Wetland Project Permitting Guide, identifies the triggering activities associated with certain restoration strategies and the likely permits and approvals that will be required. It should be noted that the permits and approvals identified in the tables below are not listed in order of when they should be acquired; timeframes and approaches to permit acquisition are discussed in Sections B.4 and B.5, respectively. Requirements of each permit/approval identified in the tables below are discussed in more detail in Section B.4.

B.1 Levee Removal/Setback and Floodplain Re-contouring

Levee removal/setback and floodplain re-contouring restoration strategies will likely involve temporarily diverting the Santa Clara River away from the work area, heavy equipment working in the active channel, removal or movement of material from the floodplain, removal of vegetation, and potentially may occur in the vicinity of protected species. The location of the Santa Clara River and scope and location of the restoration activities would place the project under the jurisdiction of the USACE, CDFG, RWQCB, VCWPD, and potentially CCC. Project triggers and likely required permits or approvals for levee removal/setback and floodplain re-contouring projects are listed in Table B-1. Table B-1 assumes the project area is greater than 10 acres (if it were less, a USACE 404 Nationwide Permit [NWP] would be required rather than an Individual Permit [IP]), that federally and state-protected species have the potential to occur within the project area, and that the project will be conducted within the coastal zone.

Table B-1. Triggers and likely required permits and approvals for levee removal/setback and floodplain re-contouring restoration strategies.

Primary Trigger	Additional Triggers	Permit/Approval	Associated Requirements
Moving material into or within the river	Project area over 0.5 acre	USACE 404 IP	• RWCQB 401 Certification[1] • CEQA compliance • wetland delineation
Altering a stream, disturbing riparian vegetation		CDFG Streambed Alteration Agreement (SAA)	CEQA compliance
Federally protected species		• USFWS or NMFS Section 7 Consultation • Section 10 Incidental Take Permit	
State protected species	CDFG Streambed Alteration Agreement (SAA) required	CDFG Section 2081 Permit Consultation	
Grading in a stream or wetland		VCWPA Grading Permit	CEQA compliance
Discretionary approval required[2]	• USACE 404 IP required • CDFG Streambed Alteration Agreement (SAA) required	CEQA compliance	• Initial Study • Negative Declaration or Mitigated Negative Declaration
Disturbing >1 acre of soil		State Water Board Construction General Permit & Stormwater Pollution Prevention Plan	
Pumping or releasing water		RWQCB Wasted Discharge /National Pollution Discharge Elimination System (WDR/NPDES) Permit	
Working in VCWPD red-line stream		VCWPD Encroachment and/or Watercourse permit	
Removing or trimming protected tree		VCPD Protected Tree Permit	
Working in coastal zone		• CCC Letter of Concurrence • VCPD Land Use/Coastal Zone Permit	CEQA compliance
Working within a California State Park		California State Parks consultation	

[1]In March 2007, the State Water Resources Control Board approved a general 401 water quality certification order for small habitat restoration projects that greatly reduces 401 certification requirements for eligible projects; see Section B.4.2 for more details.
[2]Discretionary approval involves the exercise of judgment on the part of a regulatory agency.

B.2 Non-native, Invasive Plant Removal

Non-native, invasive plant removal restoration strategies will likely involve spraying herbicides and removing live and dead vegetation with a tractor. Again, the location of the Santa Clara River and scope and location of vegetation removal would place the project under the jurisdiction of the USACE, CDFG, RWQCB, VCWPD, and potentially CCC. Project triggers and likely required permits or approvals for non-native, invasive plant removal projects are listed in Table B-2. Table B-2 assumes that federally and state-protected species have the potential to occur within the project area and that the project will be conducted within the coastal zone. In addition, Table B-2 provides guidance in the case that the project is, or is not, eligible for a USACE 404 Regional General Permit (RGP). Removal of non-native, invasive plants is one of several activities covered under USACE 404 RGPs, the simplest and quick

Table B-2. Triggers and likely required permits and approvals for non-native invasive plant removal.

Primary Trigger	Additional Triggers	Permit/Approval	Associated Requirements
Moving material into or within the river		USACE 404 RGP 41	
404 permit required		RWQCB 401 Certification	CEQA compliance
Altering a stream, disturbing riparian vegetation		CDFG Streambed Alteration Agreement (SAA)	CEQA compliance
State protected species	CDFG Streambed Alteration Agreement (SAA) required	CDFG Consultation	
Federally protected species		• USFWS or NMFS Section 7 Consultation • Section 10 Incidental Take Permit	
Grading in a stream or wetland		VCWPA Grading Permit	CEQA compliance
Discretionary approval required	• USACE 404 IP required • CDFG Streambed Alteration Agreement (SAA) required • VCWPA Grading Permit required	CEQA compliance	• Initial Study • Negative Declaration or Mitigated Negative Declaration
Disturbing >1 acre of soil		State Water Board Construction General Permit & Stormwater Pollution Prevention Plan	
Working in VCWPD red-line stream		VCWPD Encroachment and/or Watercourse permit	
Working in coastal zone		• CCC Letter of Concurrence • VCPD Land Use/Coastal Zone Permit	CEQA compliance
Working within a California State Park		California State Parks consultation	

est type of 404 permits (see Section B.4.1). RGPs often include pre-approved 401 Certification and USFWS and NOAA Fisheries endangered species consultations. To be eligible for the RGP, the purpose of non-native, invasive plant removal projects must include both habitat recovery and flood control. The items in Table B-2 that appear in grayed-out text are those permits that would not need to be acquired if the work is eligible for a RGP.

B.3 Re-vegetation

Active re-vegetation restoration strategies will involve planting native plants with hand-tools or smaller types of heavy equipment on stream banks and the floodplain. Re-vegetation work will most likely occur above the ordinary high water mark but within the floodway, putting the work within the jurisdiction of CDFG and VCWPD, but outside the jurisdiction of USACE. Project triggers and likely required permits or approvals for active re-vegetation projects are listed in Table B-3. Table B-3 assumes that federally and state-protected species have the potential to occur within the project area and that the project will be conducted within the coastal zone.

