Ventura River Watershed Spawner Surveys 2013

Prepared by:

Sam Bankston[1], Heidi Block[1] and Chris Lima[2]

Pacific States Marine Fisheries[1] Commission and California Department of Fish and Wildlife[2]

Introduction:

In 1997 Southern California steelhead were listed as endangered under the Federal Endangered Species Act. The National Marine Fisheries service has created a recovery plan that outlines necessary actions required before delisting can occur. This plan outlines 5 biogeographic population groups (BPGs) which will require a minimum number of viable populations within each group before delisting can occur. Within each BPG, watersheds are classified based on their intrinsic potential into Core 1, 2 or 3 populations, with Core 1 populations having the highest priority for recovery.

The Ventura River Watershed is listed as a Core 1 population for recovery in the Monte Arido Highlands BPG. To understand whether recovery actions are successful, it is important to have a clear idea of the steelhead population in this watershed. One way to help determine the size of the population is to look at the number of spawning individuals. One method of examining the spawning population in this watershed is to complete regular spawner surveys during the winter spawning season. The California Department of Fish and Wildlife began conducting spawner surveys throughout the Ventura River Watershed starting in January 2013. These surveys include counts and measurements of redds, counts of live fish, as well as counts of other aquatic and riparian organisms of concern.

This report covers results from the first season of spawner surveys conducted for the Department of Fish and Wildlife from January 2013 to June 2013 in the Ventura River Watershed. Surveys were conducted in eight reaches, four in the Ventura River main stem, two in San Antonio Creek, and two in North Fork Matilija Creek (Figure 1).

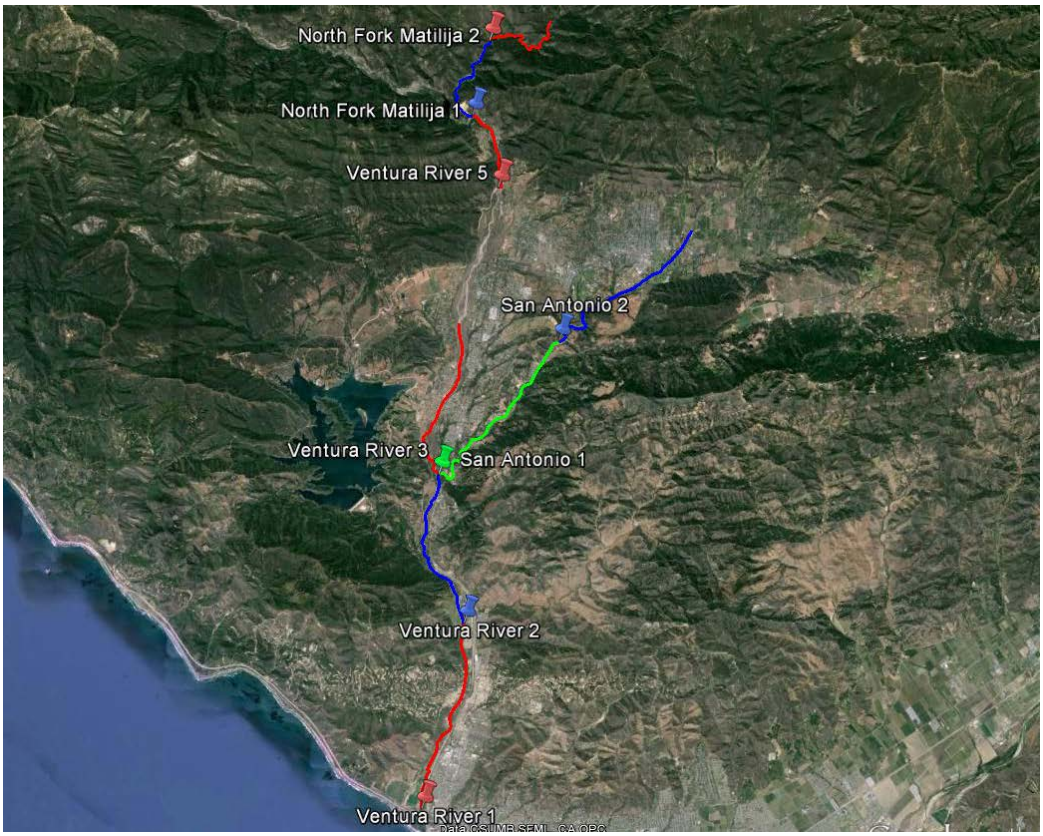


Figure 1. The surveyed portion of the Ventura River watershed highlighting the eight surveyed reaches.

Methods:

Spawner surveys were conducted from January 17th, 2013 through June 13th, 2013 in the Ventura River Watershed. Reaches were surveyed every two weeks following their initial survey date as staffing and other logistics permitted. Teams of two or more walked stream reaches looking for new and old redds, live fish, carcasses and other species of interest. Surveys were conducted using the California Department of Fish and Wildlife Salmonid Spawning Survey Personal Digital Assistant Data Entry Protocol 2011-2012 and all data was entered into Palm PDA's using a custom Pendragon® forms database. Summaries of these protocols are presented below.

Survey Header Data

Prior to beginning any survey, the following data was collected and entered into the PDA; date, watershed, stream name, reach, method (walking), weather (sunny, cloudy, etc.), air temperature, water temperature, water visibility, and surveyors names.

Redd Counting Protocol

All newly observed redds were flagged and measured for pot length (P_L), pot width (P_W), pot depth (D), pot substrate (P), tail spill length (TS_L), tail spill widths (TS) (taken from 1/3 and 2/3 the distance from the top of the tail spill) and tail spill substrate (Figure 1). GPS data was collected using a Garmin 60CSx. Flagging was accomplished by affixing flagging tape downstream of the red labeled with the date, redd record number, bearing and distance from the flag to the center of redd , the total redd length(the combined pot and tail spill lengths of the redds), the redd age, and the year. This served to keep from double counting redds and to track if redds underwent any changes between subsequent surveys. Redd age was assigned according to the following rubric:

1=New since last survey
2=Previously identified and still measurable
3=No longer measurable but still visible
4=No redd apparent only flag
5=Poor conditions cannot see substrate

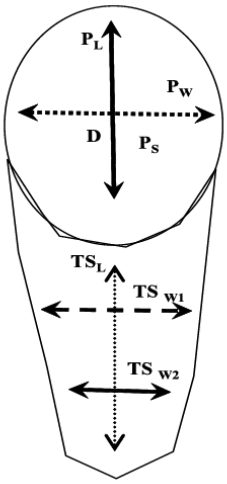


Figure 2: Redd measurement locations

Oncorhynchus mykiss Observations

Data was taken for all visual observations of *O. mykiss* on the Palm PDA. Observations were recorded as either an individual or as a batch count when multiple individuals were observed in the same habitat unit. In each instance data was taken for condition (live or dead, if dead, level of decomposition was noted), sex, length (total length), and GPS coordinates. When carcasses were encountered, measurements were taken and the carcasses were collected for eventual transfer to the National Marine Fisheries Service for analysis.

Wildlife Observations

For the duration of the survey season, data was gathered for the federally threatened species (California red-legged frog, *Rana draytonii*) and California Fish and Wildlife species of special concern (Pacific Pond Turtle, *Actinemys marmorata;* and Two-striped Gartersnake, *Thamnophis hammondii.* Data taken for these observations followed the same protocol for *O. mykiss* observations outlined above.

Results:

Redd Survey Results

A total of 23 redds were observed during the 2013 spawner survey season. These redds were observed in 5 reaches, Ventura Reaches 2 and 3 (VR2 and VR3), San Antonio Reach 1 (SA1), and North Fork Matilija Reaches 1 and 2 (NFM1 and NFM2) (Table 1). Ventura reach 4 was never surveyed because it remained dry for the duration of the survey season. North Fork Matilija 1 and 2 had the largest number of redds, with 9 and 8 redds respectively (Table 1). Redds were observed in this watershed between February 27, 2013 and May 23, 2013, with the majority observed in March and April.

The average total length of redds observed throughout the Ventura River watershed was 89.3 cm including the pot and tail spill. Table 2 outlines the average measurements for redds in the surveyed reaches, as well as the averages for the watershed as a whole.



Figure 3. Redd observed in North Fork Matilija, Reach 1 with a total length of 100 cm. Size and shape are representative of most observed redds.

Table 1: New redd observations by stream reach. Redd observations are given for each survey and stream reach. The number of redds seen on the survey is shown in red. When a survey was completed but no new redds were found a black 0 is used. Blank cells indicate days where no survey occurred.

Survey Date	**Stream Reach**							
	VR1	VR2	VR3	VR5	SA1	SA2	NFM1	NFM2
1/17/2013	0	0						
1/31/2013	0	0						
2/1/2013		0						
2/14/2013	0	0			0			
2/27/2013					**1**	0	**1**	
2/28/2013	0	**2**						
3/12/2013		0						
3/13/2013		0			**1**	0		
3/14/2013							**4**	**1**
3/26/2013					**1**	0	**2**	**3**
3/28/2013		0						
4/3/2013	0							
4/4/2013				0				
4/9/2013					0	0		
4/11/2013		0					**2**	**1**
4/18/2013	0		**1**					
4/22/2013		0			0	0		
4/23/2013							0	**2**
4/26/2013				0				
5/6/2013		0	0		0			
5/10/2013							0	0
5/21/2013		0						
5/23/2013							0	**1**
6/6/2013							0	0
6/13/2013		0						
TOTAL	**0**	**2**	**1**	**0**	**3**	**0**	**9**	**8**

Table 2: Average Redd Measurements. Average redd measurements are given for each surveyed reach and for the watershed as a whole.

Surveyed Reaches	# of Redds	Avg. Pot Length (cm)	Avg. Pot Width (cm)	Avg. Pot depth (cm)	Avg. Pot substrate Size (cm)	Avg. Tail spill length (cm)	Avg. Tail Spill Width 1 (cm)	Avg. Tail Spill Width 2 (cm)	Avg. Tail Spill Substrate size (cm)	Avg. Total Length (cm)
VR1	0	-	-	-	-	-	-	-	-	-
VR2	2	37.5	40.0	7.5	2.0	50.0	40.0	32.5	1.0	87.5
VR3	1	42.0	35.0	3.0	4.0	40.0	24.0	20.0	2.0	82.0
VR5	0	-	-	-	-	-	-	-	-	-
SA1	3	35.7	36.3	5.7	3.0	66.3	44.3	42.0	1.3	102.0
SA2	0	-	-	-	-	-	-	-	-	-
NFM1	9	34.0	33.3	4.4	1.9	57.8	33.4	26.3	0.9	91.8
NFM2	8	30.4	34.7	4.9	1.3	53.9	33.1	27.0	0.9	83.4
Watershed Total	**23**	**33.8**	**34.9**	**5.0**	**2.0**	**56.1**	**34.9**	**28.9**	**1.0**	**89.3**

Oncorhynchus mykiss Observation Results

O. mykiss observations were recorded during each of the spawner surveys. It is likely that with repeat surveys of the same reaches some of the same *O. mykiss* individuals were recorded more than once. *O. mykiss* were observed in 5 reaches throughout the Ventura River watershed: Ventura Reach 2 (Figure 5), North Fork Matilija 1 and 2 (Figure 6), and San Antonio 1 and 2 (Figure 7).

O. mykiss were recorded only when there was a positive sighting. Generally O. mykiss observations were recorded when fish were over 10 cm in size. Fish measuring 10 cm or less were often difficult to differentiate from similar species under survey conditions. There were a few instances where young of the year *O. mykiss* were recorded; this was when fry were confirmed as being the correct species. These have not been included in the graphs as they were not consistently recorded by different survey groups.



Figure 4. *O. mykiss* observed in Ventura River, Reach 2

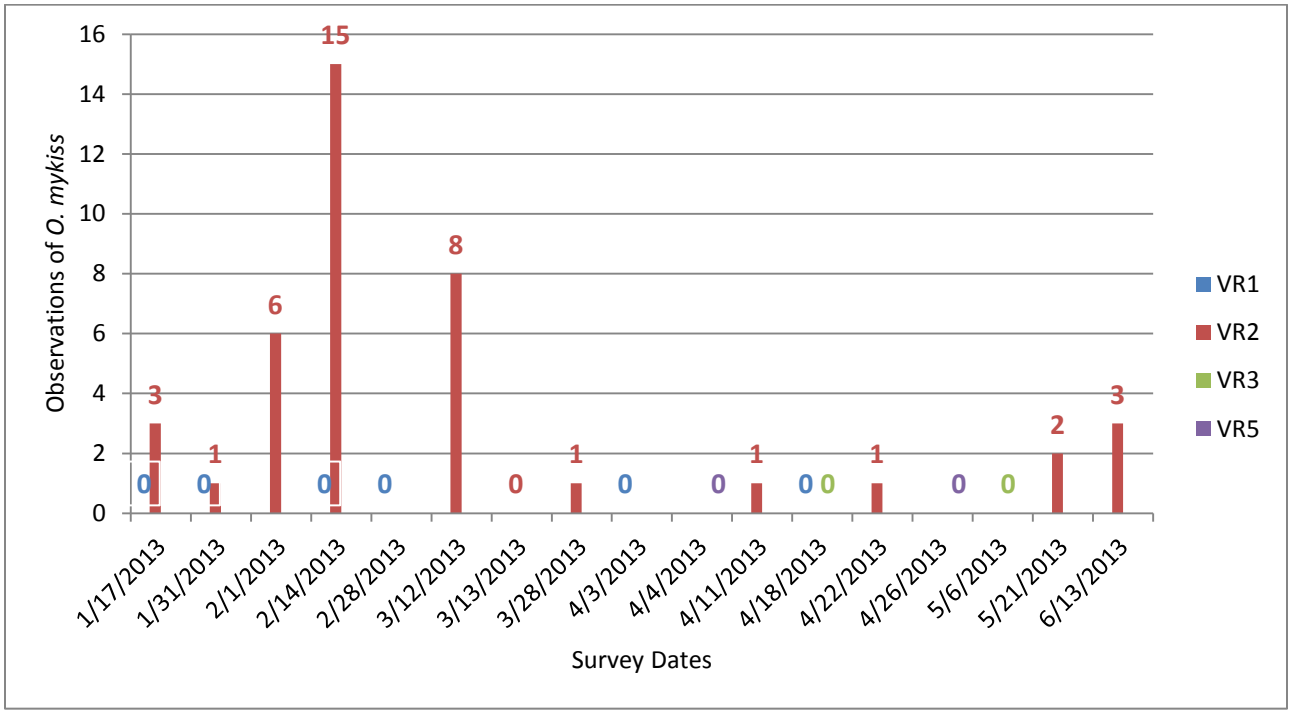


Figure 5: Observations of *O. mykiss* in the Ventura River. Each reach is represented by a different color. *O. mykiss* were only observed in reach 2 of the Ventura River. The colored zeros represent the dates where the other reaches were surveyed and no fish were observed.

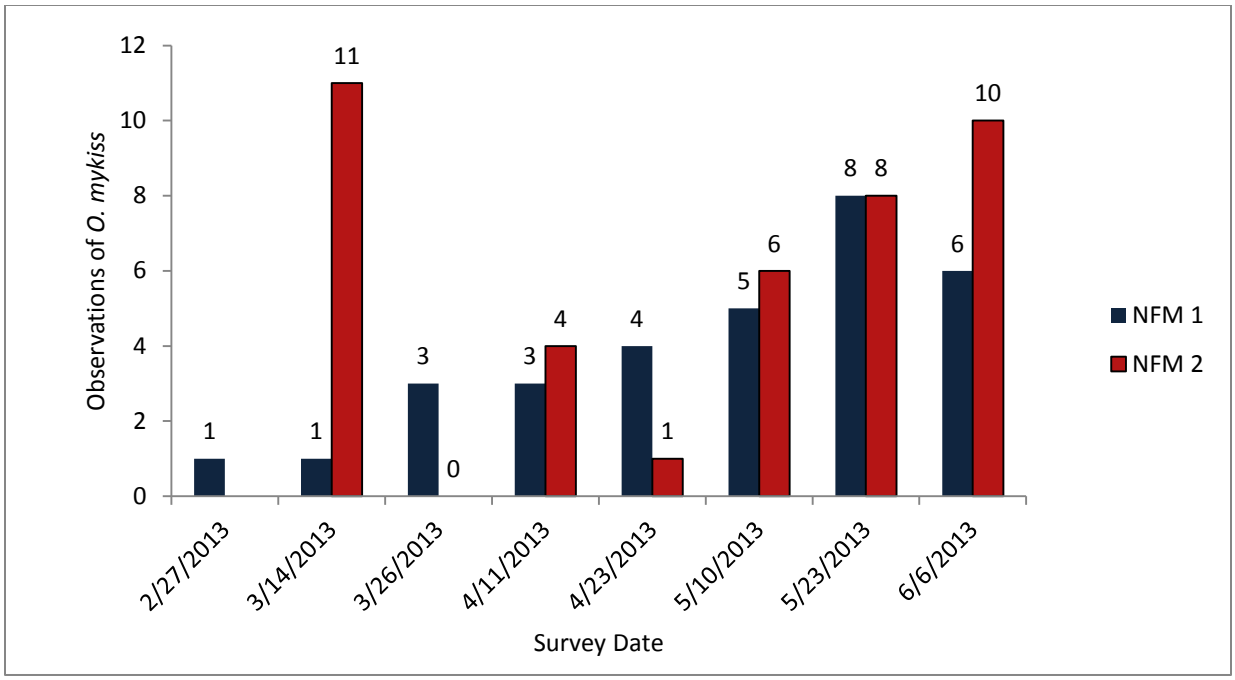


Figure 6: Observations of *O. mykiss* (>3in) in North Fork Matilija Creek. Observations are recorded by survey dates. Zeros indicate that a survey was completed but no fish were observed. North Fork Matilija

Reach 1 is shown in blue and North Fork Matilija Reach 2 is in red. For this graph fish observations are included for individuals that were greater than 3 inches in length.