Table B-3. Triggers and likely required permits and approvals for active revegetation.

Primary Trigger	Additional Triggers	Permit/Approval	Associated Requirements
Altering a stream, disturbing riparian vegetation	Working above the Ordinary High Water mark and inside of floodway	CDFG Streambed Alteration Agreement (SAA)	CEQA compliance
Discretionary approval required	• USACE 404 IP required • CDFG Streambed Alteration Agreement (SAA) required • VCWPA Grading Permit required	CEQA compliance	Notice of Exemption
Federally protected species		USFWS or NMFS Section 7 Consultation	
State protected species	CDFG Streambed Alteration Agreement (SAA) required	CDFG Section 2081 Permit Consultation	
Working within floodway of VCWPD red-line stream		VCWPD Encroachment and/or Watercourse permit	
Working in coastal zone		• CCC Letter of Concurrence • VCPD Land Use/Coastal Zone Permit	CEQA compliance
Working within a California State Park		California State Parks consultation	

B.4 Regulatory Statutes and Implementing Agencies

This section describes the regulations and permits identified in the tables above in more detail. Regulatory requirements of each statute and/or implementing agency are described with the assumption that each permit would be acquired on a project-by-project basis. Requirements would be modified if a programmatic approach to environmental compliance that includes all restoration strategies for the entire river is taken. Programmatic approaches are discussed in Section B.5.

B.4.1 USACE Section 404 Permit

The USACE regulates activities that involve discharge of dredged and fill material into "Waters of the United States", including wetlands, under Section 404 of the federal Clean Water Act (CWA) (CWA 1977). Waters of the United States include navigable waters, interstate waters; all other waters where the use or degradation or destruction of the waters could affect interstate or foreign commerce, tributaries to any of these waters, and wetlands that meet any of these criteria or that are adjacent to any of these waters or their tributaries. The jurisdiction of the USACE over non-tidal waters covers the bank-to-bank portion of a river along its entire length and extends up to the "ordinary high-water mark" as well as adjacent wetlands. The ordinary high-water mark is defined by the USACE (2007) as "a line on the shore established by the fluctuations of water and indicated by physical characteristics, or by other appropriate means that consider the characteristics of the surrounding areas."

A USACE Section 404 Permit is triggered by any activity that adds material to or disturbs the bed of a water body or wetland, even if the area is dry at the time the activity takes place. There are three types of Section 404 Permits that may be required for any particular project depending on the size and overall complexity of the project, listed in order of increasing complexity and requirements:

- Regional General Permits (RGPs)
- Nationwide Permits (NWPs)
- Individual Permits (IPs)

The specific details of the three types of USACE Section 404 Permits are described below.

Regional General Permit

RGPs are region-specific permits that have already been prepared for a small number of project categories. These permits may be issued for general maintenance-related activities with minimal environmental impacts and are therefore the simplest and quickest permits to receive from the USACE (VCPD 2006). If applicable, RGPs often include pre-approval from the RWQCB for a

CWA Section 401 Certification, USFWS and NMFS Endangered Species Act consultations or permits, and a CCC Letter of Concurrence for those projects located in the Coastal Zone (VCPD 2006). The processing time for an available RGP is approximately one month. For projects that require development of new categories of RGPs for routine maintenance activities, the processing time may take 6 to 12 months. There are currently no application fees for RGPs, although some RGPs have associated review and processing fees. RGP 41 could potentially be utilized for non-native, invasive plant removal projects. Projects eligible for RGP 41 include those whose purpose is both habitat recovery and flood control. The permit review and processing fee for RGPs is $60.

Nationwide Permit

NWPs are another type of USACE-issued permit required for any project that: 1) involves discharging or moving material into or within a river; 2) has a permanent impact area less than 0.5 acres; and 3) does not meet the criteria for a Section 404 RGP. Similar to RGPs, NWPs are pre-written permits for authorized categories of activities, except that they are available nationwide. NWPs provide an expedited authorization process for activities that have minimal individual and cumulative impacts on the aquatic environment provided that the project satisfies the terms and conditions of the associated NWP. There are currently about 50 types of NWPs, including: maintenance, bank stabilization, survey activities, minor dredging, stormwater management, flood control maintenance, and wetland restoration for the benefit of improving wildlife habitat (USACE 2007)

Depending upon the scope and location of a project, he NWP process may require: 1) a biological review with estimates of expected impacts to water and wetlands to be completed; 2) pre-authorization for RWQCB 401 Certification; 3) USFWS or NMFS ESA consultation or permits; 4) a CCC Letter of Concurrence for projects located in the Coastal Zone; and 5) a wetland delineation to determine the lateral extent of USACE jurisdiction for projects conducted in wetlands beyond the stream channel (VCPD 2006). Some NWPs do not require submission of a pre-construction notification to the USACE prior to initiating work, provided that all permit conditions are satisfied. Other NWPs, that do require pre-construction notification, may take three to four months to process while the USACE determines if the proposed work is eligible for NWP authorization. There are no application fees for NWPs (VCPD 2006).

Individual Permit (IP)

IPs are the most complex type of the Section 404 Permits issued by the USACE. IPs are required for projects that impact greater than 0.5 acre of USACE jurisdictional area through discharging or placing materials into or within a river. Similar to a NWP, an IP may have additional requirements, including: 1) a biological review; 2) RWQCB 401 Certification; 3) USFWS or NMFS ESA consultation or permits; 4) a CCC Letter of Concurrence for projects located in the Coastal Zone; and 5) a wetland delineation for projects conducted in wetlands beyond the stream channel (VCPD 2006). A project may be issued an IP as a standard permit or as a Letter of Permission (LOP). A standard permit includes public review and is issued following a case-by-case evaluation of the proposed project. The processing time of a standard permit could take up to one year or longer due to the need for public review and the complexity of the permitting process (VCPD 2006). Projects having only minor or routine work with expected minimum impacts and objections may qualify for a LOP, which can be issued quickly because a public review is not required (USACE 2007).