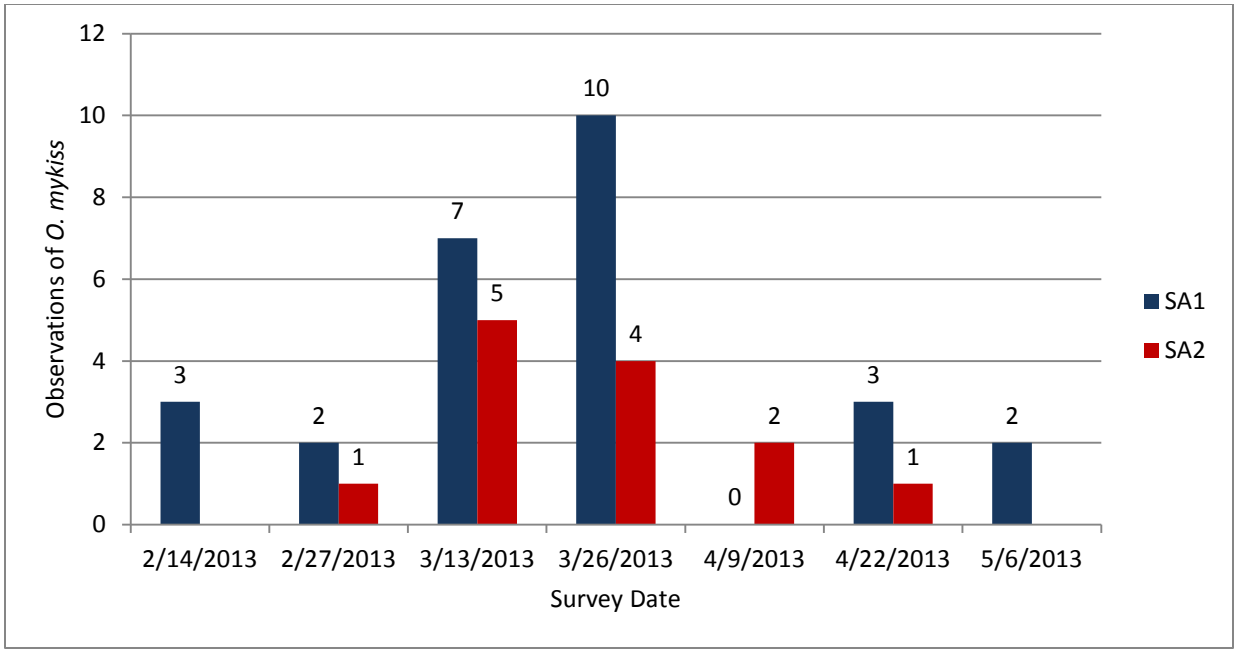


Figure 7: Observations of *O. mykiss* in San Antonio Creek. Survey dates are shown on the x-axis and observations of *O. mykiss* are shown on the y-axis. Zeros above the x-axis indicate that there was a survey completed on that survey date but no fish were observed. Observations from San Antonio Reach 1 are in blue and observations from Reach 2 are in red.

Other Species Observation Results

Observations of the federally threatened California Red-legged Frog and the California Department of Fish and Wildlife Species of Special Concern Pacific Pond Turtle and Two-striped Gartersnake were generally recorded for all surveys. Observations were made opportunistically without altering survey protocols or methodology.

California Red-legged Frogs

California Red-legged frog (CRLF) *Rana draytonii* observations consisted only of egg masses with the exception of an 8 cm tadpole seen on June 13th. The absence of adult frog observations can likely be attributed to abundant cover combined with the fact that mature frogs are primarily nocturnal. Egg masses were observed from March to April with the majority being seen in San Antonio Creek (Table 3). Efforts were made to avoid double counting by referencing GPS data from previous surveys.

Table 3. New CRLF observations by stream reach. CRLF observations are given for each survey and stream reach. The number of CRLF seen on the survey is shown in red. The single tadpole observation is shown in blue. When a survey was completed but no new CRLF were observed, a black 0 is used. Blank cells indicate days where no survey occurred.

Survey Date	**Stream Reach**							
	VR1	VR2	VR3	VR5	SA1	SA2	NFM1	NFM2
1/17/2013	0	0						
1/31/2013	0	0						
2/1/2013		0						
2/14/2013	0	0			0			
2/27/2013					0	0	0	
2/28/2013	0	0						
3/12/2013		0						
3/13/2013		0			0	0		
3/14/2013							0	0
3/26/2013					**1**	**5**	0	0
3/28/2013		**1**						
4/3/2013	0							
4/4/2013				0				
4/9/2013					0	**3**		
4/11/2013		0					0	0
4/18/2013	0		0					
4/22/2013		0			0	**1**		
4/23/2013							0	0
4/26/2013				0				
5/6/2013		0	0		0			
5/10/2013							0	0
5/21/2013		0						
5/23/2013							0	0
6/6/2013							0	0
6/13/2013		**1**						
TOTAL	**0**	**2**	**0**	**0**	**1**	**9**	**0**	**0**



Figure 8. California Red-legged Frog egg mass in San Antonio Creek.

Two-striped Gartersnake

Observations of Two-striped Gartersnakes (TSGS*) Thamnophis hammondii,* were recorded only when an individual could be positively identified. In instances where snakes took cover before they could be thoroughly observed no data was taken. This was necessary to keep from including misidentified snakes of similar physical appearance in our counts. TSGSs were seen throughout the Ventura River watershed from late March to early June with the majority of observations taking place in reach 2 of North Fork Matilija (Table 4). Double counting may have occurred, as individuals were never marked or tagged.

Table 4. New TSGS observations by stream reach. TSGS observations are given for each survey and stream reach. The number of TSGS seen on the survey is shown in red. When a survey was completed but no new TSG were observed a black 0 is used. Blank cells indicate days where no survey occurred.

Survey Date	**Stream Reach**							
	VR1	VR2	VR3	VR5	SA1	SA2	NFM1	NFM2
1/17/2013	0	0						
1/31/2013	0	0						
2/1/2013		0						
2/14/2013	0	0			0			
2/27/2013					0	0	0	
2/28/2013	0	0						
3/12/2013		0						
3/13/2013		0			0	0		
3/14/2013							0	0
3/26/2013					0	0	0	**1**
3/28/2013		0						
4/3/2013	0							
4/4/2013				0				
4/9/2013					0	0		
4/11/2013		0					**1**	0
4/18/2013	**1**		0					
4/22/2013		0			0	0		
4/23/2013							0	**1**
4/26/2013				0				
5/6/2013		0	0		0			
5/10/2013							0	**4**
5/21/2013		**1**						
5/23/2013							**1**	**1**
6/6/2013							0	**3**
6/13/2013		0						
TOTAL	**1**	**1**	**0**	**0**	**0**	**0**	**2**	**10**



Figure 9. Two-striped Gartersnake in North Fork Matilija, Reach 2.

Pacific Pond Turtles

Pacific Pond Turtles (PPT) *Actinemys marmorata*, were seen in every reach surveyed. Observations were recorded from mid-March to mid-June. The greatest concentrations were seen in the Ventura River main stem (Table 5). PPT observations were only recorded when a turtle was positively identified. Double counting may have occurred, as individuals were never marked or tagged.



Figure 10. Pacific Pond Turtle neonate in the Ventura River, Reach 5.

Table 5. New PPT observations by stream reach. PPT observations are given for each survey and stream reach. The number of PPT seen on the survey is shown in red. When a survey was completed but no new PPT were observed a black 0 is used. Blank cells indicate days where no survey occurred.

Survey Date	Stream Reach							
	VR1	VR2	VR3	VR5	SA1	SA2	NFM1	NFM2
1/17/2013	0	0						
1/31/2013	0	2						
2/1/2013		0						
2/14/2013	0	0			0			
2/27/2013					0	0	0	
2/28/2013	0	0						
3/12/2013		**1**						
3/13/2013		0			**3**	**1**		
3/14/2013							**1**	0
3/26/2013					**2**	0	0	**1**
3/28/2013		**3**						
4/3/2013	**3**							
4/4/2013				**20**				
4/9/2013					0	**3**		
4/11/2013		**2**					0	0
4/18/2013	**5**		0					
4/22/2013		**4**			**3**	**2**		
4/23/2013							0	**1**
4/26/2013				0				
5/6/2013		**1**	**5**		**5**			
5/10/2013							0	**1**
5/21/2013		**1**						
5/23/2013							**1**	**1**
6/6/2013							0	0
6/13/2013		**4**						
TOTAL	**8**	**16**	**5**	**20**	**13**	**6**	**2**	**4**

Discussion:

The entirety of this survey season was carried out under drought conditions, which have persisted in Southern California since 2010. Downtown Ventura received 8.86 inches of rain in the 2012 water year (60% of normal) and 6.46 inches in 2013 (44% of normal) (Ventura County Public Works website). The combined effect of these dry years was a dramatic reduction in flow throughout in the Ventura River watershed.

It is unlikely that any anadromous adults were able to travel beyond the Ventura River estuary due to low flow conditions and subsequent barriers to migration. In the absence of substantial high flow events, vegetation has become well established in the floodplain. Primrose and watercress were most abundant, and formed dense cross-channel thickets that may have acted as further barriers to steelhead migration (Figure 11). As a result, all redds surveyed were almost certainly those of resident *O. mykiss*. This is reflected in the relatively short overall average redd length of 89.3 cm. Data on resident *O. mykiss* spawning behavior is useful for a variety of reasons. It provides us with baseline data for comparison with steelhead redds, it cues us in to which sections of stream see the highest concentration of spawning activity and allows us to estimate current resident fish abundance. However; the primary objective of these surveys remains to gather data on Ventura River steelhead. The difficulty of obtaining this data will remain high until the area sees increased rainfall.



Figure 11. High densities of watercress and primrose in Ventura River, Reach 1

Staffing limitations were another source of additional challenges. Staff members were routinely reallocated to take part in other critically important monitoring work. None of the surveyed reaches were completed on a bi-weekly basis 100% of the time. Reaches were prioritized so that reaches with better spawning habitat and a higher likelihood of steelhead presence were surveyed most often. This leads to inconsistency and potential false trends in the data.

Proficiency in identifying species other than *O. mykiss* varied among staff members. The ability of a survey group to positively identify these species was influenced by who participated. This should be taken into account when evaluating observation totals.

ECOLOGY AND MANAGEMENT OF *ARUNDO DONAX*, AND APPROACHES TO RIPARIAN HABITAT RESTORATION IN SOUTHERN CALIFORNIA.

Gary P. Bell

The Nature Conservancy of New Mexico, 212 E. Marcy Street, Suite 200, Santa Fe, NM 87501

Abstract

By far the greatest threat to the dwindling riparian resources of coastal southern California is the alien grass species known as *Arundo donax*. Over the last 25 years the riparian forests of coastal southern California have become infested with *A. donax* which has spread by flood-fragmentation and dispersal of vegetative propagules. *Arundo donax* dramatically alters the ecological/successional processes in riparian systems and ultimately moves most riparian habitats towards pure stands of this alien grass.

By current estimates there are tens of thousands of acres of *A. donax* along the major coastal drainage systems of southern California, including the Santa Ana, Santa Margarita, Ventura, Santa Clara, San Diego, and San Luis Rey rivers. The removal of *A. donax* from these systems provides numerous downstream benefits in terms of native species habitat, wildfire protection, water quantity and water quality.

Introduction

Arundo (L.) is a genus of tall perennial reed-like grasses (Poaceae) with six species native to warmer parts of the Old World. *Arundo donax* (L.) (giant reed, bamboo reed, giant reed grass, arundo grass, donax cane, giant cane, river cane, bamboo cane, canne de Provence), is the largest member of the genus and is among the largest of the grasses, growing to a height of 8 m (Figure 1). This species is believed to be native to freshwaters of eastern Asia (Polunin and Huxley 1987), but has been cultivated throughout Asia, southern Europe, north Africa, and the Middle East for thousands of years and has been planted widely in North and South America and Australasia in the past century (Perdue 1958, Zohary 1962). It was intentionally introduced to California from the Mediterranean in the 1820's in Los Angeles area as an erosion-control agent in drainage canals, and was also used as thatching for roofs of sheds, barns, and other buildings (Hoshovsky 1987). Subsequent plantings have been made for the production of reeds for a variety of musical instruments including bassoons and bagpipes. Today it is an invasive pest throughout the warmer coastal freshwaters of the United States, from Maryland to northern California.

Arundo donax is a hydrophyte, growing along lakes, streams, drains and other wet sites. It uses prodigious amounts of water, as much as 2,000L/meter of standing *A. donax*, to supply its incredible rate of growth (Purdue 1958; Iverson 1994). Under optimal conditions it can grow more than 5 cm per day (Purdue 1958). *Arundo donax* stands are among the most biologically

productive of all communities. Under ideal growth conditions they can produce more than 20 tons per hectare above-ground dry mass (Perdue 1958).

Perhaps as much as 90% of the historic riparian habitat in the southern part of California has been lost to agriculture, urban development, flood control, and other human-caused impacts (Jones & Stokes 1987; Katibah 1984). The greatest threat to the remaining riparian corridors today is the invasion of exotic plant species, primarily *Arundo donax*. This alien grass readily invades riparian channels, especially in disturbed areas, is very competitive, difficult to control, and to the best of our knowledge does not provide either food or nesting habitat for native animals. *Arundo* competes with native species such as *Salix* (willows), *Baccharis salicifolia* Ruiz Lopez & Pavon (mulefat), and *Populus* (cottonwoods) which provide nesting habitat for the federally endangered bird, the least Bell's vireo (*Vireo bellii pusillus*), the federally threatened bird, the willow flycatcher (*Empidonax traillii eximus*) and other native species (Hendricks and Rieger 1989; Franzreb 1989; Zembal 1986 and 1990).

Ecological value of native riparian systems

Like most riparian systems, the cottonwood/willow riparian forest is a dynamic community, dependent upon periodic flooding to cycle the community to earlier successional stages (Warner and Hendrix 1985). Periodic floods of large magnitude and migration of the river channel are essential to depositing fresh alluvium where seeds and vegetative propagules of *Baccharis*, *Salix*, and *Populus* can germinate and take root (Gregory et al. 1991; Richter and Richter 1992).

Adequate moisture and an absence of subsequent heavy flooding is critical to the survival of the young trees through their first year. As these seedlings mature they increase channel roughness and alter flow during small flood events, increasing sediment deposition (Kondolf 1988; Richter and Richter 1992; Stromberg *et al.* 1993). Sediment deposition builds river terraces and, as they elevate, other plant species colonize resulting in further diversification in the floodplain community (Richter and Richter 1992).

When *Populus/Salix* riparian scrub, which may include such species as *Baccharis salicifolia*, *Vitis californica* (Benth.), *Rubus ursinus* (Cham. & Schldl.), and *Urtica dioica* ssp. *holosericea* (Nutt.) Thorne, reaches four or five years of age, it begins to exhibit the structural diversity required for breeding by the bird, the least Bell's vireo (Franzreb 1989, Hendricks and Rieger 1989). Least Bell's vireo, along with the riparian birds, southwestern willow flycatcher, yellow-breasted chat (*Icteria virens*), yellow warbler (*Denroica petechia*), and many other species may continue to use this diverse community for another ten to twenty years. Gradually the canopy of the maturing willows and cottonwoods begins to shade out the diverse understory of vascular plants required by these birds. Older riparian gallery forests will continue to be used by western yellow-billed cuckoo (*Coccyzus americanus occidentalis*), Cooper's hawk (*Accipiter cooperii*), warbling vireo (*Vireo gilvus*) and other species (Zembal 1990; Zembal *et al.* 1985), but as the stand ages the diversity of the flora and fauna within the forest declines. Annual flooding, channel migration, and occasional large flood events maintain this cycle of succession and therefore maintains a mosaic of diverse natural communities (Gregory *et al.* 1991).

Arundo donax as a competitor

Within its introduced range, *A. donax* is an aggressive competitor. *Arundo donax* flowers in late summer with a large, plume-like panicle. Fortunately for California land managers, the seeds produced by *A. donax* in this country are seldom, if ever, fertile. It is not known if this is because of clonal isolation or because of the physiological effects of climate as has been observed in the related *Phragmites communis* Trin. (common reed) (Haslam 1958; Rudescu et al. 1965). *Arundo donax* is well adapted to the high disturbance dynamics of riparian systems as it spreads vegetatively. Flood events break up clumps of *A. donax* and spread the pieces downstream. Fragmented stem nodes and rhizomes can take root and establish as new plant clones. Thus invasion, spread, and therefore management, of *A. donax* is essentially an intra-basin and downstream phenomenon.

Once established *A. donax* tends to form large, continuous, clonal root masses, sometimes covering several acres, usually at the expense of native riparian vegetation which cannot compete. Root masses, which can become more than a meter thick, stabilize stream banks and terraces (Zohary and Willis 1992), altering flow regimes. *Arundo donax* is also highly flammable throughout most of the year, and the plant appears highly adapted to extreme fire events (Scott 1994). While fire is a natural and beneficial process in many natural communities in southern California it is a largely un-natural and pervasive threat to riparian areas. Natural wild fires usually occur during rare lightening storm events in late fall, winter, and early spring. Under these

conditions the moist green vegetation of riparian areas would normally act as a fire break. Human-caused wild fires, in contrast, often occur during the driest months of the year (July through October). Drier conditions in riparian zones at this time of year make them more vulnerable to fire damage. Because *A. donax* is extremely flammable, once established within a riparian area it redirects the history of a site by increasing the probability of the occurrence of wildfire, and increasing the intensity of wildfire once it does occur. If *A. donax* becomes abundant it can effectively change riparian forests from a flood-defined to a fire-defined natural community, as has occurred on the Santa Ana River in Riverside County, California. *Arundo donax* rhizomes respond quickly after fire, sending up new shoots and quickly outgrowing any native species which might have otherwise taken root in a burned site. Fire events thus tend to help push riparian stands in the direction of pure *A. donax.* This results in river corridors dominated by stands of giant reed with little biological diversity.

***Arundo donax* as habitat**

All evidence indicates that *A. donax* provides neither food nor habitat for native species of wildlife. *Arundo donax* stems and leaves contain a wide array of noxious chemicals, including silica (Jackson and Nunez 1964), tri-terpines and sterols (Chandhuri and Ghosal 1970), cardiac glycosides, curare-mimicking indoles (Ghosal *et al.* 1972), hydroxamic acid (Zuñiga *et al.* 1983), and numerous other alkaloids which probably protect it from most native insects and other grazers (Miles *et al.* 1993, Zuñiga *et al.* 1983). Areas taken over by *A. donax* are therefore largely

Control Methods

A suite of methods is needed to control *A. donax* depending upon the presence or absence of native plants, the size of the stand, the amount of biomass which must be dealt with, the terrain, and the season.

The key to effective treatment of established *A. donax* is killing of the root mass. This requires treatment of the plant with systemic herbicide at appropriate times of the year to ensure translocation to the roots. Only one herbicide is currently labeled for wetlands use by the EPA; Rodeo®, a tradename formulation of glyphosate, produced by Monsanto Corporation. Glyphosate is a broad-spectrum herbicide which can be used on *A. donax*, *Tamarix ramosissima* (saltcedar), and most other monocots and dicots. It has proven very effective against *A. donax* (Finn and Minnesang 1990; Jackson 1994; USDA Forest Service 1993). Other herbicides might also be used as labels and conditions allow. Monocot-specific chemicals, such as Fusilade-DX® (fluazapop-butyl) and Post® (Sethoxidan), might be particularly useful for treating *A. donax* in stands with a substantial component of native dicots; however, neither is currently labeled for wetlands use.