B.4.2 RWQCB 401 Certification

The State Water Resources Control Board (State Water Board), through its RWQCBs, is the lead agency charged with protecting the quality of the State's surface and groundwater supplies, per the federal CWA (1977) and the California Porter-Cologne Water Quality Control Act (2006). Section 401 of the CWA is implemented by the RWQCB to protect and minimize impacts to the quality of the surface waters of the State. Surface waters of the State include wetlands, riparian zones, streambeds, and lakes. Anyone proposing to conduct activities resulting in a discharge to surface waters is required to obtain a RWQCB Certification or Waiver. Certifications are issued in association with a USACE CWA Section 404 Permit.

Depending on the complexity of a project, 401 certification may require: 1) a biological review with estimates of expected project impacts to water or adjacent wetlands; and 2) documentation of CEQA compliance or exemption. These documents are usually prepared by a State or local agency or by the State or Regional Board when there is no other CEQA lead agency (see Section B.4.4; State Water Board 2003). The permitting process time may take 3 to 4 months (VCPD 2006). Permit fees begin at $500, and range upward depending on the spatial extent of the proposed impact and the technical complexity of the project (State Water Board 2003).

In March 2007, the State Water Board authorized a general 401 Water Quality Certification Order for small habitat restoration projects, exempting eligible projects from the certification requirements described above (State Water Board 2007). Eligible small habitat restoration projects must: 1) be categorically exempt from CEQA (Class 33 exemption; see Section B.4.4); 2) be less than five acres or 500 linear feet of stream bank or coastline; 3) not be a compensatory mitigation project; 4) have the primary purpose of habitat restoration; and 5) take less than five years to construct. To apply for the Certification Order, the project proponent must provide the State Water Board and appropriate RWQCB with a Notice of Intent (NOI), along with a $60 fee, and Monitoring Plan at least 30 days prior to the proposed project. The level of detail on the Monitoring Plan and associated reporting depends on the scope and size of the project, but at a minimum must include: 1) functions of the impacted water resources; 2) project purpose and goals; 3) measurable performance standards appropriate to each goal; 4) timeframe and responsible party for determining attainment of performance standards; and 5) appropriate reporting schedule (at least annually for the period stated in performance standards). Monitoring reports which summarize monitoring findings, identify and discuss problems with attaining performance standards, propose corrective measures, and present collected data, must be submitted annually to the appropriate RWQCB. Finally, a Notice of Completion must be submitted to the appropriate RWQCB within 30 days of project completion.

B.4.3 CDFG Streambed Alteration Agreement

Under Chapter 6 of the California Fish and Game Code, CDFG is charged with the protection and conservation and the State's fish, wildlife, and plant resources, and their habitats. Fish and Game Code Sections 1600-1616 regulate activities that would "divert, obstruct, or change the natural flow or bed, channel, or bank of any river, stream, or lake designated by the CDFG in which there is at any time an existing fish or wildlife resource or from which those resources derive benefit, or will use material from the streambeds designated by the department". CDFG requires a Streambed Alteration Agreement (SAA) for any project that may alter the bed, banks or channel or a stream, or the adjacent riparian vegetation. A SAA is a written document that includes a description of the project or activity and project conditions necessary to protect fish or wildlife resources. Routine, non-invasive monitoring activities, such as surveying and sampling, do not require a SAA.

Fish and Game Code Section 1602 requires that CDFG be notified, on a standardized notification form (FG 2023) and project questionnaire (FG 2024), of any activity that will take place in or in the general vicinity of a river, stream or lake, including rivers or streams that only flow periodically. Following review of the completed notification package, CDFG determines whether the project requires a SAA. A field meeting with a CDFG representative is recommended after submitting the application materials (VCPD 2006). If CDFG determines that a proposed project may substantially adversely affect existing fish or wildlife resources, a SAA must be obtained and the proposed project, unless otherwise exempt, must comply with CEQA (see Section B.4.4). SAAs include project-specific conditions that must be satisfied as part of the agreement between the applicant(s) and the CDFG. These conditions are related to project techniques and any measures that will be incorporated into the project to mitigate or compensate for project-related impacts to fish, wildlife, and plant resources. The SAA process may take three to four months, provided that CEQA compliance is complete (VCPD 2006). A permitting fee is required and the amount is dependent on the cost of the project and the term of the agreement.

B.4.4 CEQA Compliance

CEQA requires California's state and local agencies to: (1) identify the significant environmental effects of their actions, independently, and with consideration of other reasonably foreseeable projects; and, (2) either avoid those significant environmental effects, where feasible, or mitigate those significant environmental effects, where feasible (CEQA 1970). CEQA applies to any action other than those exempted by law that requires a permit or entitlement from a California public agency (*i.e.*, "discretionary approval"), or is funded or undertaken by a California public agency. CEQA compliance can also be required by other permits and/or certifications prior to issuance; within Ventura County CEQA compliance in required for VCPD Land Use/Coastal Zone Permits, VCPWA Grading Permits, CDFG SAAs, and RWQCB 401 Certification (VCPD 2006).

Several types of projects are exempt from complying with CEQA either by law or because they are in a category of projects deemed to not have significant effects on the environment. There are three forms of exemptions: complete exemptions, partial exemptions, or exemptions that apply to the timing of NEPA compliance (CEQA Guidelines 2006). Examples of projects that are typically exempt include resource and environmental protection actions by regulatory agencies, wildlife habitat acquisition, small habitat restoration (less than five acres or 500 linear feet of stream channel), and maintenance activities. Examples of small habitat restoration projects that are typically exempt from CEQA include: 1) revegetation of disturbed areas with native plant species; 2) wetland restoration to improve waterfowl and other wetland species habitat; 3) stream or river bank revegetation to improve amphibian or native fish habitat; 4) restoration projects carried out primarily with hand labor rather than mechanized equipment; 5) stream or river bank stabilization with native vegetation or bioengineering techniques to reduce erosion and sedimentation; and 6) culvert replacement done in accordance with CDFG and NOAA Fisheries guidelines to improve habitat or reduce sedimentation (State Water Board 2007).

The public agency with the greatest authority over the project generally assumes the role of lead agency. The lead agency is the single agency responsible for determining the type of environmental analysis required by CEQA and preparing the required environmental review document (CEQA Guidelines 2006). In most cases, the project proponent prepares a draft of the required environmental review documents for lead agency review and adoption. In cases where compliance with both NEPA and CEQA is required, a joint document can be prepared if there is agreement by the lead agencies.

Unless it is determined a priori that an Environmental Impact Report (EIR) will be prepared for the project, compliance with CEQA requires a lead agency to complete an Initial Study that identifies the environmental impacts of the proposed project and determines whether those impacts are significant. Depending on the level of impact, the lead agency must prepare one of three environmental review documents. If the Initial Study finds that a project will have no significant impacts on the environment, a Negative Declaration (Neg Dec) can be prepared. A Neg Dec describes why a proposed project will not have significant effects on the environment and thus does not require an EIR to be prepared. If the Initial Study finds that a project will have impacts, but that those impacts can be mitigated to less-than-significant levels, then a Mitigated Negative Declaration (Mitigated Neg Dec) is prepared. A Mitigated Neg Dec describes the potential impacts of the proposed project and the conservation and/or mitigation measures to be implemented to reduce the impacts to less-than-significant levels. An EIR must be prepared if the project will result in significant environmental impacts. The purpose of an EIR is to: 1) inform public agencies and the public about any adverse effects that the proposed project may have on the environment; 2) present any minimization measures that may lessen the impact of the project; and 3) indicate alternatives to the project. If it is stated in an EIR that significant environmental impacts cannot be feasibly reduced to less-than-significant levels, then the lead agency must issue a statement of overriding consideration before it can approve the project (CEQA Guidelines 2006).

The time frame of processing either a Neg Dec or Mitigated Neg Dec is estimated at 180 days from the date the project application is accepted as complete by the lead agency. An EIR may take one year following application acceptance (VCPD 2006). The project proponents may be required to pay fees to the lead agency to compensate them for costs associated with CEQA compliance and document preparation, and for mitigation monitoring or reporting (VCPD 2006).

B.4.5 USFWS or NMFS Section 7 Consultation and Section 10 Incidental Take Permit

Both the USFWS and NMFS share responsibility for implementing the federal Endangered Species Act (ESA); USFWS generally manages land and freshwater species, while NMFS manages marine and anadromous species. Sections 7 and 10 of the ESA charge federal agencies to aid in the conservation of listed species, and require federal agencies to consult with USFWS or NMFS to ensure that project actions will not jeopardize the continued existence of any listed species or their habitats. In general, Section 7 consultation and/or the need for a Section 10 Incidental Take Permit is triggered when a project's Initial Study (per CEQA) or biological survey indicates that a federally listed or protected plant or animal species likely occurs within a project area. Federally listed species that have been documented to occur within the Santa Clara River watershed and could potentially trigger the need for Section 7 consultation or a Section 10 Incidental Take Permit during restoration strategy implementation are discussed in Section B.4.3. As an example, when federally-listed southern California steelhead are present in a proposed project area, the following actions trigger NMFS Section 7 consultation or a Section 10 Incidental Take Permit: 1) working in or near a stream channel between December 1 and June 15; 2) diverting water in a stream channel; 3) catching and relocating steelhead; and 4) grouting riprap along stream bank revetments (VCPD 2006).

Section 7 Consultation is specifically triggered when the project has a "federal nexus", which would often exist when the project requires another federal permit (*e.g.*, USACE Section 404 Permit). If the lead federal agency determines that a project may adversely affect a listed species or their habitat, USFWS or NMFS will require formal consultation followed by issuance of a biological opinion (BO) on whether the proposed action would likely jeopardize the survival of the listed species or adversely impact their habitat. The BO may include a statement of incidental take based on the anticipation of USFWS or NMFS that the proposed action may lead to harassing, harming, capturing, or killing listed species, but will not jeopardize the continued existence of the listed species. The extent of take allowed will be clearly specified. The set consultation period is to last no longer than 90 days and the subsequent BO is to be prepared within 45 days.

A Section 10 Incidental Take Permit is specifically triggered when non-federal entities such as states, counties, local governments, and private landowners propose a project action that might incidentally, but not intentionally, "take" a listed species. A Habitat Conservation Plan (HCP) must first be submitted prior to receiving this permit. A HCP is designed to offset harmful effects a proposed project action might have on listed species. The processing time for a Section 10 Incidental Take Permit may take 18 months or longer (VCPD 2006).