The most effective treatment on *A. donax* is the foliar application of a two-to-five percent (2-5%) solution of Rodeo applied post-flowering and pre-dormancy at a rate of 0.5 to 1 L/hectare. During this period of time, usually mid-August to early November, the plants are actively translocating nutrients to the rootmass in preparation for winter dormancy which results in

effective translocation of herbicide to the roots. Recent preliminary comparison trials on the Santa Margarita River (Omori. 1996) indicate that foliar application during the appropriate season results in almost 100% control, compared with only 5-50% control using cut-stem treatment. Two to three weeks after foliar treatment. treatment the leaves and stalks brown and soften creating an additional advantage in dealing with the biomass: cut green stems might take root if left on damp soil and are very difficult to cut and chip. Treated stems have little or no potential for rooting and are brittle. They may be left intact on the ground or chipped *in situ* for mulch.

Cut-stem treatment requires more time and man-power than foliar spraying and requires careful timing. Cut stems must be treated with concentrated herbicide within one to two minutes in order to ensure tissue uptake (Monsanto 1989). This treatment is also most effective post-flowering. The chief advantage of the cut-stem treatment is that it requires less herbicide that can be more-or-less surgically applied to the stem. Because of its reduced efficacy, and due to the labor required, it is rarely cheaper than foliar spraying except on very small, isolated patches or individual plants.

A popular approach to dealing with *A. donax* has been to cut the stalks and remove the biomass, wait three to six weeks for the plants to grow to about one meter tall, then apply a foliar spray of herbicide solution. The chief advantage of this approach is that less herbicide must be applied to treat the fresh growth compared with tall, established plants, and that coverage is often better because of the shorter and uniform-height plants. However, cutting of the stems may result in the plants returning to growth-phase, drawing nutrients from the rootmass.

As a result there is less translocation of herbicide to the roots and less root-kill. Therefore many follow-up treatments must be made which negates any initial savings in herbicide and greatly increases the manpower costs.

Pure stands (>80% canopy cover) of *A. donax* or *T. ramosissima* are most efficiently treated by aerial application of an herbicide concentrate, usually by helicopter. Helicopter application can treat at least 50 hectares per day. Special spray apparatus produces extremely fine droplets (400 microns) of concentrated herbicide which actually reduces herbicide use, minimizes over-spray, and results in greater kill.

In areas where helicopter access is impossible, where *A. donax* makes up the understory, where patches are too small to make aerial application financially efficient, or where weeds are mixed with native plants (<80% cover), herbicides must be applied by hand. Street-vehicles with 400 liter spray tanks are a good alternative where road access is available, but small "quad-runner" vehicles equipped with 60 liter sprayers are the preferred approach where the streambed is not so rocky as to prevent access. Twenty liter backpack sprayers are the final alternative where the vegetation is too dense, or the landscape too rugged for vehicles to be effective.

Methods for vegetation removal include use of prescribed fire, heavy machinery (e.g. bulldozers), handcutting by chainsaw or brushcutter, hydro-axe, chipper, biomass burning or removal by vehicle. Removal of the biomass should only be done where the weed cover is so dense as to prevent recovery by native vegetation after treatment, or where cut vegetation might create a debris-dam hazard during flood events. Prescribed fire, or burning piles of stacked biomass, is the most cost-effective way of removing biomass as long as it does not threaten

native vegetation or other resources. Chipping is more costly in terms of equipment and labor, and cut, dried chips pose no threat for regeneration or for forming debris dams. Hauling of biomass by vehicle is extremely expensive and should only be done as a last resort. Most landfills will not accept *A. donax* and those that do will only accept if cut into short lengths and bagged into plastic trash bags, making the labor costs far too great. The use of heavy machinery such the Hydro-ax® is extremely expensive. The machines are very slow - a Hydro-ax can only cut about 3-4 acres per day.

Riparian restoration and management

One of the prime incentives for riparian habitat restoration has been endangered species recovery, including the federal Endangered Species Act (ESA). The ESA has focused attention on declining species and sought to protect those species in greatest risk by provisions against take (Under the ESA the term "take" means to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct.). Focus of the legislation has been on individual protected species with little attention given to the dynamics of the natural systems of which these species are a part. There are important historical and legislative reasons for this approach. In the 1970's, when the ESA was drafted, ecologists and wildlife managers were highly focused on single species; system-oriented approaches were not widely applied. In addition, it is far easier to attach legal definition to something tangible, such as an individual animal, than it is to the more vague concept of ecological processes (Gregory *et al.* 1991).

been successful in terms of establishing a matrix of riparian habitat which is used by some native species, re-vegetating is the not necessarily the best way to create habitat.

The best way to address habitat loss in southern California riparian systems is through a comprehensive program of eradication of *A. donax, T. ramosissima*, and other invasive aliens, and relying on natural physical processes, especially flood dynamics, for the recovery of native natural communities and species. This approach might be just as easily argued for other high disturbance-adapted communities.

This strategy is based upon two of important factors. First, riparian habitats are flood-dynamic communities, dependent upon natural cycles of flood scouring and sediment deposition to create the proper conditions for community establishment (Gregory *et al.* 1991; Richter and Richter 1992; Stromberg *et al.* 1991). The Santa Ana, Santa Margarita, San Luis Rey, and many other southern California streams have all of the factors necessary for the recovery and maintenance of healthy riparian communities and riparian species. These watersheds retain flood regimes sufficient to move and sort sediment and extensive sources of seed and vegetative propagules for *Salix* and other native riparian plants. Second, the only real threats to the integrity of the system are (1) habitat fragmentation by development and (2) introduced exotic species which have altered the successional dynamics and stability of the natural communities. In other words, the native riparian communities of the Santa Ana and other major riparian corridors (and thus riparian-dependent species such as least Bell's vireo) are limited, not by the capacity of the community to regenerate, or the available area of riparian zones, but by the capacity of native species to compete with aggressive invasive exotic species, chiefly *A. donax.*

The majority of the limited resources available for riparian management on these rivers should therefore be directed at managing for the process of riparian systems: removing the key perturbation from the system, thereby allowing natural flood dynamics to operate and the natural communities to recover. Attempts to re-vegetate riparian species in floodplains that retain both native riparian species and flood regimes are redundant, and resources spent to this end are largely wasted. This is not to imply that riparian (and other habitat) re-vegetation efforts should not be applied; however, they should be applied judiciously and only in situations where specific management goals are achieved by carrying out a re-vegetation project (e.g. closing up an important corridor or re-establishing native species in a depauperate watershed). Relying on natural processes for the recovery of the riparian communities has the following major benefits:

a. Cost-effectiveness. Riparian forest restoration is extremely expensive, often on the order of tens of thousands of dollars per hectare. This necessarily limits the size, and therefore the biological value, of any funded restoration project. *Arundo donax* can be removed from most areas of a river for a fraction of the cost of revegetation, opening up areas for natural re-colonization by native riparian species.

b. Biological value. As indicated above, the high cost of re-vegetation limits the size of restoration projects. Additionally, artificially-produced riparian habitat lacks the high stem densities characteristic of naturally regenerating riparian habitat, making the actual biological value of re-vegetated sites questionable. Much higher value may be achieved by removing invasive exotics such as *A. donax* from the system. Areas opened up for

tributaries to prevent reinfestation of treated downstream sites from upstream sources. Removal of *A. donax* requires treatment with systemic herbicides in order to kill the large root mass.

Past practices of riparian restoration have focused on re-vegetation of small sites without consideration of natural riparian processes. Resources should be spent on managing for the natural dynamic processes of these systems on a watershed-wide scale. In coastal southern California the primary perturbation to the natural riparian succession process in invasion by *A. donax*, and its removal from river systems will have a far greater beneficial effect on most riparian species than planting of riparian vegetation.

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Figure 1. *Arundo donax.* Plant X 1/3; spikelet and floret X 3 (from Hitchcock and Chase 1950).

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Acronyms

AF	acre-feet
AFY	acre-feet per year
ALERT	Automated Local Evaluation in Real Time
AMPA	aminomethylphosphonic acid
amsl	above mean sea level
ASFPM	Association of State Floodplain Managers
BMPs	Best Management Practices
Casitas	Casitas Municipal Water District
CDFG	California Department of Fish and Game
CFR	Code of Federal Regulations
cfs	cubic feet per second
CIMIS	California Irrigation Management System
CIP	Capital Improvements Program
CRS	Community Rating System
CTP	Cooperating Technical Partners
CRWQCB-LA	California Regional Water Quality Control Board-Los Angeles Region
CWD	County Water District
cy	cubic yards
dbh	diameter at breast height
DBS&A	Daniel B. Stephens & Associates, Inc.
DDT	dichloro-diphenyl-trichloroethane
DFIRM	Digital Flood Insurance Rate Map
District	Ventura County Watershed Protection District
DO	dissolved oxygen
DWR	California Department of Water Resources
EPA	Environmental Protection Agency
ESA	Endangered Species Act
FEMA	Federal Emergency Management Agency
FIS	Flood Insurance Study
Forest	Los Padres National Forest
Forest Plan	Los Padres National Forest Land and Resource Management Plan
GWMP	groundwater management plan
HRU	hydrologic response unit
HSPF	Hydrological Simulation Program–FORTRAN

IRWM	Integrated Regional Water Management
IRWMP	Integrated Regional Water Management Plan
IWPP	Integrated Watershed Protection Plan
km	kilometer
LOMR	Letter of Map Revision
MCL	maximum contaminant level
mg/L	milligrams per liter
mm	millimeters
MO	management objective
MUN	municipal and domestic supply
NAVD	North American Vertical Datum
NPDES	National Pollutant Discharge Elimination System
NCDC	National Climatic Data Center
NFIP	National Flood Insurance Program
NOAA	National Oceanic and Atmospheric Administration Fisheries
NPDES	National Pollutant Discharge Elimination System
OVLC	Ojai Valley Land Conservancy
OVSD	Ojai Valley Sanitary District
PGA	peak ground acceleration
ppt	parts per thousand
QAPP	Quality Assurance Project Plan
QA/QC	Quality Assurance/Quality Control
Reclamation	Bureau of Reclamation
RM	River Mile
SCAG	Southern California Association of Governments
SR	State Route
TDS	total dissolved solids
TMDL	Total Maximum Daily Load
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
WDR	Waste Discharge Requirements
WY	water year
µg/l	micrograms per liter, equivalent to parts per billion

Executive Summary

This Watershed Protection Plan Report was developed to summarize existing information and reports prepared for the Ventura River watershed, and to fulfill a requirement of an Integrated Regional Water Management grant from the State Water Resources Control Board (SWRCB). This report is largely focused on water supply and water resources and does not provide a comprehensive assessment of the watershed, but does provide information that can inform the development of a comprehensive Watershed Management Plan.

The Ventura River watershed is entirely dependent on local resources for water supply and is mostly undeveloped, with urban and suburban development mostly concentrated along the river, tributary streams, and valley floors. Prevailing storm patterns, along with steep topography and the east-west orientation of the mountains in the upper portions of the watersheds, frequently create the potential for significant precipitation. Dams, reservoirs, and diversion structures have been developed to capture runoff, which has enhanced the reliability of water supplies. Some of these structures, however, act as barriers to fish migration and have adversely affected some aquatic species, including anadramous fish.

Various structural improvements have been implemented on the Ventura River and tributary streams to address flood risks, but flood management deficiencies remain at various locations. The Ventura County Watershed Protection District (District) has proposed additional structural improvements, but their implementation is limited by the availability of funding. In addition, flood risks are also present at other locations in the watershed, including alluvial fans in the Ojai Valley, where traditional flood management methods are not effective. To address residual risks along floodplains, Ventura County has adopted a floodplain ordinance that limits development in these areas or imposes conditions upon such development. Nonetheless, property owners located in areas that at risk for flooding must be aware of and take appropriate precautions to minimize such risks.

Total annual water demand for the entire watershed is estimated at 35,905 acre-feet, although actual water demand varies considerably due to variable annual precipitation patterns. Development of a comprehensive water budget for the watershed is limited by the availability of data, although the major inputs and outputs for this balance have been estimated.

Watershed plans have been developed for many coastal watersheds in Southern California, and a review of three plans (Ballona Creek, Tujunga-Pacoima Wash, and Calleguas Creek) suggests that the proposed Ventura River watershed management plan would benefit from identifying the intended audience; finding ways to engage watershed stakeholders; clearly defining and stating the plan's goals and objectives; focusing the plan by addressing issues where stakeholders can make a meaningful difference; prioritizing projects to meet the plan's objectives; and identifying a process to gauge progress towards plan implementation.

Recent studies prepared for the development of a watershed runoff model and a groundwater budget identified data gaps that limit the effectiveness of the runoff model at some locations and hamper a more accurate assessment of groundwater in the upper and lower Ventura River

groundwater basins. The installation and/or maintenance of additional gages and wells would provide additional data and improve the accuracy of the subsequent runoff modeling and enhance the understanding of the interaction between surface and groundwater flows.

Various state and local programs provide recommendations to enhance water supply, water quality, and habitat, and these are collectively termed Best Management Practices (BMPs). The compendium of BMPs identifies opportunities to improve the management of stormwater, expand water conservations, and to minimize adverse impacts to sensitive species and their associated habitats.

To improve water sustainability and ecosystem functions in the watershed, several key recommendations are provided, including continue meetings of the Ventura River Watershed Council; improve and update the Watershed Council's webpage; identify a mechanism(s) to assure continued funding of a watershed coordinator; convene a technical advisory group to assess and prioritize data gaps that limit development of a comprehensive water budget and develop a scope of work for that effort; conduct a facilitated discussion about the opportunities and constraints for development of a groundwater management plan; and convene a technical advisory group to develop a scope of work to address alternative options for sediment management and water diversion for the Matilija Dam Ecosystem Restoration Study.

Chapter 1

Introduction

1.1 Background

In 2006, the State Water Resources Control Board (SWRCB) awarded the Watersheds Coalition of Ventura County a Proposition 50 Integrated Regional Water Management (IRWM) grant to fund the implementation of several projects identified in the Ventura County Integrated Regional Water Management Plan (IRWMP). Collectively, the projects funded by the grant located within the Ventura River Watershed were identified as the "V-1" projects, and included the development of a watershed runoff model, surface water quality monitoring, groundwater monitoring, removal of invasive plants, and the development of this Ventura River Watershed Protection Plan Report (Report).

The contents of this Report include:

- Chapter 2: A summary of existing watershed characteristics, based on existing, readily available documents.
- Chapter 3: Summaries of the other elements of the V-1 project, including the results or conclusions of those efforts.
- Chapter 4: An estimate of water demand for the entire watershed, and a discussion of issues related to the development of water budget and an estimate of safe yield.
- Chapter 5: A summary of lessons learned from a review of three watershed plans for coastal watersheds in Southern California, and recommendations that can guide development of a watershed management plan for the Ventura River.
- Chapter 6: A discussion of data gaps, primarily identified in the reports developed for the other V-1 projects, and recommendations on how to address those gaps.
- Chapter 7: A compendium of Best Management Practices (BMPs) for water quality, water supply and habitat.
- Chapter 8: Recommendations for key actions that can improve water sustainability and ecosystem functions.
- Chapter 9: A more detailed discussion of flood control issues in the watershed than is included in Chapter 2, along with a discussion of floodplain management strategies and future flood control projects.

Chapters 2 and 3, 6, and 9 summarize information from available sources, including reports developed for the V-1 projects (which are listed below in Table 1-1). Chapter 7 provides a compendium of BMPs which were derived from other sources, but compiled for this report. Chapters 4, 5, and 8 provide information that was developed specifically for this Report.

1.2 The IWPP and V-1 Projects

To support ongoing watershed protection efforts, the Ventura County Watershed Protection District (District) developed the Integrated Watershed Protection Plan (IWPP) as the culmination of a series of long-range planning efforts. The objectives of the IWPP include the provision of a systematic process for the inclusion of projects into the District's Capital Improvement Plan and to improve the long-range District planning process (District 2011a).

The IWPP process achieves these objectives by gathering information about the existing flooding, operations and maintenance, drainage facility deficiency, access, or environmental concerns in the District and developing a prioritized project list based on the gathered information. Projects are proposed to address identified issues, and are ranked relative to each other using a scoring matrix. The highest priority projects are subjected to further study and, if the proposed alternative is found to be cost-effective and environmentally-friendly, the project can be selected for inclusion into the Capital Improvement Plan.

As part of the IWPP, a total of 33 projects were identified for Zone 1, which includes the Ventura River watershed. Project V-1 was proposed to include:

- Creation of the Ventura River Watershed Council.
- Data Gap Analysis.
- Existing Condition Studies.
  - Water Supply/Demand Study.
  - Ojai Groundwater Supply Reliability Study.
  - Development of Future Conditions Model.
  - Habitat Protection Plan.
  - Water Quality Study.
- Ventura River Watershed Protection and Supply Plan.

In 2007, the Watersheds Coalition of Ventura County, of which the District is a member, was awarded an Integrated Regional Water Management Proposition 50 implementation grant to complete elements of the V-1 project, including:

- Development and testing of the Ventura River Watershed Hydrology Model, which can simulate historic conditions on a continuous basis and will serve as the basis for water supply and water quality evaluations of the Ventura River watershed.
- Ojai Basin Groundwater Monitoring Plan.
- Upper and Lower Ventura River Basin Groundwater Budget and Approach to a Groundwater Management Plan.
- Upper San Antonio Creek Watershed Giant Reed Removal Project.
- Ventura River Watershed Protection Plan Report.

This Report fulfills a requirement of the IRWM grant from the State Water Resources Control Board and, therefore, the scope and content of this document, which is largely focused on water supply and water resources, was determined by the scope of the original grant application and a subsequent grant agreement with the SWRCB. Thus, this report is not intended to provide a comprehensive assessment of the watershed, but does provide information report that can inform the development of a comprehensive Ventura River Watershed Management Plan.

The reports produced to date under the V-1 grant are shown in Table 1-1. They are posted on the Ventura River watershed section of the District's website at: http://portal.countyofventura.org/portal/page/portal/PUBLIC_WORKS/Watershed_Protection_District/Watersheds/Ventura_River.

Table 1-1 V-1 Project Reports

Development of the Ventura River Watershed Hydrology Model		
Report Name	Preparer	Date
Data Summary Report, Ventura River Watershed Hydrology Model	Tetra Tech	June 2008
Simulation Plan, Ventura River Watershed Hydrology Model	Tetra Tech	June 2008
Baseline Model Calibration and Validation Report, Ventura River Watershed Hydrology Model	Tetra Tech	June 2009
Natural Condition Report, Ventura River Watershed Hydrology Model	Tetra Tech	July 2009
Surface Water Quality Monitoring Program		
Quality Assurance Project Plan for Ventura River Watershed Protection Project (V-1): Surface Water Quality Monitoring	District	June 2010
Ventura River Watershed Protection Project (V-1): Surface Water Quality Monitoring, Water Quality Monitoring Plan 2010	District	August 2010
Ventura River Watershed HSPF Model – Aluminum	Tetra Tech	June 2011
Groundwater Management and Monitoring		
Ojai Basin Groundwater Monitoring Plan	Daniel B. Stephens & Associates, Inc. (DBS&A)	December 2010
Groundwater Budget and Approach to Groundwater Management Plan, Upper and Lower Ventura River Basin	DBS&A	December 2010
Upper San Antonio Creek Watershed Giant Reed Removal Project		
Water Quality Monitoring Update, Upper San Antonio Creek Watershed Giant Reed Removal Project	District	April 2010
Quality Assurance Project Plan for Ventura River Watershed Protection Project (V-1): Upper San Antonio Creek Watershed Giant Reed Removal Project (SACGRRP)	District	May 2010
Upper San Antonio Creek Watershed Giant Reed Removal Water Quality Monitoring Plan	District	June 2010

Source: District, 2011

In addition to the documents listed in Table 1-1, this summary report also uses information generated during development of a proposed Multiple Species Habitat Conservation Plan for the Ventura River. Although that document is not yet complete, some of the appendices to that report were previously released to the Ventura River Watershed Council to inform ongoing

planning efforts, and were therefore utilized to expand the description of watershed conditions in this summary report.

Chapter 2

Watershed Characteristics

Overview

The Ventura River watershed is located primarily in western Ventura County, California, although a small portion is located in southeastern Santa Barbara County (Figure 2.1-1). The watershed drains an area of about 228 square miles. Major tributaries include San Antonio Creek, Coyote Creek, Cañada Larga, Cañada del Diablo, and Cañada de Rodriguez. Several smaller watersheds feed into the Ventura River upstream of San Antonio Creek. Coyote Creek enters the Ventura River from the west just downstream of the confluence with San Antonio Creek. Downstream, Cañada Larga enters from the east, and Cañada de Rodriguez and Cañada del Diablo enter from the west. The watershed also contains Lake Casitas, which serves as the primary water supply for the area within the watershed.

The Ventura River headwaters are in the San Rafael and Topatopa mountains on the north (maximum elevations of approximately 6,000 feet), the Santa Ynez Mountains in the west-central area (maximum elevations of approximately 4,600 feet), and Sulphur Mountain in the east (maximum elevation of 2,730 feet) (U.S. Bureau of Reclamation [Reclamation] 1954). The mainstem of the river flows southward, approximately 16.5 miles from the confluence of Matilija Creek and North Fork Matilija Creek, to the river mouth at the Emma Wood State Beach in the City of Ventura.

Over 75 percent of the Ventura River watershed is classified as rangeland covered with shrub and brush, and 20 percent of the watershed is classified as forested habitat. In general, the highest sediment-producing parts of the watershed are located in the upper parts of the watershed where slopes are greater and annual rainfall is larger. Topography in the watershed is rugged; and, as a result, the surface waters that drain the watershed have very steep gradients ranging from 40 feet per mile at the mouth to 150 feet per mile at the headwaters. Nearly 45 percent of the watershed may be classified as mountainous, 40 percent as foothill, and 15 percent as valley area (Reclamation 1954 and 2003). Lowland portions contain urban development and agriculture (including citrus, orchards, avocado, and pasture) (Tetra Tech 2008a).

Precipitation varies widely, both temporally and spatially. Most occurs as rainfall during just a few storms between November and March. Summer and fall months are typically dry. Although snow occurs at higher elevations, melting snowpack does not sustain significant runoff in warmer months. The erratic weather pattern, coupled with the steep gradients throughout much of the watershed, can result in high-flow velocities in the Ventura River and its tributaries during large storm events, with most runoff reaching the ocean.

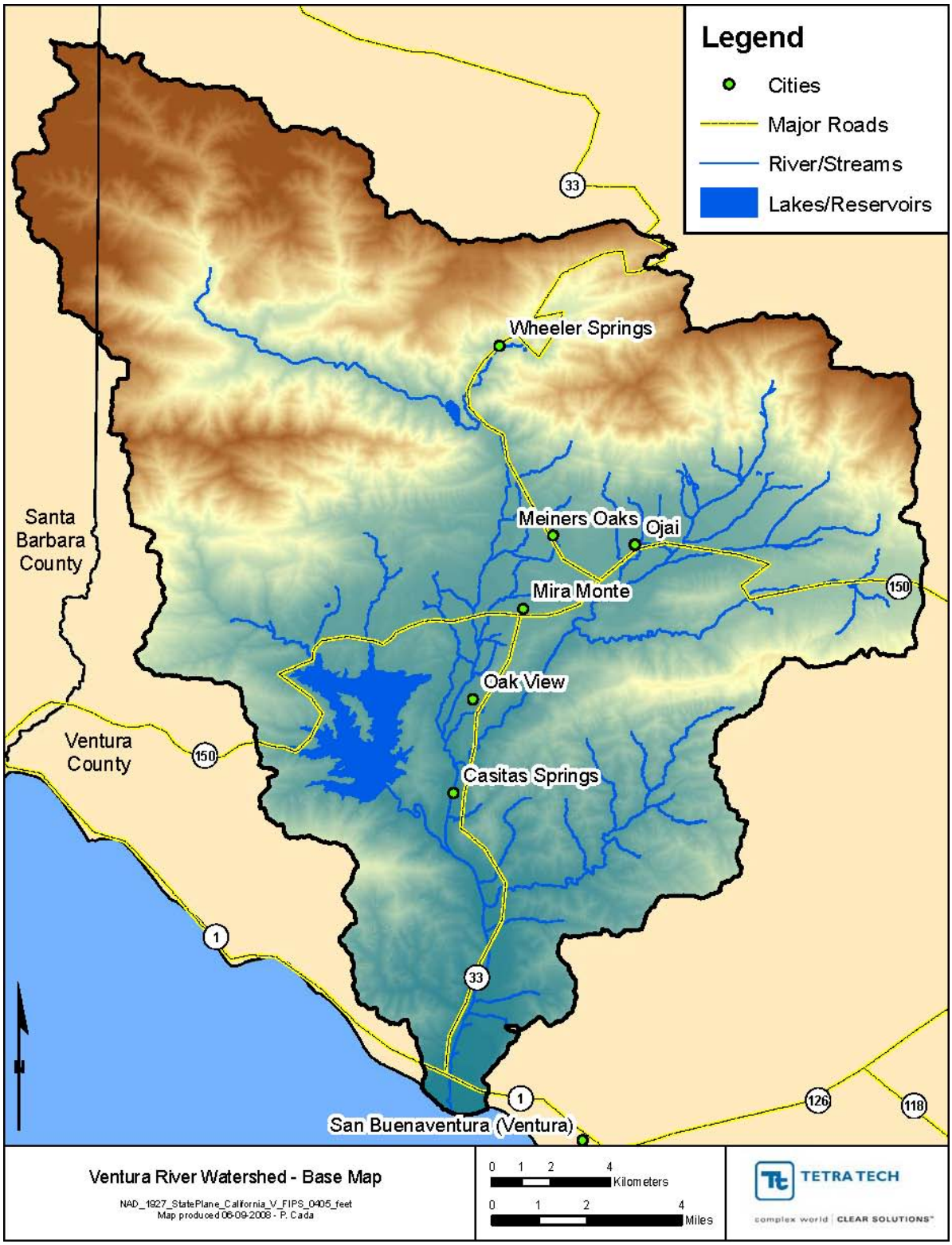


Figure 2.1-1 Ventura River Watershed

Source: Tetra Tech 2008a

2.1 Meteorology/Climate

The climate of the Ventura area is influenced primarily by the prevailing westerly transoceanic air currents, which often results in substantial cooling of the land surface at night. Dry and warm offshore winds (Santa Ana winds) may be generated in the fall and winter. Coastal fog is also an important characteristic of the Ventura River watershed. The coastline of Southern California is subjected to an inversion layer in the late spring and early summer that traps cool, moist air at low elevations, producing fog or low clouds during the night and early morning. The Ventura River Valley acts as a corridor through which moisture-laden marine air moves inland. As ocean temperatures increase during the summer, the occurrence of fog decreases (Ferren et al. 1990).

2.1.1 Air Temperature

Air temperature near the ocean generally has smaller seasonal and daily variations due to the regulating presence of the ocean than inland areas. The mean high varies between 64ºF in the winter months, to a mean high of 76ºF near the city of Oxnard (located approximately 8 miles southeast of Ventura). The mean low varies between 44ºF in the winter months and 60ºF in the summer months. Farther inland, at Ojai (located approximately 12 miles north of Ventura), the mean highs vary between 64ºF and 90ºF, while the mean lows vary between 36ºF and 56ºF (Reclamation 2003).

2.1.2 Precipitation

Rainfall gauging is available at multiple locations in and near the Ventura River watershed (Figure 2.1-2). Sources of locally observed weather data include (1) the District weather monitoring network, including both regular monitoring and Automated Local Evaluation in Real Time (ALERT) flood warning monitoring stations, and (2) National Climatic Data Center (NCDC). The District weather datasets provide a dense network of rainfall monitoring sites with daily, hourly, and 15-minute observations, as well as pan evaporation measurements at key locations in the watershed. The NCDC weather gages provided daily and hourly precipitation observations (Tetra Tech 2008a).

In general, the higher elevations receive more rain. The average annual rainfall for the drainage basin upstream of Matilija Dam is 23.9 inches per year, while the average annual rainfall near the mouth of the Ventura River is approximately 16.9 inches per year. The average for the entire watershed is approximately 20 inches per year. There is extreme seasonal variation in the rainfall, and over 90 percent of the rainfall occurs between the months of November and April. The peak historic rainfall intensity is approximately 4.04 inches per hour measured during a 15-minute period at the Wheeler Gorge gage in the mountains adjacent to Ojai (District 2011b).

Figure 2.1-3 is a graph of average annual precipitation totals sorted by gage elevation. On average, precipitation totals increase by about a factor of two from the lowest elevation areas to the highest. Among gages located at or near the same elevation, the major factor influencing precipitation total appears to be the slope aspect (Tetra Tech 2008a).

2.1.3 Evaporation

Figure 2.1-4 shows evaporation measured within the Ventura River watershed at Casitas Dam and Recreational Area and Matilija Dam, as well as nearby locations outside of the watershed, including Cachuma, El Rio Spreading Grounds, and Piedra Blanca Guard Station.

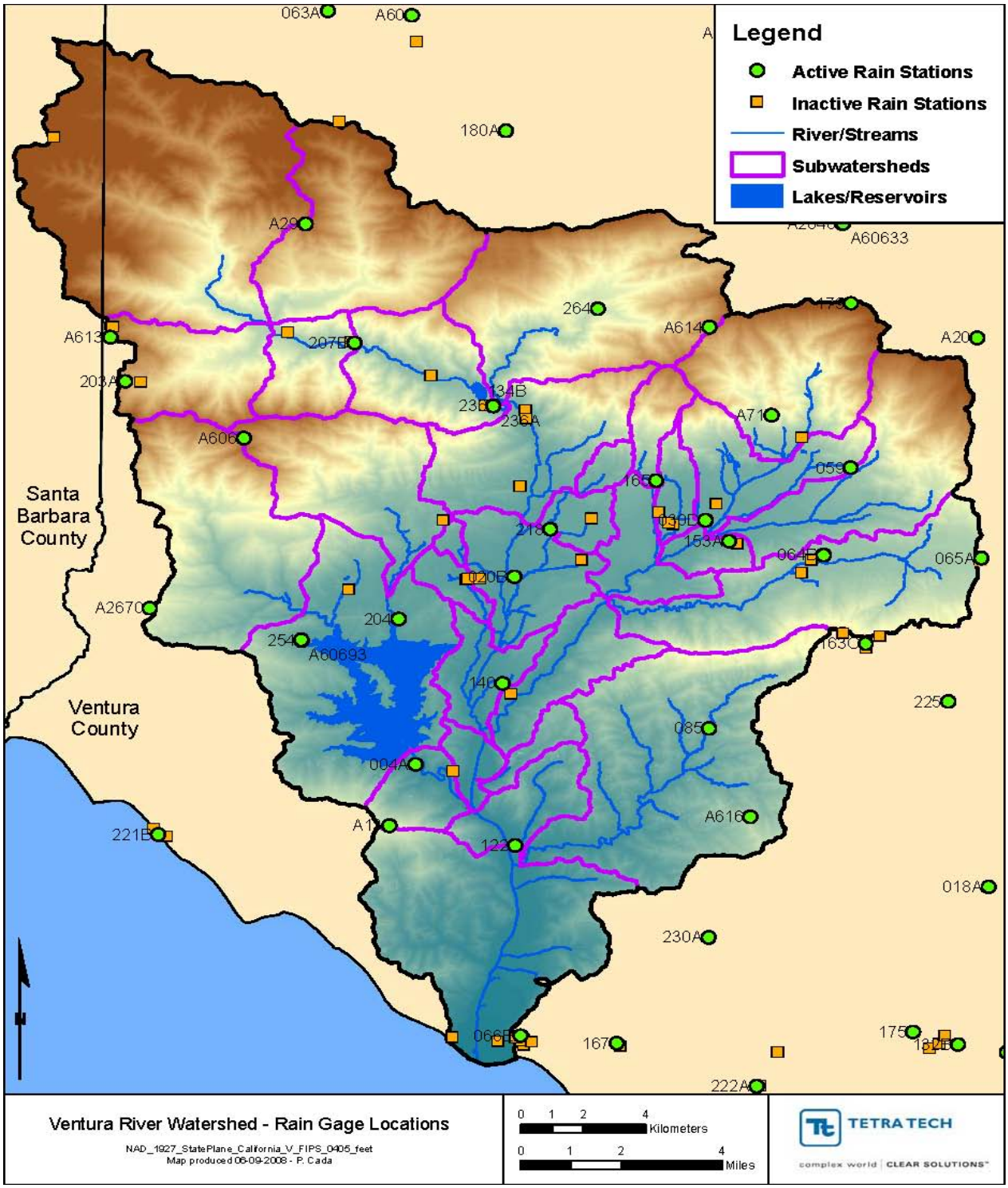


Figure 2.1-2 Precipitation Station Locations for the Ventura River Watershed

Note: Only active stations are labeled.
Source: Tetra Tech 2008a

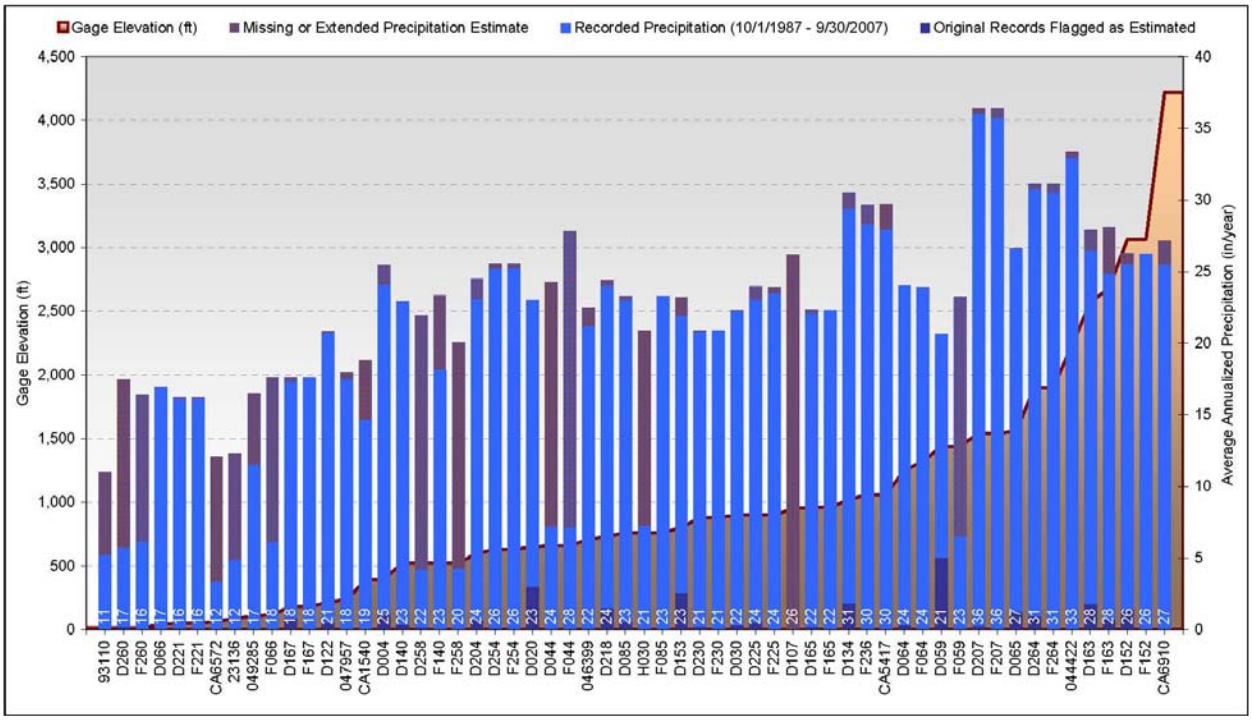


Figure 2.1-3 Average Annual Precipitation Totals versus Gage Elevation

Source: Tetra Tech 2008a

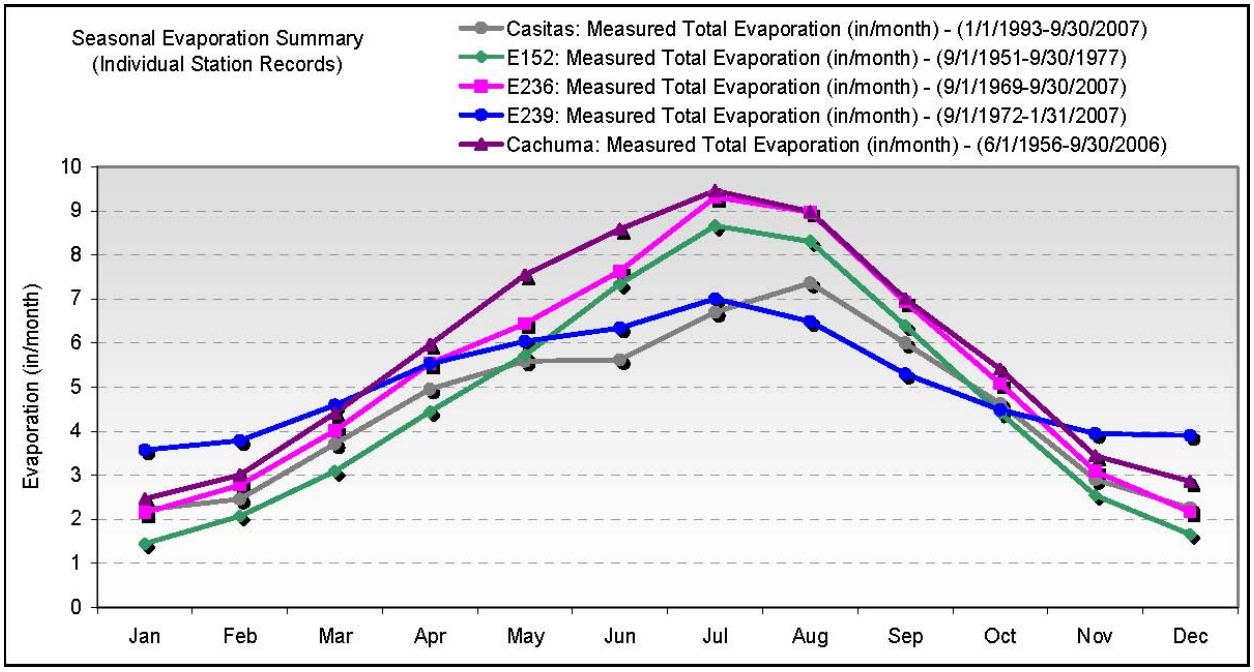


Figure 2.1-4 Seasonal Evaporation Trends at Stations in and around the Ventura River Watershed

Source: Tetra Tech 2008a

In terms of observed seasonal variability at the gages, the data follow similar seasonal trends, with the exception of El Rio Spreading Grounds (239), which had a flatter annualized pattern with higher winter evaporation and lower summer evaporation. Among the stations within the Ventura River watershed, the Matilija Dam station (236) on average reported 25 percent higher evaporation than the Casitas Dam station (Tetra Tech 2008a).