B.4.6 CDFG Section 2081 Incidental Take Permit

CDFG administers the California Endangered Species Act (CESA) (California Fish and Game Code §2050, et seq.). CESA serves to protect and preserve native plant and animal species, and associated habitats, threatened with extinction or that are experiencing significant population declines which, if not halted, would lead to a threatened or endangered designation. Section 2081 of CESA allows CDFG to require an Incidental Take Permit if: 1) a project's Initial Study (per CEQA) or SAA indicates that a plant or animal species that is state-listed as threatened or endangered likely occurs within a project area; and 2) the proposed project will potentially adversely affect the state-protected plant or animal or their habitat. The take of species that are "fully protected" and "specified birds" is never authorized (Fish and Game Code §3505, 3511, 4700, 5050, 5515, and 5517). Conversely, an Incidental Take Permit is not required for California Species of Concern (CSC), since they are not listed under either the federal ESA or CESA. CSC species protection is often addressed as part of a SAA, if applicable. A CDFG Section 2081 Incidental Take Permit may take 6 to 8 months for processing and will only be issued if the impacts of the authorized take are minimized and fully mitigated and the project will not jeopardize the continued existence of the species (VCPD 2006). State-protected species that have been documented to occur within the Santa Clara River watershed and could potentially trigger the need for a Section 2081 Incidental Take Permit during restoration strategy implementation are discussed in Section B.4.3.

B.4.7 State Water Board Construction General Permit and Storm Water Pollution Prevention Plan

The State Water Board and nine RWQCBs regulate discharges that may adversely impact surface and ground water. Their authority is derived from the federal CWA and the Porter-Cologne Water Quality Control Act (California Water Code). The State Water Board issues the General Permit for Discharges of Storm Water Associated with Construction Activity (Construction General Permit 99-08-DWQ) to projects that could result in wastewater discharges. Construction activities that are required to obtain a State Water Board Construction General Permit include those that disturb at least one acre of soil, the total of several individual developments equal at least one acre, or there is significant impact to water quality. Examples of construction projects that are subject to this permit include clearing, grading, and disturbances to the ground such as stockpiling or excavation. Depending on the nature of the construction activity and the decision of the RWQCB representative, additional Waste Discharge Requirements or National Pollution Discharge Elimination System permits may not be required (see Section B.4.8 below).

Discharges must initially notify the State Water Board of any wastewater discharges by submitting a Notice of Intent (NOI) to obtain coverage under the permit. The permit also requires that a Storm Water Pollution Prevention Plan (SWPPP) be developed and implemented. The SWPPP is a document that outlines Best Management Practices (BMPs) to avoid and minimize movement of sediment and pollutants into waters. The SWPPP must also contain a comprehensive monitoring program to be implemented if there is a failure of BMPs. The SWPPP and NOI should be prepared one month prior to construction activities begin (VCPD 2006). A waste discharger's identification (WDID) number will be issued to the discharger upon receipt of a complete NOI. Following construction activities, dischargers are required to file a Notice of Termination (NOT) with the RWQCB to certify that all State and local requirements have been satisfied in accordance with the Construction General Permit. Annual updates with the RWQCB may be required for long-term projects. A Construction General Permit may take one month for processing and will only be issued if the authorized discharge meets certain conditions (VCPD 2006).

B.4.8 RWQCB Waste Discharge Requirements and National Pollution Discharge Elimination System Permits

All wastewater discharges in the state, including land and surface and ground waters, are subject to regulation under the California Water Code and the CWA. The RWQCB will issue Waste Discharge Requirements (WDRs) to projects that discharge wastewater to land and groundwater. Discharges to surface waters from point sources require implementation of portions of the CWA, specifically the National Pollution Discharge Elimination System (NPDES) program. The RWQCB has the authority to issue a joint NPDES/WDR permit for discharges to surface waters from a point source. Several types of project activities may require either of these permits, including pumping or releasing water, diverting water in a stream, and dewatering. A Report of Waste Discharge (Form 200) is required for all discharge types. A project is not required to obtain an NPDES permit for discharges of dredged or fill material into water of the United States provided that the dredging or filling is authorized by a permit issued by the USACE or an EPA-approved state under Section 404 of CWA. The majority of WDRs and joint NPDES/WDRs are treated as project-specific Individual Permits which may take 6 to 8 months to process (VCPD 2006).

B.4.9 CCC Coastal Zone Development Permit

The California Coastal Act (CCA) and the Federal Coastal Zone Management Act are implemented by the CCC. The Coastal Zone encompasses some 1.5 million acres of land in California and extends inland about 3 miles, but can extend up to 5 miles in less-developed areas. The lower X miles of the Santa Clara River are within the Coastal Zone. A Coastal Zone Development Permit is required by any project that is a regulated land use or activity and occurs within the Coastal Zone. Many coastal cities and counties issue Coastal Zone Development Permits through their own Coastal Program (see Section B.4.10 below), but in certain coastal environments, such as lagoons, estuaries, and harbors, and public trust lands, Coastal Zone Development Permits are issued directly by the CCC (VCPD 2006). The time required to process this permit may take 6 to 8 months or longer depending on the project scope.

B.4.10 VCPD Land Use/Coastal Zone Permit

The Ventura County Planning Division (VCPD) is a division of the Ventura County Resource Management Agency. The VCPD regulates land uses according to the county's General Plan, Coastal Plan, and Coastal and Non-coastal Zoning Ordinances. Projects located in unincorporated Ventura County that involve regulated land uses may require a VCPD Land Use Permit. This permit is triggered if a project is within a stream or wetland and is part of a broader construction project, such as a residential or commercial development. Any projects in the Coastal Zone also require VCPD Land Use Permits that simultaneously serve as Coastal Zone Development Permits (VCPD 2006). Compliance with CEQA will generally be required for a VCPD Land Use/Coastal Zone Permit, and if applicable, the VCPD will serve as the lead agency. Permit processing may take between 6 to 8 months for small projects with limited environmental effects and several years for larger developments in sensitive areas (VCPD 2006).

B.4.11 VCWPD Encroachment and Watercourse Permits

The Ventura County Watershed Protection District (VCWPD) is charged by Ventura County Ordinance FC-18 to regulate activities in red-line streams. To this end, the VCWPD issues two types of permits: an Encroachment Permit and a Watercourse Permit (VCPD 2006). The need for these permits is triggered by projects that occur in a VCWPD red-line stream and that will alter the bed, bank, or channel of the stream or is located within the floodway (VCPD 2006). Projects that are in a VCWPD right-of-way or facility require an Encroachment Permit; projects that are not require a Watercourse Permit. The permit processing takes about one month and projects must demonstrate that project activities will not negatively impact the flood conveyance capacity of the red-line stream to be issued a permit (VCPD 2006).