2.2 Land Use and Land Cover

2.2.1 Land Cover

Undeveloped land cover in the Ventura River watershed is shown in Figure 2.2-1, along with developed areas. Numerous plant communities are found within the Ventura River watersheds: Venturan coastal sage scrub, chaparral, coast live oak woodland, three types of riparian woodland (south coast live oak, central coast cottonwood-sycamore, and southern willow scrub) and non-native annual grasslands. Elevation, aspect (shade or sun), rainfall, and water availability are the primary determinants of where each community exists (District 2010d).

2.2.2 Existing Land Uses and Zoning

The Ventura River watershed supports a variety of land uses, including agricultural, commercial, light industrial, and residential. Open space and residential uses account for over 99 percent of the watershed. Development in the watershed has generally been limited to the floodplain areas (Figures 2.2-1 and 2.2-2). Most of the land in the Ventura River valley is privately held. Included in the watershed is the incorporated City of Ojai and several unincorporated population centers, including Casitas Springs, Live Oak Acres, Meiners Oaks, Mira Monte, and Oak View. Land use and land development within these incorporated cities is controlled by the policies of each City's General Plan and the regulations set forth in each City's zoning ordinance. Figures 2.2-3 through 2.2-5 show the zoning maps for Ventura County, the City of Ventura, and Ojai, respectively.

In addition to the activities to be permitted, a variety of other activities are conducted along the Ventura River and its tributaries by other agencies, commercial and industrial interests, and private parties. A brief summary of these activities is provided below.

2.2.3 Recreational Land Uses

The northern half of the Ventura River watershed is contained within the Los Padres National Forest (Forest), Ojai District. The Forest is managed for many purposes. The Los Padres National Forest Land and Resource Management Plan (Forest Plan) contains forest-wide guidelines, as well as specific "management areas," which have a set of compatible management goals and practices. In general, the Forest Plan has the following management objectives in the Ventura River watershed: recreation, visual resources, wilderness preservation, watershed, and biological resources. The Upper Matilija Creek watershed is within the Matilija Wilderness, where only foot access is allowed along established trails. In contrast, most of the remainder of the Forest in the watershed is designated as semi-primitive motorized or road-containing natural areas.

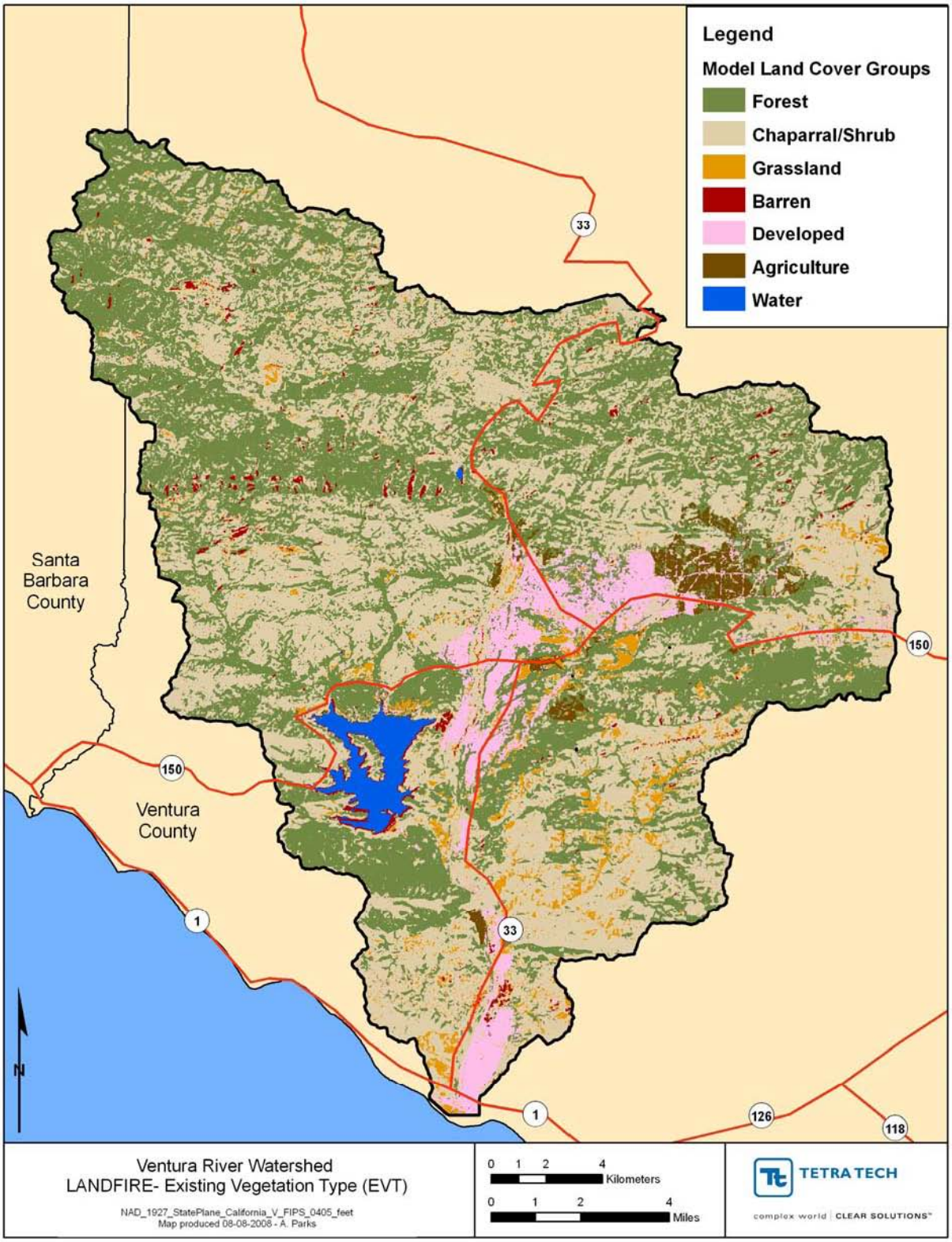


Figure 2.2-1 Undeveloped Land Cover in the Ventura River Watershed

Source: Tetra Tech 2009a

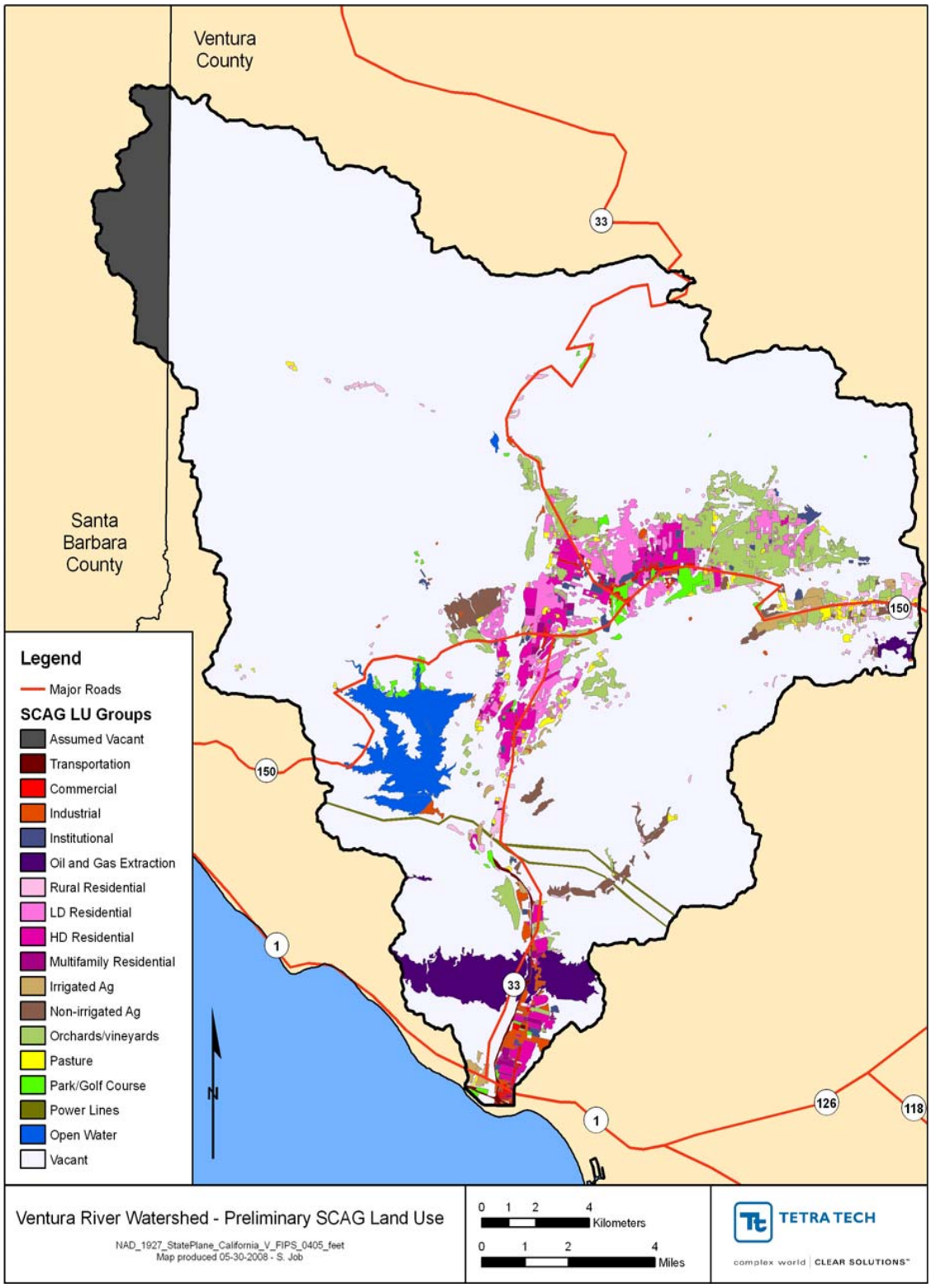


Figure 2.2-2 SCAG Land Use Groups (Year 2005) for the Ventura River Watershed

Note: This figure shows generalized land uses in the watershed, based on GIS data from the Southern California Association of Governments (SCAG). SCAG does not cover Santa Barbara County; however, this remote area of the watershed is predominately vacant.

Source: Tetra Tech 2009a

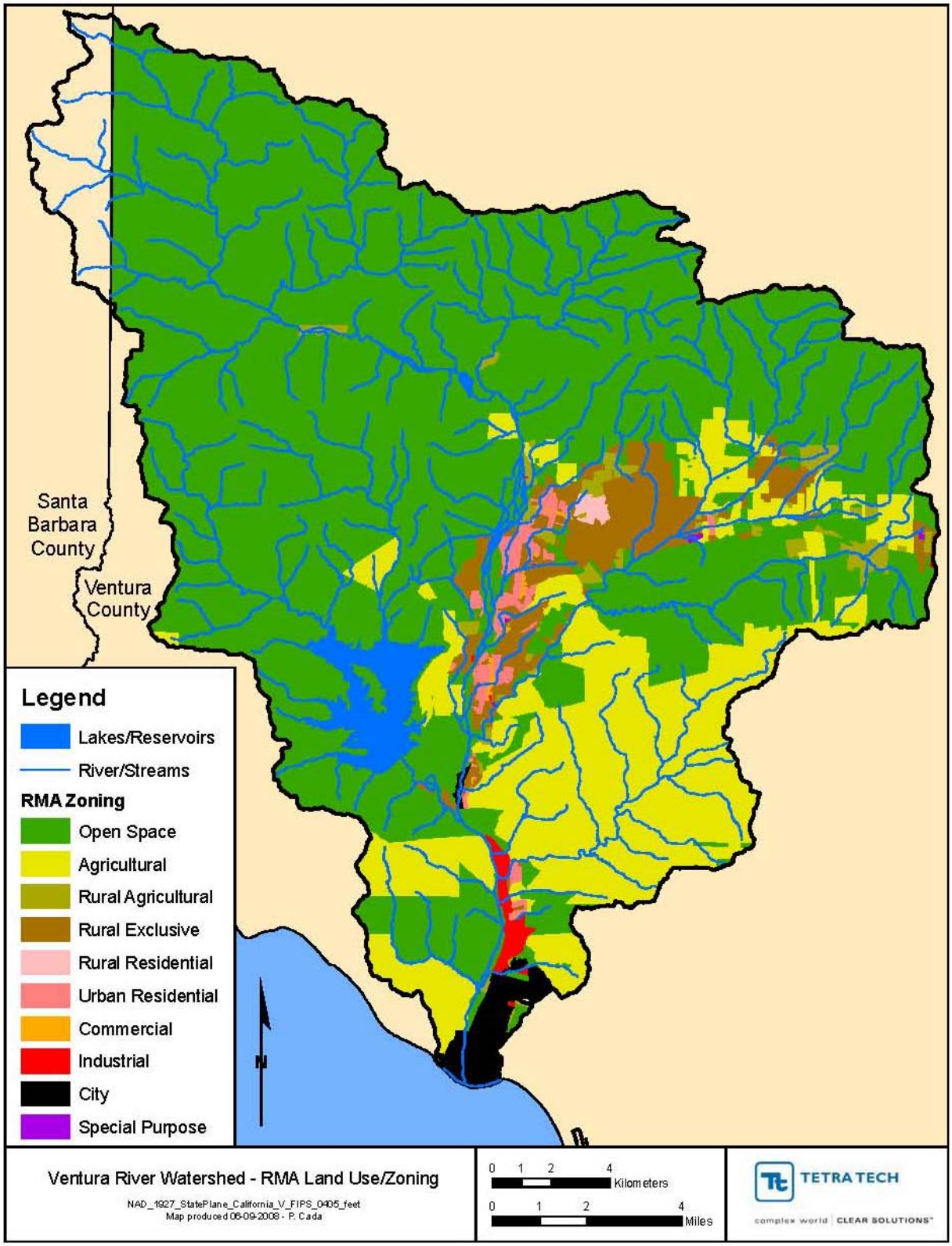


Figure 2.2-3 Ventura County Zoning in the Ventura River Watershed

Source Tetra Tech 2008a

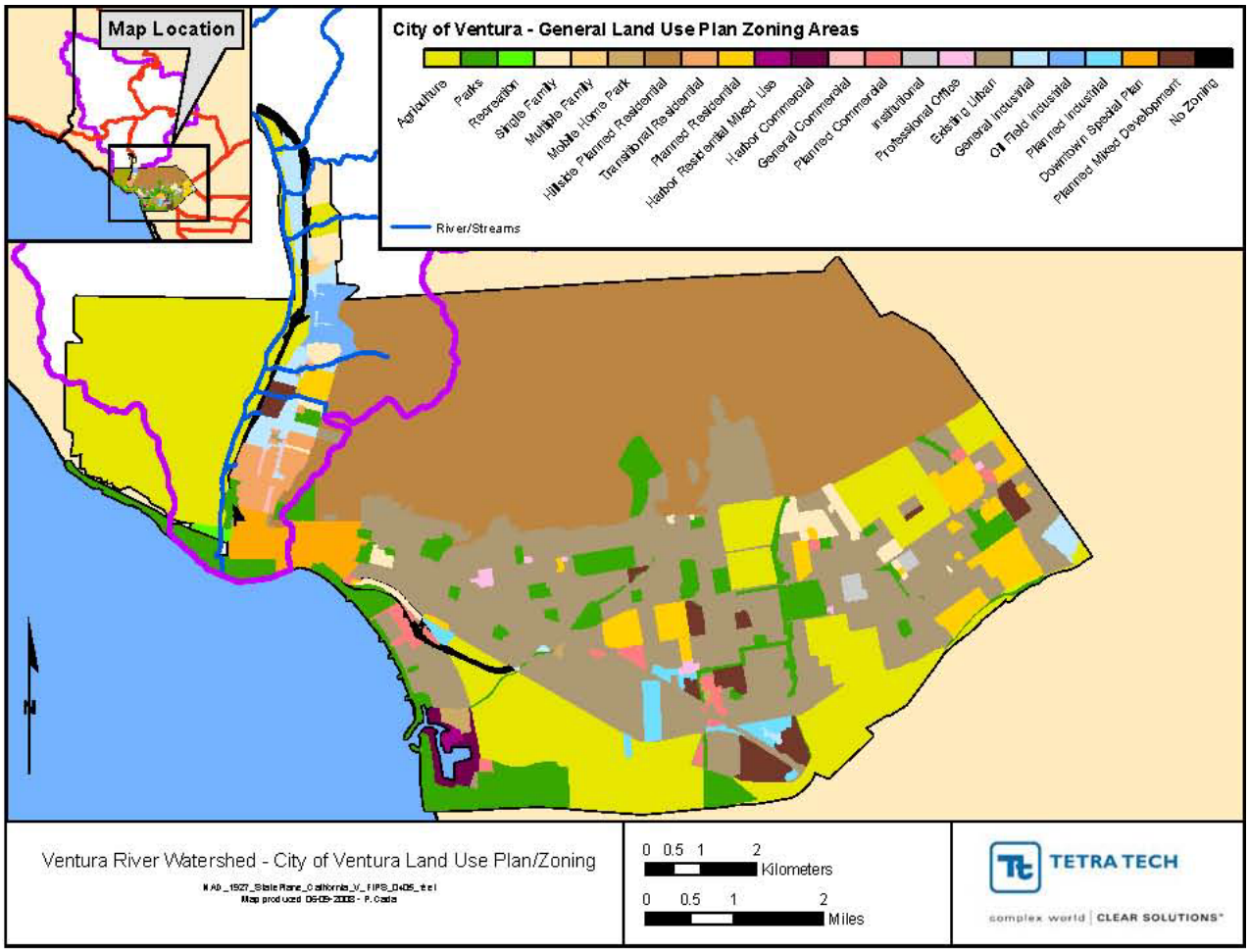


Figure 2.2-4 City of Ventura Land Use Plan/Zoning Map

Source: Tetra Tech 2008b

Numerous trails in the Forest are used for hiking, mountain biking, and horseback riding. Fire breaks and services roads are also used for the same purposes, as well as by off-road vehicles and motorcycles. Significant private land inholdings exist along the southern boundary of the Forest, and particularly along Matilija Creek, with many residences adjacent to the creek. These residences include domestic pets, small vegetable gardens, horses, and small livestock. Nearly the entire Forest in the Ventura River watershed was burned in the 1985 Wheeler Fire; hence, the vegetation age class in the watershed is very young. Erosion in the watershed has slowly decreased since Wheeler Fire.