B.4.12 VCPD Protected Tree Permit

The Ventura County Non-coastal Zoning Ordinance (Sections 8107-25) identifies several tree species that are protected from damage or removal. Protected trees are defined as any heritage or historical tree of significant size that are usually associated with streams and wetlands. A Protected Tree Permit issued by the VCPD is required if tree damage or removal is part of a project requiring a discretionary permit. Specifically, a VCPD Protected Tree Permit is triggered when a project involves pruning, trimming, removal or disturbance either within the drip line (canopy perimeter) of protected trees or that exceeds the allowed minimums of trunk or branch circumference as well as other measures (VCPD 2006). Discretionary permits may take at least three months depending on the scope of the project and the associated effects to protected trees. A Ministerial Tree Permit may be approved by the Planning Director and issued in one day provided that all application requirements have been completed and one of several potential situations are present, including emergency actions to safeguard human safety and infrastructure. Trees protected under the Venture County Non-coastal Zoning Ordinance are listed in Table B-4.

Table B-4. Trees protected by the Ventura County Planning Division.

Tree	Species
Heritage Tree	All species
Historical Tree	Any species
Alder *(Alnus)*	All species
Ash *(Fraxinus)*	All species
Bay *(Umbellularia californica)*	This species only
Cottonwood *(Populus)*	All species
Elderberry *(Sambucus)*	All species
Big Cone Douglas Fir *(Pseudotsuga macrocarpa)*	This species only
White Fir (*Abies concolor)*	This species only
Juniper (*Juniperus californica)*	This species only
Maple (*Acer macrophyllum)*	This species only
Oak (*Quercus)*	All species
Pine *(Pinus*)	All species
Sycamore (*Platanus*)	All species
Walnut (*Juglans)*	All species

Source: VCPD (2006)

B.4.13 VCPWA Grading Permit

The Ventura County Public Works Agency (VCPWA) oversees construction projects in the unincorporated areas of Ventura County. The VCPWA issues Grading Permits for projects involving moving earth. The permit is issued in accordance with grading regulations in the Ventura County Building Code, Section 3306. This permit may be triggered by several activities, including: 1) excavations greater than two feet in depth; 2) excavations that cut a slope greater than five feet in height and steeper than 67%; 3) fill that is greater than one foot in depth and is on slopes that exceed 20%; and 4) fill that is greater than three feet in depth and exceeds 50 cubic yards/lot. A ministerial permit may be issued for projects that do not trigger CEQA compliance. This permit type may take one month to process (VCPD 2006). Projects that are within a waterway or wetland will trigger CEQA compliance and will therefore require a discretionary permit. Discretionary permits may take 6 to 8 months to process (VCPD 2006).

B.5 Programmatic Permitting

The project permitting examples and discussions of environmental compliance requirements in the previous sections assume that permits for restoration strategies on the Santa Clara River would be done on a project-by-project basis. However, since all restoration strategies will be occurring within the Santa Clara River watershed, many strategies will have project areas greater than 10 acres, and many of the same permits will be needed for each strategy, a programmatic approach to permitting may be preferred. A programmatic approach would involve acquiring one set of permits for all restoration strategies, or three sets of permits for each of the primary restoration strategies, throughout the watershed. Programmatic permitting is designed to address programs of two or more actions that are not necessarily joined by interrelatedness or interdependence, and so might have been permitted separately, with predictable environmental effects, and similar requirements for project approval (NMFS 2003). Programmatic permitting analyzes the combined effects of all the actions that make up a program (in this case, levee setback, floodplain re-contouring, non-native, invasive plant removal, and active revegetation), and presents that analysis and its conclusion in a single document.

This approach would require more preparation and reporting up-front, but will likely save significant effort for the duration of restoration implementation and result in more comprehensive measures to prevent or mitigate for short-term negative impacts to the environment. NMFS (2003), using the example of ESA consultation, describes the pros and cons of programmatic approaches:

> *"The primary benefits of programmatic consultation are more consistent use of conservation measures, the ability to address the effects of multiple activities at larger scales, efficient workload management, improved internal communication, better public relations, and a sharper vision of interagency consultation overall. The primary drawback of programmatic consultation concerns the availability of appropriate information for analysis and decision making. Developing adequate information to initiate formal programmatic consultation can be time consuming. However, the programmatic consultation process can account for information gaps and include processes to ensure the agencies possess adequate information to make scientifically sound and legally defensible decisions, when those decisions are made."*

Using a programmatic approach, permits would be acquired for one large-scale restoration project that includes levee-setback, floodplain re-contouring, non-native, invasive plant removal, and active revegetation components. A project of this nature would required that all the permits identified in Table B-1 be acquired, but they would only need to be acquired once. Given the large scope of work and project area, reporting requirements for each of these permits would be extensive. For example, CEQA compliance would require the preparation of an Initial Study and most likely a Mitigated Neg Dec to demonstrate how the implementation of the restoration strategies will prevent or mitigate for short-term negative impacts on the environment. The completed CEQA document, which includes a detailed project description and analysis of impacts, would assist in acquiring a Section 404 Individual Permit from USACE, 401 Certification from RWQCB, an SAA from CDFG, and a Grading Permit from VCPWA. The Section 404 Permit and SAA would trigger programmatic consultation by USFWS, NMFS, and CDFG to evaluate potential project impacts to federally- and state-protected species. Approaches to programmatic consultation include: 1) an informal concurrence process for "not likely to adversely affect" actions that are not reasonably expected to result in the take of a protected species; 2) a "full" programmatic approach for actions that are "likely to adversely affect" protected species and which may be exempted from take without further review; and 3) a "tiered" programmatic approach for "likely to adversely affect" actions that require subsequent project-specific review before a take exemption is applied (NMFS 2003).