The California Department of Parks and Recreation owns and manages the 115-acre Emma Wood State Beach, located at the mouth of the Ventura River. The western portion along the beach is used for family camping, while the eastern portion adjacent to the Ventura River Lagoon is used for group camping. The City of Ventura's Seaside Wilderness Park is located adjacent to the mouth of the Ventura River.

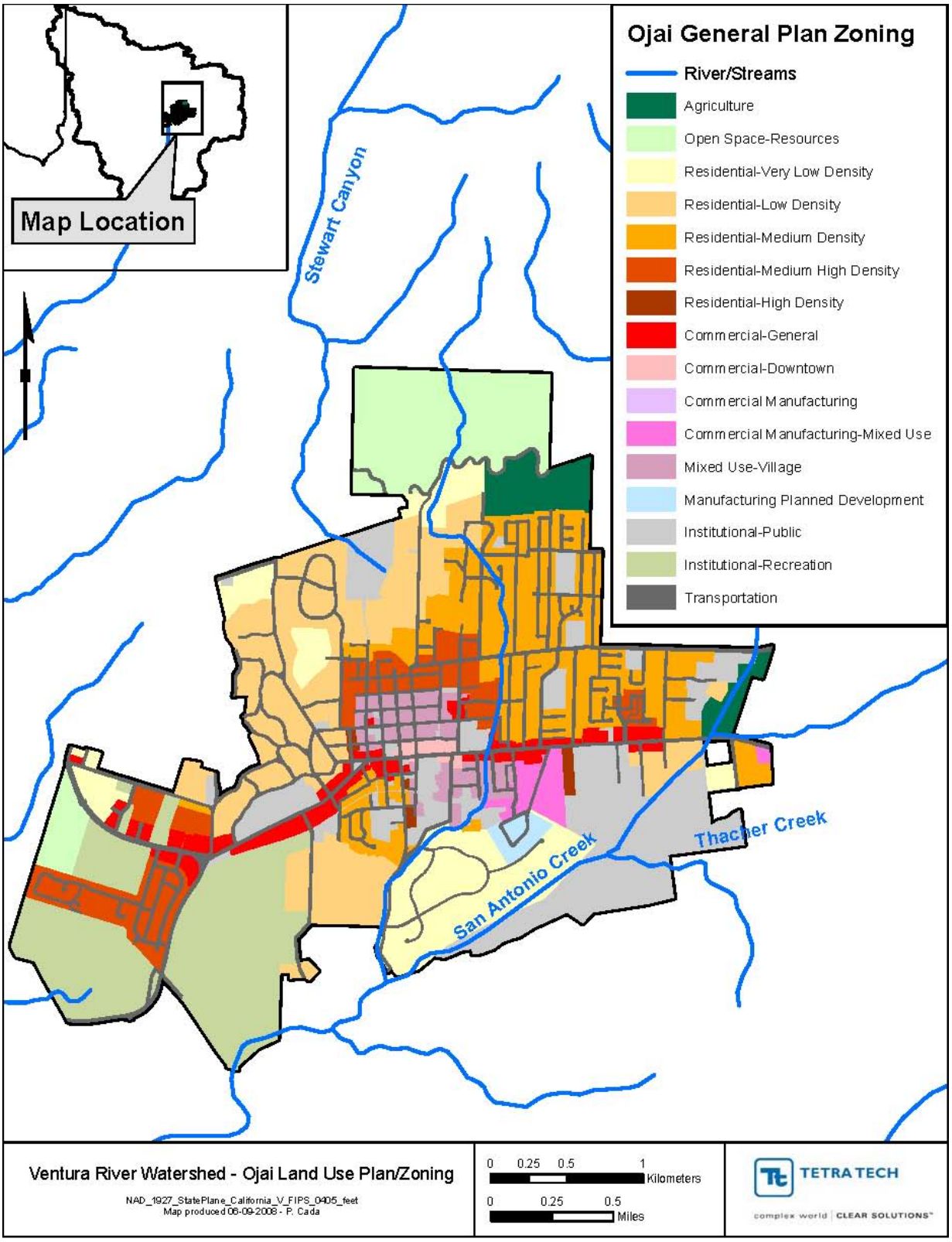
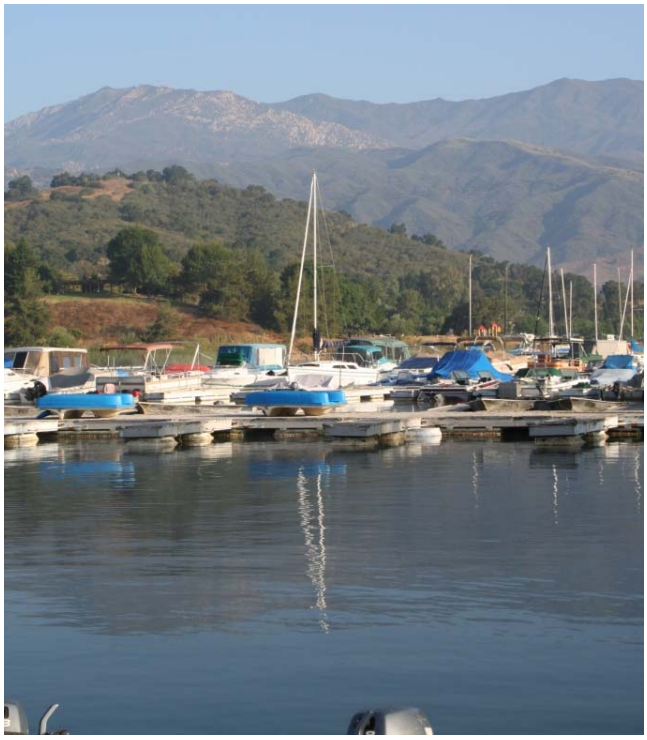


Figure 2.2-5 Ojai Zoning Map

Source: Tetra Tech 2008b

Several multiple-use trails serve bicyclists, equestrians, and pedestrians in the watershed. The Ojai Valley Trail follows the abandoned Southern Pacific Railroad right-of-way and is located along the west side of State Route 33 from Ojai to northern Foster Park. The Ventura River Trail, managed by the City of Ventura, is a multi-purpose trail that extends from Foster Park to the beach. It follows the Southern Pacific Railroad easement and connects the Ojai Valley Trail with the Omer Raines Trail (which extends along the coastline).

Lake Casitas is open to the public for non-body contact recreational activities. All recreational activities are operated by Casitas Municipal Water District (Casitas) or by concessionaries.



The Recreation Area encompasses approximately 4,097 acres and consists primarily of open space. The recreational facilities are located on approximately 400 acres scattered about the perimeter of the lake. Existing recreational facilities include camping, picnicking, motor boating, sailing, canoeing, and fishing. Lake Casitas hosted the 1984 Olympic Rowing and Canoeing Events and is currently the home of the Lake Casitas Rowing Association which provides recreational and competitive rowing training to youth and adults in the community. The lake is also used by bird watchers to view the many migratory birds that use Lake Casitas as they pass through the Pacific flyway. Facilities include stores, campgrounds, RV campgrounds, showers, restrooms, picnic areas, boat ramps, water playground, a radio-controlled airplane landing strip, and boat and trailer storage.

Lake Casitas is famous for its record fish catches. Fishing takes place from docks, boats, and shore. Lake Casitas contains a warmwater fishery that includes bass (primarily large mouth), catfish, sunfish, and crappie. These fish are non-native and were introduced when the lake was formed, but now are self-sustaining populations. Casitas stocks the lake annually with catchable size rainbow trout. Lake Casitas has also been stocked on an irregular basis with crappie and other panfish.

The Ventura County Parks Department maintains three regional parks (Camp Comfort, Soule Park, and Foster Park) located adjacent to waterways of the Ventura River. Camp Comfort Regional Park is situated adjacent to San Antonio Creek. Soule Park recreation area consists of a golf course and a public park. The confluence of San Antonio and Thacher creeks occurs within Soule Park, and the Ventura River runs through Foster Park. Activities at all parks include picnicking and playground areas and services such as public restrooms. Park users also wade in San Antonio Creek at Camp Comfort and in the Ventura River at Foster Park. Soule Park includes baseball and equestrian facilities as well as a public golf course. Water for golf course

irrigation at Soule Park comes from an on-site well operated by the golf course concessionaire and from water purchased from Casitas.

Other open spaces in the watershed near the Ventura River and its tributaries (excluding Lake Casitas Recreation Area) include:

- **Ojai Valley Land Conservancy's (OVLC) Ventura River Preserve.** In 2003, OVLC opened this preserve to the public. The preserve was formerly the 1,591-acre Rancho El Nido ranch. The property lies in the western half of the Ojai Valley and is bordered by 3 miles of the Ventura River. It is located adjacent to the Los Padres National Forest and other protected watershed lands. The preserve is a popular recreation destination for horseback riding, swimming, picnicking and hiking. As of May 2011, a new trailhead and public parking area located on Old Baldwin Road provides easy access to the Ventura River Preserve. The Old Baldwin Road Trailhead also includes a unique wheelchair-accessible paved trail leading to a scenic vista within the preserve.
- **OVLC's Ventura River-Confluence Preserve.** Established in April 2004, this thirty-acre parcel is named for the merging of the river's two major year-round streams. The preserve is located on both sides of Highway 33 just south of the San Antonio Creek Bridge at the base of the Arnaz Grade near Oak View. The Ojai Valley Bike and Bridle Path pass through the center of the Preserve. Lands within the river bottom will be open for special tours only and are still privately owned by OVLC, while the land lying between the Ojai Valley Bike Path and Highway 33 will be open for public use.
- **OVLC's San Antonio Creek Preserve.** The nine-acre San Antonio Creek Preserve is located adjacent to San Antonio Creek Road and 3/10 of a mile south of Camp Comfort County Park. For public safety and protection of sensitive habitat, this Preserve is open only for special tours and upon prior written requests.
- **Ventura Beach Resort (RV Park).** This privately owned facility is located on the west side of the river in the floodplain between Main Street and U.S. 101. The park has suffered several major floods due to its low-lying location in the floodplain. Park users can access the river directly.

In addition to the above facilities, there are many small commercial and residential equestrian facilities and stables in the watershed for boarding horses, equestrian training, and general equestrian recreation. Many of these stables are located along San Antonio Creek and along the stretch of the Ventura River north of the Robles Fish Passage Facility along Oso Road. These facilities include pastures and corrals that traverse the creek. Some horse-related facilities, grooming areas, manure or hay stockpiles, and training areas exist in or immediately adjacent to San Antonio Creek on private property. Equestrian riders routinely use informal trails in the bed and on the banks of the Ventura River and San Antonio Creek for recreation.

2.2.4 Urban Land Uses

Ojai is the most densely populated portion of the upper watershed, but it has a rural atmosphere and lifestyle. Industrial activities in Ojai are few and primarily related to agricultural support. Ojai attracts many out-of-town tourists due to the large number of cultural events, many small shops and art galleries, and various outdoor recreation and resort facilities. In 1979, the City of Ojai implemented growth management controls that remain in place today. As a result, the

overall land use pattern in Ojai is well established and is not intended to substantially change over time (City of Ojai 1997). The overall goal of the Land Use Element of the General Plan is to preserve the community's "small town" character. In addition, the Land Use Element specifies that the large expanses of open lands surrounding the city be preserved as agricultural open space or very low intensity residential development (less than one unit per 10 acres). The Land Use Element also discourages traditional suburban development around the perimeter of Ojai because it is separated from the main part of Ojai and contrary to its character (City of Ojai 1997).

The Land Use Element also expresses an intention for the City to take a stewardship role in the management of natural environments in the Ojai Valley and to consider preservation of natural features such as arroyos and creeks, hillsides, and viewsheds in future development.

Outside of Ojai are many small rural residential communities, including Meiners Oaks, Oak View, Live Oak Acres, and Casitas Springs. In general, residences and commercial buildings do not encroach into the river, except along selected portions of San Antonio Creek, Coyote Creek, and Live Oak Creek. Development in these areas is under the jurisdiction of Ventura County.

2.2.5 Agricultural Land Uses

Agricultural-related activities along the river and its tributaries include:

- Orchards scattered among industrial and residential development, east of SR 33 along Ventura Avenue.
- Dryland farming and cattle grazing between Santa Ana Road and the river, on the west side of the river between Foster Park and Santa Ana Road Bridge and along lower Live Oak Creek.
- Irrigated row crop farming and minimal cattle grazing at the Gramckow Ranch, previously Rancho Matilija/Farmount property west of the river, between SR 150 and the National Forest.
- Cattle grazing in the hills south of San Antonio Creek and along Lions Creek.
- Orchards in the northern and eastern portions of Ojai Valley adjacent to upper San Antonio Creek and major tributaries to San Antonio Creek, including Thacher, Reeves, McNell, Senior, Wilsie Canyon, Steward Canyon, McDonald Canyon, Gridley, and Cozy Dell creeks.
- Orchards scattered on both sides of the river on narrow terraces between Meiners Oaks and the confluence of Matilija Creek and the North Fork.
- Orchards and row crops on the floodplain west of the river and north of Main Street.

2.2.6 Industrial Land Uses

The major industrial area along the Ventura River and its tributaries is on the lower river where oil development occurs in the hills above the river, and industrial activities occur along Ventura Avenue east of the river. The latter consists of various manufacturing, construction, processing, and industrial storage facilities mostly north of School Canyon Road. The area south of this road is primarily residential and commercial.

A large abandoned chemical facility, PetroChem, is located adjacent to the river south of the Ojai Valley Sanitary District (OVSD) Wastewater Treatment Plant. The owner of the refinery, USA

Petroleum Company, has proposed to sell the refinery so that the site can be remediated and used for residential development. Other industrial facilities adjacent to the river include the OVSD Wastewater Treatment Plant, City of Ventura's Avenue Water Treatment Plant (for potable water), Enviro-Lene, Ventura County Hazardous Materials Recycling Facility, Brooks Institute of Photography (Ventura Campus), and Ojai Rubbish.

Oil development in the hills above the lower river has created a large system of well pads and access roads in relatively steep and rugged terrain. Primary access to the Area (formerly Shell) oil fields on the west side of the river is across Shell Road Bridge. A series of oil-related paved and dirt roads are located on west side of the Ventura River floodplain and the adjacent mountains.

The Ojai Schmidt Rock Quarry, an active aggregate mine, operates on the hillsides over the North Fork of Matilija Creek near SR 33. The mine operates under a Conditional Use Permit from Ventura County. The mine has steep barren slopes that exhibit evidence of severe erosion and sediment production that could enter the creek.

An in-channel sand mine along the lower river, operated by S. P. Milling for many decades, was closed in 1992. The site has been undergoing reclamation since that time, resulting in the development of dense willow woodland on the west side of the river downstream of the Shell Road Bridge.

2.3 Watershed Topographic Characteristics

The Ventura River watershed has three distinct sections that differ in topography and geology, and as a result, surface and groundwater hydrology in these sections differ (Keller and Capelli 1992, Fugro West 1996). These topographic sections can generally be described as:

- Mountainous upland creeks above the confluence of Matilija and North Fork Matilija creeks.
- Alluvial channel and floodplain areas along the mainstem of the Ventura River.
- The lagoon or delta, which is approximately 2 miles wide at the coast and extends about 1 mile upstream, almost to the Main Street Bridge.

Elevations and slopes in the Ventura River watershed are shown in Figure 2.3-1 and 2.3-2.