In addition to the greater reporting requirements, there may also be monitoring requirements, such as tracking of incidental take of protected species, associated with programmatically permitted restoration programs, since the scope of permitting extends beyond an individual project. Programmatically acquired permits are also more likely than individual permits to require re-initiation when new information becomes available, to respond to adaptive management or new policy development, or to adjust to changes in the status of listed species or designated critical habitats (NMFS 2003).

B.6 References

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APPENDIX C
Revegetation Species Requirements

Description of column entries for Table C-1: (by column number)

Growth Form: forb, graminoid, shrub, or tree growth form

Wetland Indicator Status

- OBL (Obligate Wetland). Occur almost always (estimated probability >99%) under natural conditions in wetlands.
- FACW (Facultative Wetland). Usually occur in wetlands (estimated probability 67%-99%), but occasionally found in non-wetlands.
- FAC (Facultative). Equally likely to occur in wetlands or non-wetlands (estimated probability 34%-66%).
- FACU (Facultative Upland). Usually occur in non-wetlands (estimated probability 67%-99%), but occasionally found in wetlands (estimated probability 1%-33%).
- UPL (Obligate Upland). Occur in wetlands in another region, but occur almost always (estimated probability >99%) under natural conditions in non-wetlands in the region specified.
- + Indicates a frequency toward the higher end of the category (more frequently found in wetlands)

Moisture Use: Relative moisture requirement for growth (Low, Medium, High)

Minimum Root Depth (inches): Minimum depth of soil required for good growth in inches

Precipitation

- **Minimum**: Minimum precipitation required for good growth in inches.
- **Maximum**: Maximum precipitation tolerated for good growth in inches.

Minimum Temperature (°F): Minimum temperature under which the plant will survive in degrees F.

Adaptability to Soil Types: Whether the species establishes and grows in fine/medium/coarse textured soils? (yes/no)

Nitrogen Fixation: Amount of nitrogen fixed relative to other species (None, Low, Moderate, High, Unknown (blank))

Fertility Requirement: Relative fertility requirements needed for growth (Low, Medium, High)

pH

- **Minimum**: Minimum pH under which the plant can maintain good growth.
- **Maximum**: Maximum pH under which the plant can maintain good growth.

Tolerance Levels

- **Anaerobic**: Relative tolerance of anaerobic conditions of the growth medium (None, Low, Medium, High)
- **Drought**: Relative tolerance to drought conditions compared to other plants in the same region (None, Low, Medium, High)
- **Salinity**: Tolerance to saline soil conditions (None, Low, Medium, High)
- **Hedge**: Tolerance to hedging by livestock or wildlife (None, Low, Medium, High, Unknown (blank))
- **Shade**: Relative tolerance for this plant to grow in shade conditions (Intolerant, Indeterminate, Tolerant)
- **CaCO3**: Relative tolerance of calcium carbonate in the growth medium (None, Low, Medium, High, Unknown (blank))

Table C-1. Revegetation species requirements.

Species	Growth Form	Wetland Indicator Status		Moisture Use	Minimum Root Depth (inches)	Precip.		Temperature Min. (F)	Adaptability to Soil Type			Nitrogen Fixation	Fertility Requirement	pH		Tolerance Levels					
		National	California			Min	Max		Fine	Medium	Coarse			Min	Max	Anaerobic	Drought	Salinity	Hedge	Shade	CaCO3
Bigberry manzanita (*Arctostaphylos glauca*)	shrub	UPL	UPL	L	30	8		12	N	Y	Y	*None*	L	5.9	7	*None*	H	*None*	M	Intermediate	L
White alder (*Alnus rhombifolia*)	tree	FACW	FACW	H	12	50	125	-23	Y	Y	Y	L	L	6	7.5	L	*None*	*None*	M	Tolerant	*None*
Buckbrush (*Ceanothus cuneatus*)	shrub	UPL	UPL	M	20	16	36	-13	Y	Y	Y	L	L	7.1	8.5	*None*	H	M	M	Intolerant	H
Mountain mahagony (*Cercocarpus montanus*)	shrub	UPL	UPL	L	20	10	25	-38	N	Y	Y	L	L	6	8	*None*	H	*None*	M	Intermediate	H
Yerba santa[1] (*Eriodictyon crassifolium*)	shrub	UPL	UPL	L	6	9	24	-3	Y	Y	Y	*None*	L	7	8	*None*	H	*None*	H	Intolerant	L
California sycamore (*Platanus racemosa*)	tree	FACW	FACW	M	36	14	20	7	N	Y	Y	*None*	L	5.8	7.3	M	M	*None*	*None*	Intolerant	M
Balsam popular (*Populus balsamifera*)	tree	FACU FACW	FACW	H	30	20	70	-43	Y	Y	Y	*None*	M	4.5	7	M	L	*None*	*None*	Intolerant	H
Fremont cottonwood (*Populus fremontii*)	tree	FACW-, FACW	FACW	H	32	20	26	-13	Y	Y	Y	*None*	M	6	8	M	M	L	*None*	Intolerant	M
California live oak (*Quercus agrifolia*)	tree	UPL	UPL	M	36	20	60	7	N	Y	Y	*None*	L	5.5	7.5	*None*	M	L	*None*	Intolerant	L
Valley oak (*Quercus lobata*)	tree	FAC	FAC	M	42	16	40	7	N	Y	Y	*None*	M	4.5	7.5	*None*	M	*None*	*None*	Intolerant	*None*
Narrowleaf willow (*Salix exigua*)	shrub	FACW OBL	OBL	H	20	20	30	-38	N	Y	Y	*None*	L	6	8.5	H	M	L	M	Intermediate	H
Arroyo willow[2] (*Salix lasiolepis*)	tree/ shrub	FACW	FACW	H	26	35	60	7	Y	Y	Y	*None*	M	5.5	7.5	H	*None*	*None*	M	Intolerant	L
Shining willow (*Salix lucida*)	tree/ shrub	FACW	FACW	H	10	30	60	-43	Y	Y	N	--	M	5.8	7.2	M	L	*None*	L	Intermediate	M

Species	Growth Form	Wetland Indicator Status		Moisture Use	Minimum Root Depth (inches)	Precip.		Temperature Min. (F)	Adaptability to Soil Type			Nitrogen Fixation	Fertility Requirement	pH		Tolerance Levels					
		National	California			Min	Max		Fine	Medium	Coarse			Min	Max	Anaerobic	Drought	Salinity	Hedge	Shade	CaCO3
Blue elderberry[3] (*Sambucus mexicana*)	tree/ shrub	FACU FAC	FAC	L	12	10	60	-38	N	Y	Y	*None*	L	4.9	7.5	M	H	*None*	L	Intermediate	M
Chamise (*Adenostoma fasciculatum*)	shrub	UPL	UPL	M	8	6	30	32	Y	Y	Y	--	L	4	6	*None*	H	M	H	Intolerant	L
Big sagebrush (*Artemisia tridentata*)	shrub	UPL	UPL	M	20	6	16	-43	N	Y	N	--	L	6	8.2	*None*	H	L	L	Intolerant	H
Big saltbush (*Atriplex lentiformis*)	shrub	FAC FACW	FAC	L	20	4	20	7	N	Y	N	*None*	M	7	10	H	H	H	H	Intolerant	H
Coyotebrush (*Baccharis pilularis*)	shrub	UPL	UPL	L	20	12	30	22	N	Y	Y	--	L	6	8.5	*None*	H	H	H	Intolerant	H
Mule's fat[4] (*Baccharis salicifolia*)	shrub	FACW	FACW	M	12	10	18	-3	Y	Y	Y	--	L	7	8.5	L	L	H	L	Intolerant	H
California brome (*Bromus carinatus*)	graminoid	UPL	UPL	L	8	8	20	17	N	Y	Y	--	L	5.5	8	*None*	M	M	*None*	Intolerant	M
Saltgrass (*Distichlis spicata*)	graminoid	FAC+, FACW+	FACW	M	2	5	70	-35	Y	Y	N	*None*	M	6.4	10.5	H	M	H	*None*	Intolerant	H
Western rye (*Elymus glaucus*)	graminoid	FACU	FACU	L	12	16	60	-38	Y	Y	Y	--	L	5.8	8.5	H	H	M	*None*	Tolerant	H
California brittlebush[5] (*Encelia californica*)	shrub	UPL	UPL	L	12	n/a	10	27	Y	Y	Y	--	L	7	8.5	*None*	H	*None*	H	Intolerant	H
Eastern Mohave buckwheat (*Eriogonum fasciculatum*)	shrub	UPL	UPL	L	10	8	20	7	N	Y	Y	--	L	7.5	8.5	*None*	H	M	L	Intolerant	H
Western goldentop (*Euthamia occidentalis*)	forb	FACW OBL	OBL	M	10	16	32	-28	Y	Y	Y	*None*	M	4.5	7	L	M	*None*	*None*	Intolerant	M
Salt heliotrope (*Heliotropium curassavicum*)	forb	FAC OBL	OBL	M	10	10	24	-28	Y	Y	N	*None*	L	6.5	8.5	L	M	H	*None*	Intolerant	*None*

Species	Growth Form	Wetland Indicator Status		Moisture Use	Minimum Root Depth (inches)	Precip.		Temperature Min. (F)	Adaptability to Soil Type			Nitrogen Fixation	Fertility Requirement	pH		Tolerance Levels					
		National	California			Min	Max		Fine	Medium	Coarse			Min	Max	Anaerobic	Drought	Salinity	Hedge	Shade	CaCO3
Mexican rush (*Juncus mexicanus*)	graminoid	FACW	FACW	M	8	8	20	-18	Y	Y	N	*None*	M	6.2	8.2	H	L	H	*None*	Intolerant	M
Beardless wildrye (*Leymus triticoides*)	graminoid	FACU	FAC	H	10	7	60	-33	Y	Y	N	*None*	M	6	9	H	H	H	*None*	Intolerant	H
Hardstem bulrush[6] (*Scirpus acutus*)	graminoid	OBL	OBL	H	14	12	60	-38	Y	Y	N	*None*	M	5.2	8.5	H	M	L	*None*	Intolerant	M
California bulrush[7] (*Scirpus californicus*)	graminoid	OBL	OBL	H	14	40	60	17	Y	Y	N	*None*	M	4	9	H	L	L	*None*	Intolerant	M
Chapparal yucca (*Yucca whipplei*)	shrub	UPL	UPL	L	14	8	14	7	N	Y	Y	*None*	L	6.4	8.5	*None*	H	L	*None*	Intolerant	M

Source: USDA and NRCS. 2002. The PLANTS Database, Version 3.5 (http://plants.usda.gov). National Plant Data Center, Baton Rouge, LA 70874-4490 USA.

[1] Classification information based on *Eriodictyon californicum*.
[2] Data is for the "Rogue" cultivar.
[3] Listed under *Sambucus nigra* L. ssp. *cerulea*
[4] Status taken from *Baccharis glutinosa*.
[5] Classification information based on *Encelia farinosa*.
[6] Listed as *Schoenoplectus acutus* var. *acutus*
[7] Listed as *Schoenoplectus californicus*

Key to abbreviations:
Y, N = Yes, No
H, M, L = High, Medium, Low
-- = unknown