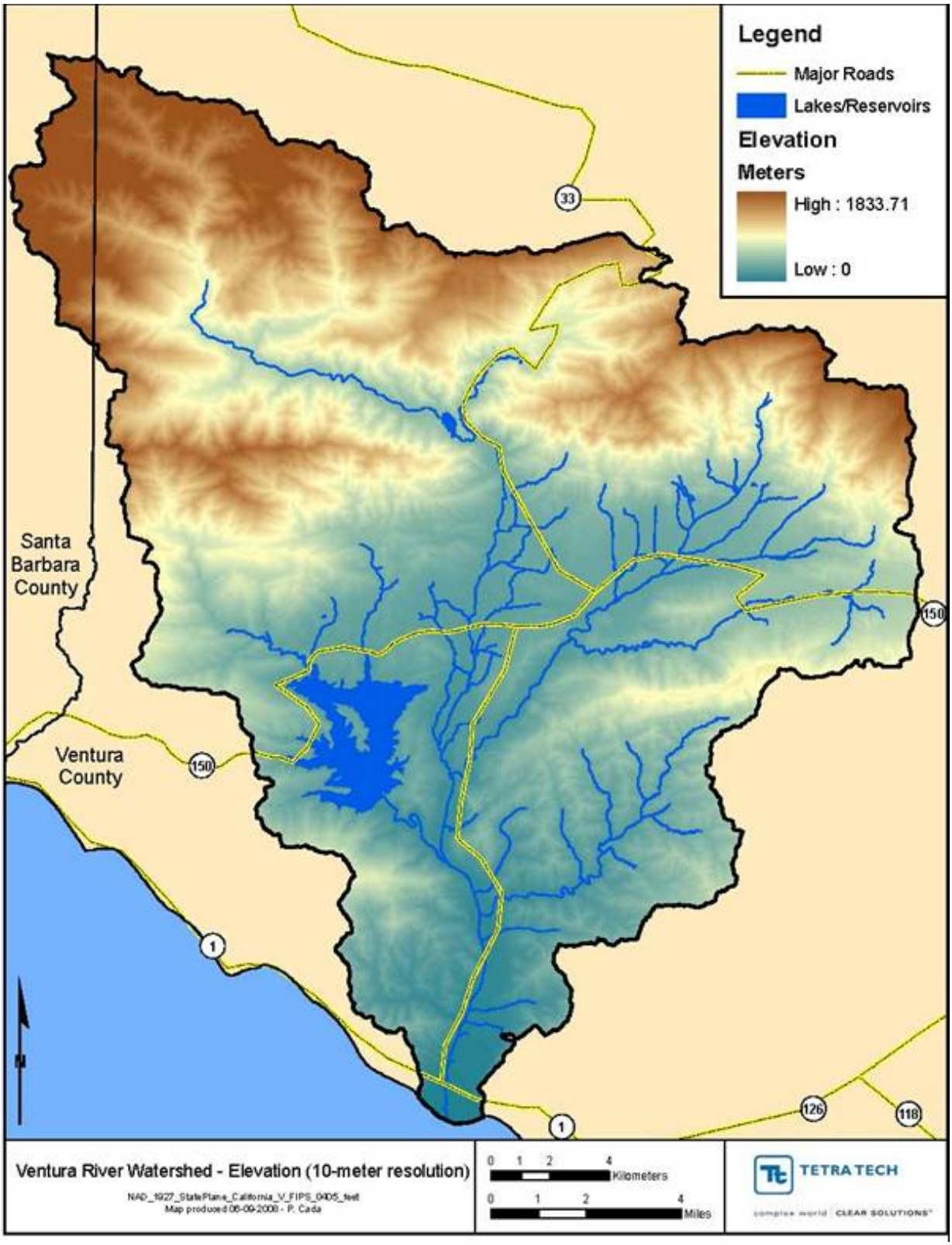


Figure 2.3-1 Ventura River Watershed Elevations

Note: Elevation Data derived from the 10-meter Digital Elevation Model for the Ventura River Watershed
Source: Tetra Tech 2008a

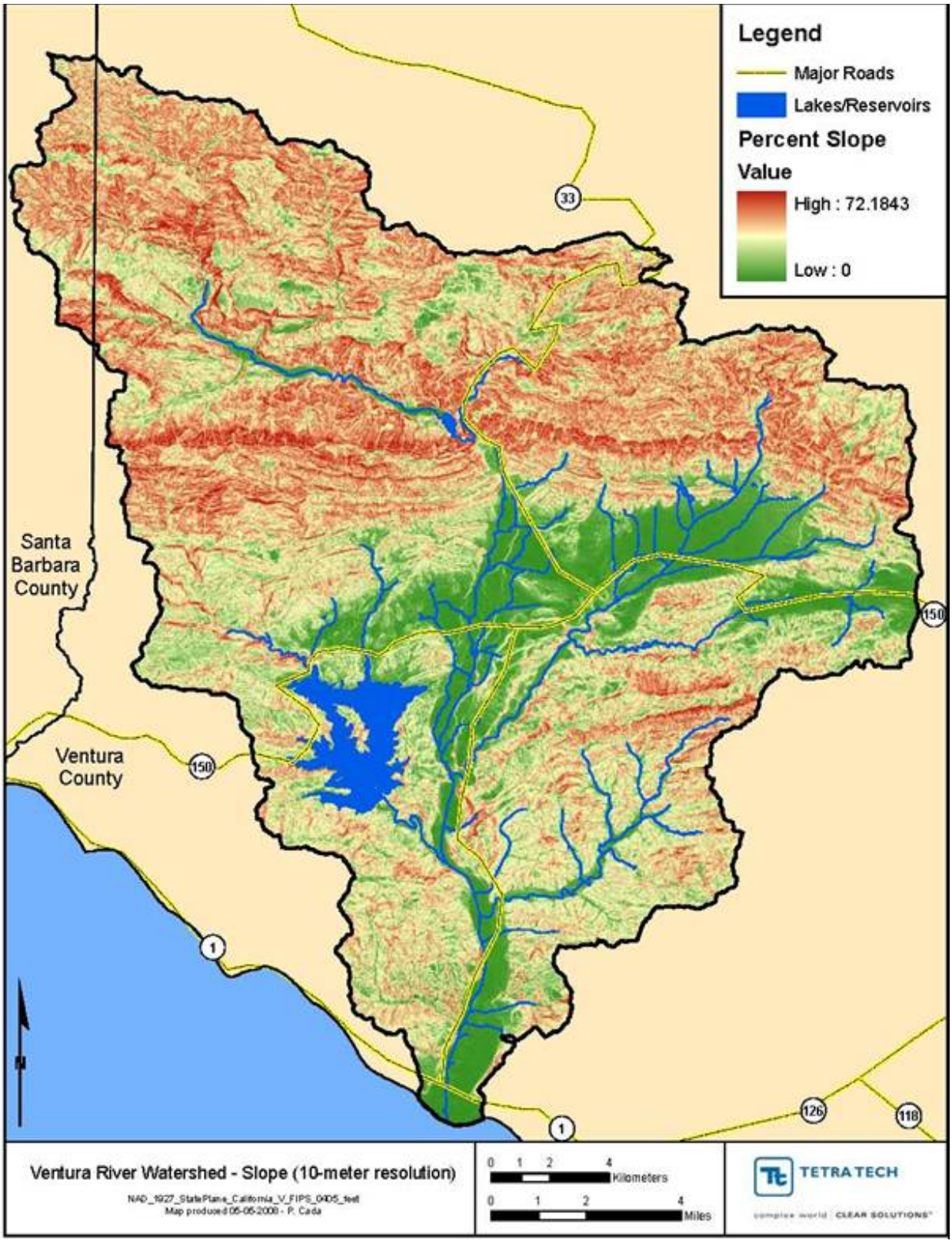


Figure 2.3-2 Ventura River Watershed Slopes

Note: Slope Data derived from the 10-meter Digital Elevation Model for the Ventura River Watershed.
Source: Tetra Tech 2008a

2.3.1.1 Mountainous Uplands

The mountainous uplands are the primary water and sediment production areas, with few or no alluvial deposits and steep streambed gradients. The major sub-basins with significant uplands include Matilija, North Fork Matilija, Coyote, Santa Ana, and San Antonio creeks (Tables 2.3-1 and 2.3-2). This is also the zone in which two major water supply and flood control facilities are located (Matilija Dam and Casitas Dam).

Table 2.3-1 Major Ventura River Watershed Sub-Basins and Water Facilities

Sub-Basin	Unit Area (sq. mi.)	Percent of Area at Foster Park (%)	Storage and Diversion Facilities	Present Capacity
Uplands: Headwaters/Tributaries				
Matilija Creek	55	29.3	Matilija Dam	500[a] acre-feet (AF)
North Fork Matilija Creek	16	8.5		
San Antonio Creek (includes Ojai Valley)	51	27.1		
Coyote and Santa Ana Creeks	41	21.8	Casitas Dam	254,000 AF
Alluvial Valleys: Mainstem				
Upper Ventura River	74[b]	39.4	Robles Dam	900 AF/day
Ventura River near Ventura at Foster Park	188	100.0	Foster Park	Surface: 21.4AF/day[c] Sub-surface: 11.1 AF/day
Ventura River below Foster Park	100			
Total	228			

a. Estimated by Reclamation (2000)
b Includes area of all upstream sub-basins
c. Average daily capacity, exclusive of Nye well field. Maximum production is effectively limited by the 13 mgd (20 cfs) capacity of the water treatment plant.

Source: ENTRIX and Woodward Clyde Consultants 1997 and Reclamation 2000

Table 2.3-2 Drainage Area of Sub-Watersheds in the Ventura River Watershed

Local Area Watershed Name	Drainage Area (mi^2)	Maximum Length of Watershed (ft)	Minimum Elevation of Watershed (ft)	Maximum Elevation of Watershed (ft)	Mean Annual Precipitation (inches)
Matilija at Matilija Dam	54.6	83,363	1,009.29	5456.77	23.5
North Fork Matilija Creek	16.2	40,554	1009.29	5006.72	22.1
Ventura River D/S of Willis Canyon	7.4	22,090	696.87	4,278.56	20.2
Ventura River at Live Oak Creek	11.6	45,685	290.61	2,310.04	17.8
San Antonio Creek	51.0	79,331	290.41	5.410.69	18.3
Santa Ana Creek at Lake Casitas	9.5	38,211	528.60	4,645.89	18.7
Coyote Creek above Lake Casitas	13.4	36,127	560.88	4,769.48	21.1
Drainage area that includes Lake Casitas	15.3	31,470	514.96	2,342.64	18.2
Ventura River Subarea to Foster Park	9.3	25,313	195.36	1,302.82	17.3
Cañada Larga Subarea to Foster Park	19.3	50,752	195.78	2,788.00	17.9

Table 2.3-2 Drainage Area of Sub-Watersheds in the Ventura River Watershed

Local Area Watershed Name	Drainage Area (mi^2)	Maximum Length of Watershed (ft)	Minimum Elevation of Watershed (ft)	Maximum Elevation of Watershed (ft)	Mean Annual Precipitation (inches)
Lower Ventura River	15.5	35,470	0.00	2,117.63	16.9
Entire Ventura River Watershed	228	—	0.0	5,456.77	19.9

Source: U.S. Army Corps of Engineers (USACE) 2004

Approximately 80 percent of the watershed is composed of uplands of hill slopes and ridges with surface geology of Tertiary sedimentary rocks (3 million to 70 million years old). The bedrock units of the Tertiary sedimentary rocks (i.e., well-cemented sandstones, siltstones, conglomerates, and shales) have been severely deformed by folding and faulting, and have low permeability relative to the unconsolidated alluvial deposits in the main valleys (Reclamation 2003).

2.3.1.2 Alluvial Valleys

The alluvial valleys are primarily a zone of storage and transfer of water and sediment and include the mainstem river, floodplain, and valley bottom downstream of the confluence of Matilija and North Fork Matilija creeks and the Ojai Valley (or the San Antonio Creek sub-basin). The upper portion of the Ventura River mainstem valley (upstream of Foster Park) is the reach of the river with the majority of groundwater production and surface diversions.

The alluvial valleys are underlain by relatively shallow deposits, ranging in age from 10,000 to 1 million years old. The Ventura River has slowly migrated to the west during the late Quaternary Period, leaving a series of terraces marking former channel and floodplain locations (Putnam 1942 and Rockwell et al. 1984, as cited in Keller and Capelli 1992).

The alluvial deposits continue to be affected by active regional tectonic forces that tilt and bend sediments and create vertical and horizontal offsets (faults), affecting subsurface water flow and water levels. The alluvial valley fills constitute the major groundwater aquifers, and the major groundwater basins of the Ventura River watershed are located in these valleys and include the Ojai Valley basin, the Upper Ventura River basin (above Foster Park), and the Lower Ventura River basin (Fugro West 1996). In addition, minor groundwater basins occur in the Upper Ojai Valley (along Lion Creek) and along lower San Antonio Creek (Turner 1971, as cited in EDAW et al. 1981).

2.3.1.3 Lagoon/Delta

The Ventura River lagoon encompasses approximately 3.7 acres between the shoreline and a few hundred yards upstream of the U.S. Highway 101 Bridge. The lagoon is separated from the Pacific Ocean by a sand/cobble bar during the dry season and opens and closes in response to storms and flow changes throughout the year. When full, the lagoon covers approximately 1.5 surface hectares and ranges in depth from 0.6 to 2.4 meters. The river lagoon includes the shifting channels and depositional environments at the mouth of the river, occurring in an arc-shaped delta that extends approximately 1 mile upstream from the ocean and is 2 miles wide at the coast. An estuary at the second mouth exists to the west of the main lagoon (CRWQCB-LA 2002).

In general, sandbar formation and breaching depends on wave action to deposit or remove sand, freshwater streamflow in the river, and tidal action. Lagoons generally open during periods of high river flow and storm-generated waves in the winter storm season. Low streamflow during drought years can prevent sandbar breaching; some California streams may be closed for multiple years under such conditions.

For most years, the lagoon is dominated by freshwater during most of the year (CRWQCB-LA 1993, Moore 1980). When the lagoon is open to the ocean, tidal water level changes are observed to about 150 meters upstream of the railroad bridge (Casitas and City of Ventura 1984). The sandbar breaches readily under natural conditions and has never been artificially breached. The lagoon opens in winter after the first few major storms and usually remains open until early spring. With the sandbar open, water levels in the lagoon depend on tide levels and the height of the sandbar, and reach a maximum depth of approximately 4 feet (City of Ventura 1990). Tidal influence can extend to just above the U.S. Highway 101 Bridge (Ferren et al. 1990). During the summer, the lagoon will open periodically, usually two to six times for brief periods (2 to 7 days).

2.4 Seismicity, Soils, and Geomorphology

2.4.1 Faults and Seismicity

Potential for earthquake damage exists throughout Ventura County, as with most of Southern and coastal California due to the number of active faults within and near the county. These faults are described below (URS 2005).

- San Andreas Fault. The San Andreas is the longest and most significant fault in California. Due to clearly established historical earthquake activity, this fault has been designated as active by the State of California. The last major earthquake on this fault near Ventura County was the Fort Tejon earthquake of 1857, which is estimated to have had a magnitude of 8.0 (Richter Scale) and would have caused considerable damage had there been structures in the southern county area. The occurrence of another such earthquake along this fault is considered possible within the near future.
- Malibu Coast Fault system. The Malibu Coast Fault system includes the Malibu Coast, Santa Monica and Hollywood faults. The system begins in the Hollywood area, extends along the southern base of the Santa Monica Mountains, and passes offshore a few miles west of Point Dume. The 1973 Point Mugu earthquake, described in the following section, is believed to have originated on this fault system.
- San Cayetano-Red Mountain-Santa Susana Fault system. This fault system consists of a major series of north-dipping reverse faults that extend over 150 miles from Santa Barbara County into Los Angeles County. The San Cayetano Fault is a major, north-dipping reverse fault that extends for 25 miles along the northern portion of the Ventura Basin. The San Fernando earthquake of 1971, described in the following section, was caused by activity along this fault.
- Oak Ridge Fault system. The Oak Ridge Fault system is a steep (65 degrees) southerly-dipping reverse fault that extends from the Santa Susana Mountains westward along the southerly side of the Santa Clara River Valley and into the Oxnard Plain. The system is over 50 miles long on the mainland and may extend an equal or greater distance offshore. Several

recorded earthquake epicenters on land and offshore may have been associated with the Oak Ridge Fault system. Portions of the system are zoned by the state as active.

- Simi-Santa Rosa Fault System. This fault system extends from the Santa Susana Mountains westward along the northern margin of the Simi and Tierra Rejada Valleys and along the south slope and crest of the Las Posas Hills to their westerly termination.
- Pine Mountain Thrust Fault and Big Pine Fault. These two large faults occur in the mountainous portion of the county north of the Santa Ynez Fault; the faults are located 9 and 16 miles north of the City of Ojai, respectively. The Pine Mountain Thrust Fault is reported to have ruptured the ground surface for a distance of 30 miles along its length during the northern Ventura County earthquakes of November 1852.

The Ventura River basin is underlain by Tertiary-age marine and continental deposits, primarily sandstone, clay/siltstone, and shale (Dibblee 1988). These deposits have been deformed by tectonism, resulting in east-west trending fold and fault structures and geologic units inclined toward the north and south (Jennings 1994). The Santa Ana/Arroyo Parida fault is an east-west trending structure that runs from the south-central portion of the Ojai Valley across the Ventura River near the SR 150 Bridge. The relative displacement along this fault is such that the northerly fault block has been lowered relative to the southerly fault block. The other fault is the San Cayetano fault, a steep, north-dipping thrust fault that runs over a distance of 30 miles from the Ojai Valley to northeast of Piru.

Additionally, several flexural-slip faults in the vicinity of Oak View have produced tilted terrace surfaces south of the Santa Ana fault within the Ayers Creek syncline (Rockwell et al. 1984). The Red Mountain anticline and thrust fault dominates the reach from Oak View to Foster Park.

Ongoing field and laboratory studies suggest the following maximum likely magnitudes and recurrence intervals for the major local faults: San Andreas (M8.0, recurrence interval of 300 years), Malibu Coast Fault system (M6.7, recurrence interval 2,908 years), San Cayetano Fault system (M6.8, recurrence interval 150 years), Red Mountain Fault system (M7.0, recurrence interval 507 years), Santa Susana Fault system (M6.6, recurrence interval 138 years), Oak Ridge Fault system (M6.9, recurrence interval 299 years), and the Simi-Santa Rosa Fault system (M6.7, recurrence interval 933 years) (URS 2005, and Reclamation 2010).

The strength of an earthquake's ground movement can be measured by peak ground acceleration (PGA). PGA measures the rate in change of motion relative to the established rate of acceleration due to gravity 980 centimeters per second. PGA is used to project the risk of damage from future earthquakes by showing earthquake ground motions that have a specified probability (10 percent, 5 percent, or 2 percent) of being exceeded in 50 years. These ground motion values are used for reference in construction design for earthquake resistance. The ground motion values can also be used to assess relative hazard between sites when making economic and safety decisions (URS 2005).

The Ventura County Resource Management Agency derived probabilistic PGA data based on seismic data from the California Geological Survey. The county data were used to assess exposure to moderate and high-risk areas for earthquake hazards. Moderate earthquake hazard areas were defined by ground accelerations of 0.65, 0.75, and 0.85; and high earthquake hazard areas were defined by ground accelerations of 0.95 and 1.05 (URS 2005).

Ventura County falls within the middle to top ranges of the scale. Regions at the upper end of this scale are often near major active faults. These regions will, on average, experience stronger earthquake shaking more frequently, with intense shaking that can damage even strong modern buildings (URS 2005).

2.4.2 Soils

Soils in the United State are assigned to one of four groups according to the rate of water infiltration when the soils are not protected by vegetation, are thoroughly wet, and receive precipitation from long-duration storms. Based on the infiltration rate, soils are assigned to four groups (A, B, C, and D) or may be assigned to one of three dual classes (A/D, B/D, and C/D). The groups are defined as follows (Natural Resources Conservation Service 2011):

- Group A. Soils having a high infiltration rate (low runoff potential) when thoroughly wet. These consist mainly of deep, well drained to excessively drained sands or gravelly sands. These soils have a high rate of water transmission.
- Group B. Soils having a moderate infiltration rate when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.
- Group C. Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission.
- Group D. Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clays that have a high shrink-swell potential, soils that have a high water table, soils that have a clay pan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission. Soils in this group may also be assigned to a dual hydrologic group (A/D, B/D, or C/D), with the first letter for drained areas and the second for undrained areas.

Hydrologic soil groups in the Ventura River watershed are shown in Figure 2.4-1.

2.4.3 Channel Geomorphology and Sediment Transport

2.4.3.1 Historical Context

Based on a review of the historical ecology of the Ventura River (SFEI, 2011), the form of the river valley has not changed substantively since the arrival of European settlers. The upper reach of the river, in Matilija Canyon, was relatively narrow, confined by the canyon walls, the river bed contained many large boulders, and flows were perennial. Once the river exited the canyon, the channel broadened into multiple braided channels, separated by large islands that supported mature vegetation, flows were intermittent, and the channel bed was comprised of gravel and sands. Below Casitas Springs and the confluence with San Antonio Creek, the channel narrowed, and flows became perennial and the river bed contained large cobbles. Below Foster Park, the river was contained in multiple braided channels, flows were perennial, and cobbles predominate. At the mouth of the river, the channel broadened into a broad willow forest, with remnant lagoons and wetlands formed from the shifting of the river channel.

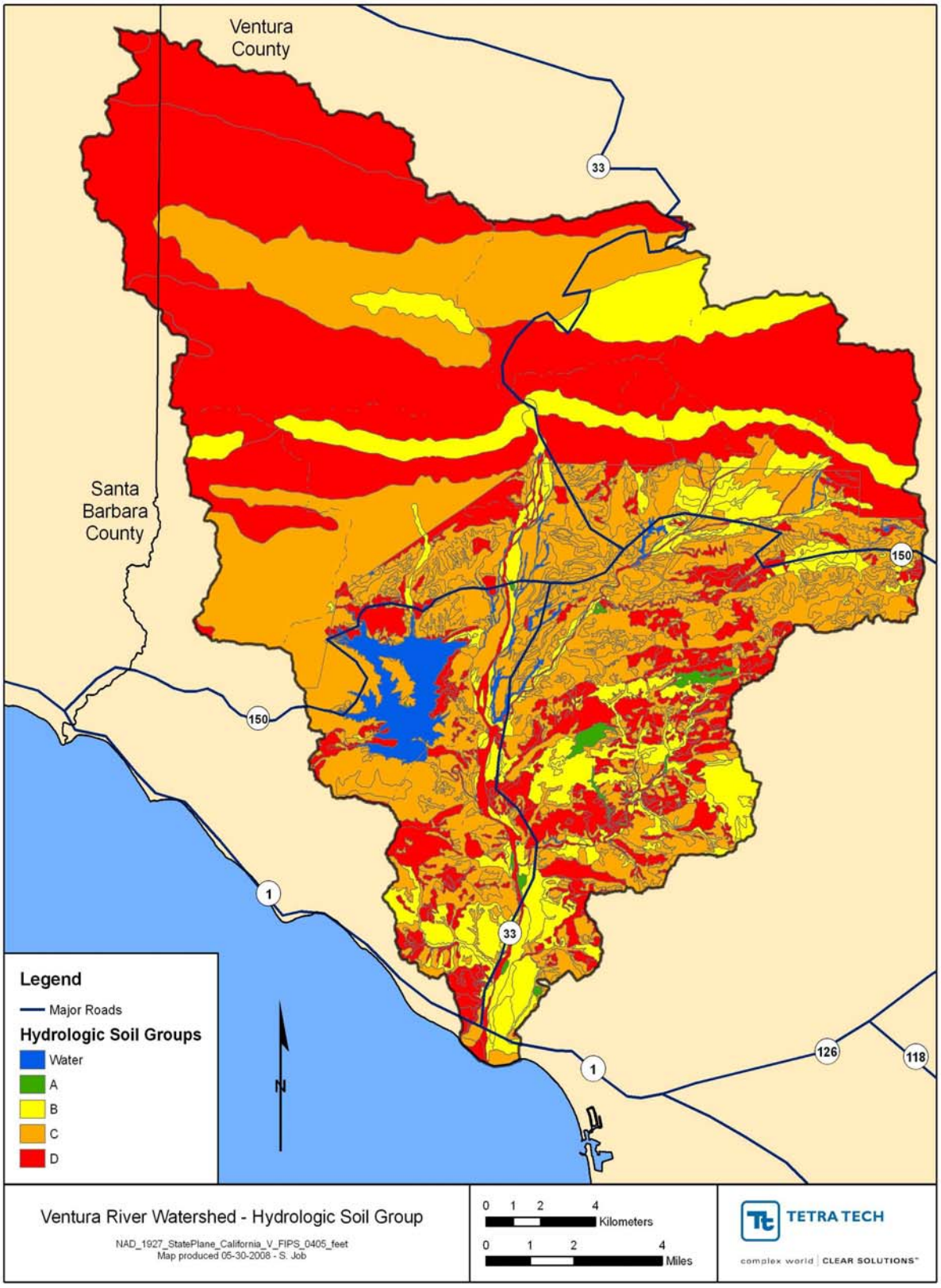


Figure 2.4-1 Hydrologic Soil Groups in the Ventura River Watershed

Source: Tetra Tech 2009a

In historic times, changes in the river channel have resulted from the installation of Matilija Dam, the placement of levees along the river in several locations, and the installation of bridges at the mouth of the river. The construction of Matilija Dam (in 1949) has altered flows and sediment transport in the river channel. Before the dam, historical evidence suggests a cycle of sediment build-up (during dry and average years) and transport (during flood events) which may have changed the elevation of the river bed (SFEI 2011). The placement of levees along several stretches of the river has constrained the lateral movement of the channel during high flow events. At the mouth of the river, the placement of levees and the installation of three bridges (for the Union Pacific railroad, Main Street, and US Highway101) have constrained the lateral movement of the river bed and reduced the size of the lagoon.

2.4.3.2 General River Description

Upstream of the Matilija Dam, Matilija Creek is a steep, cobble bed stream confined between canyon walls. Matilija Creek gradually becomes less steep and experiences active channel migration as it cuts through the delta to reach Matilija Reservoir. Downstream of the dam, Matilija Creek joins the North Fork of Matilija Creek to form the Ventura River. The 1.5 miles immediately downstream of the dam is an extremely steep reach composed primarily of boulders. As the Ventura River exits this steep canyon, it enters a wide depositional plain for approximately 1 mile until it reaches the Robles Diversion Dam. From the Robles Diversion Dam to the confluence with San Antonio Creek, the Ventura River is a slightly sinuous braided stream that experiences active channel migration. From San Antonio Creek until the lagoon, the river is relatively more confined and has fewer channels (Reclamation 2003).

The morphologic parameters of the Ventura River can be classified as a "D" type stream based on the Level 1 Classification system developed by Rosgen, which integrates information on basin relief, landform, and valley morphology. D-type streams are distinctive: multiple channel systems exhibiting a braided pattern with longitudinal, transverse and mid-channel bar formations. Historically, the cross-sectional shape of the river channel has been typically wide and relatively shallow, tending to increase in width more than in depth as discharge increases. However, recent cross-section surveys suggest the channel has incised between 1971 and 2001 and is becoming more entrenched, which could decrease the width/depth ratio (Reclamation 2003).

The morphology of the Ventura River reflects the changes in topography that occur from the headwaters to the lagoon at the ocean. Channel slopes are generally greater than 0.05 ft/ft on the tributary streams, but decrease to approximately 0.02 ft/ft between Matilija Dam and Robles Diversion. Slopes decrease further to between 0.015 ft/ft and 0.01 ft/ft from the Robles Diversion Dam to the confluence with San Antonio Creek. Below San Antonio Creek, the channel gradient generally decreases to 0.005 ft/ft to the mouth (ENTRIX 2001b).

The significant change in channel gradient reduces the capacity of the river to transport bed and suspended sediment loads derived from the upper watershed. In addition to the downstream reduction in channel slope, the more highly entrenched and narrow tributary streams give way to a wide alluvial valley that has comparatively much less energy to transport sediments. The multiple channel morphology of the mainstem is a result of the high sediment yields and reduced sediment transport capacity relative to tributary streams that creates a series of various bar types and unvegetated islands that are subject to shifting positions during high-flow events (ENTRIX 2001b).

The D-type channels indicative of the Ventura River are associated with unstable bar features and frequent lateral channel adjustments. Based on the historic aerial photography, the low- and high-flow channels may change position within a dynamic floodplain, but the floodplain width and terrace features have remained relatively stable. Over geologic time periods, there has been an approximate balance between rate of uplift due to faulting and the rate of river down-cutting (Reclamation 2000). There is considerable evidence that fault displacement and landform deformation in the central Ventura Basin and the western Transverse Ranges is causing local uplift. The Arroyo Parida-Santa Ana fault, Oak View faults, and other faults have demonstrated to cause local uplift since the late Pleistocene age. In response to this uplift, the Ventura River has been adjusting by down-cutting at an approximately equal rate as to uplift, from about 0.5 to 1.3 millimeters (mm) per year (Rockwell et al. 1984). Cross-section data from Reclamation (2003) suggests that channel down-cutting has accelerated in recent decades. Channel down-cutting could result in disconnecting the floodplain from the channel, depending upon the relative magnitude of incision.

Interpretation of the time-series aerial photography indicates that the Ventura River between Foster Park and Robles Diversion has likely always possessed the morphological characteristics and functionality of a D-type channel. However, recent decades of channel incision is an indicator that sections of the Ventura River are evolving into a different stream type that is associated with the loss of multiple high- and low-flow channels and is more characteristic of a single-thread channel, which is becoming disconnected from its former floodplain. As such, the river is not vertically stable, although the extent to which continued vertical incision may occur is not known.

2.4.3.3 Sediment Supply and Characteristics

The Ventura River is considered to produce some of the highest suspended and bedload yields per unit watershed area in Southern California (Brownlie and Taylor 1981, as cited in Keller and Capelli 1992), with steep headwater slopes in the watershed producing most of the sediment supplied to the river through mass wasting processes (Reclamation 2000). Forest fires are also believed to have a significant impact on sediment production in the watershed by increasing the erodibility of hillslopes.

Previous studies have estimated sediment yields for the Matilija sub-basin upstream of the dam at 1.92 AF per square mile per year and at 2.10 AF per square mile per year for the entire Ventura basin without the influence of Casitas and Matilija dams to 2.78 AF per square mile per year with Matilija and Casitas dams in place (Reclamation 2000). Estimated sediment yields ranged from 1.6 to 6.8 AF per square mile per year for headwater sub-basins of the Ventura River; 2.5 AF per square mile per year is an accurate estimate for solely the Matilija sub-basin (Reclamation 2000). This compares with 0.7 AF per square mile per year average sediment yield and 3.0 AF per square mile per year (considered a high sediment yield), compiled from various drainage basins of 100 square miles or less in California (Leopold 1994). However, construction of dams in the upper watershed has reduced suspended and bedload sediment transport into the mainstem of the river since the late 1940s.

Over 98 percent of the total sediment load in the Ventura River and San Antonio Creek is suspended (Reclamation 2003), which is typical of coastal California streams. Approximately 96 percent of the coarse sand load (0.062 mm to 2 mm in diameter) is suspended (Reclamation 2003). While larger particles are moved during large floods, these grain sizes comprise a

relatively small portion of the load (approximately 2 percent of the total sediment load). The relative amount of coarse material being transported increases with increasing flow rate. However, these large particle sizes dominate the bed material and exert a much greater influence on channel form (Reclamation 2003). Most of the mainstem Ventura River is dominated by large gravel-size material, with smaller-sized gravels and larger-sized boulders as sub-dominant materials.

Total sediment load is transported during only a few days each year with relatively infrequent storm events. For example between October 1976 and September 1978, 92 percent of the sediment load in the Ventura River was transported during five storm events each averaging 10 days (Reclamation 2000). It has been estimated that, over the long-term, the largest proportion of the total sediment load (i.e., suspended sediment plus bedload sediment) is transported by flows of approximately 6,000 cfs, which is equivalent to the mean annual flood, with a 2.33 year return interval.

2.5 Fire Regime

Wildfires are a common occurrence in the hills and mountainous regions of Ventura County. They generally occur in the late summer and fall when vegetation is dry and weather conditions are favorable for the occurrence and spread of fires. Moderate fires associated with floods have occurred every 10 years, while extreme fires and major floods have occurred every 20 years (Chubb 1997). The Matilija and North Fork Matilija sub-basins have experienced the most widespread, repeated fire damage, with major fires in 1932, 1949, and 1985 (the Wheeler Fire, or Wheeler #2). Wheeler #2 covered 54 percent of the watershed and the southeastern portion of the watershed also was heavily impacted by a single fire in September 1979 that covered 15 percent of the watershed, known as the Creek Road Fire (Tetra Tech 2009a). The area affected by these two fires is shown in Figure 2.5-1, and the cumulative area burned between 1965 and 2007 is shown in Figure 2.5-2.

Several other fires burned at least 5 square miles of land within the watershed and are thus considered to be potentially significant for impacts on basin hydrology (Table 2.5-1). These include the two major fires occurring in 1979 and 1985, mentioned above, as well as major fires in 1983 and 1993.

Table 2.5-1 Fires Covering more than 5 Square Miles in Ventura River Watershed, 1965-2008

	Date of Fire	Square Miles in Watershed	Percentage of Watershed Area Burned	UIDENT
Wheeler #2	07/01/1985	122.10	54%	LPNF19850027
Creek Road	09/18/1979	33.85	15%	47VENT_CO
Matilija	07/07/1983	7.35	3%	LPNF19830019
Ferndale	10/14/1985	5.65	3%	197VENT_CO
Steckel	10/27/1993	5.54	2%	187VENT_CO

Source: Tetra Tech 2009a



Figure 2.5-1 The Creek Road (1979) and Wheeler #2 (1985) Fire Areas

Source: Tetra Tech 2009a



Figure 2.5-2 Cumulative Burned Area within the Ventura River Watershed, 1985-2007

Source: Tetra Tech 2009a

Some areas of the watershed have not burned for many years, such as the area around Lake Casitas and parts of the San Antonio Creek basin. These locations may be susceptible to intense damage from future fires due to accumulated fuel loads (Chubb 1997). By reducing or destroying vegetative cover and altering soil characteristics, fires may result in conditions that can significantly increase runoff and erosion when winter rains begin to fall. These conditions may result in a debris flow (also referred to as mud flow) – a slurry of water, sediment, and rock that converges in a stream channel (URS 2005).

2.6 Hydrology

2.6.1 Historical Context

Although few records exist prior to the 20th century, a review of historical maps and documents suggests that the historical hydrology of the Ventura River was a result of the form of the river channel and the associated geology. In the reach of the river within Matilija Canyon, flows were perennial. As the river entered the Ojai Valley and the channel broadened, surface flows became intermittent. At the confluence with San Antonio Creek, and from Foster Park to the mouth of the river, flows were perennial (SFEI 2011).

2.6.2 Surface Water

Flow conditions in the mainstem of the Ventura River and tributary watersheds are naturally variable depending upon precipitation (rainfall and snowmelt). About 80 percent of the time, there is no significant surface flow in the Ventura River above the confluence with San Antonio Creek. However, there is generally year-round flow in the lower reaches of San Antonio Creek. During the wet season, the surface flows are "flashy," with sudden rises in discharge immediately following the onset of precipitation, and relatively rapid declines in streamflow after precipitation decreases (USACE 2004).

Under summer low-flow conditions, surface streamflow at various locations in the watershed is governed by a number of factors, including precipitation input, spring discharge, groundwater levels, the effects of water diversions, water storage and water supply releases, treated wastewater discharge, and groundwater extraction. Some reaches of the mainstem Ventura River tend to go dry on a yearly basis. This typically includes the Ventura River reach between Robles Fish Passage Facility and the upstream end of the Casitas Springs/Foster Park reach between the confluence of San Antonio Creek and Foster Park. The Casitas Springs/Foster Park reach and Ventura River downstream from the OVSD Wastewater Treatment Plant to the lagoon typically retains flows year round. This section of the Ventura River has perennial flows, except during some drought years, due to a natural bedrock barrier that forces subsurface flow to the surface. The river channel occurs as a wide floodplain and during high flows is "characterized by a typical pool riffle continuum found in low gradient streams." Vegetation such as watercress and water veronica is consistent with the spring-fed nature of this reach (Moore 1980).

San Antonio Creek typically goes dry upstream from Soule Park across the Ojai Valley, but is typically perennial downstream to the confluence with the Ventura River. North Fork Matilija Creek retains perennial surface flows except during long periods of severe drought (ENTRIX 2003). Along the mainstem, surface flows dry up in locations between the Robles Fish Passage Facility and the confluence of San Antonio Creek. However, small summer flows are maintained upstream of the Robles Fish Passage Facility; in the Casitas Springs/Foster Park reach, between Foster Park and the confluence of San Antonio Creek; and downstream of the OVSD Wastewater

Treatment Plant (ENTRIX and Woodward Clyde Consultants 1997). The following background information summarizes the general hydrology of the Ventura River watershed.

From the Matilija Creek headwaters to Camino Cielo, the Ventura River is perennial, supported in part from releases from Matilija Dam. The flow is intermittent from Camino Cielo to the confluence with San Antonio Creek with the reach below the Robles Fish Passage Facility typically going subsurface during the summer months (ENTRIX 2001). Historically, there has been little or no surface flow in the river in the summer from Hollingsworth Ranch (8 miles above the lagoon) to the former Soper's Ranch (14 miles inland). There is a geologic discontinuity at Casitas Springs that causes groundwater to rise and feed a perennial stretch of the surface flow below San Antonio Creek (CRWQCB-LA 2002). Surface flows in this reach come from San Antonio Creek, Live Oaks Acres Creek, and small springs and rising groundwater. Between the confluence with San Antonio Creek and Foster Park, flow is perennial, with some disruption at Foster Park by the groundwater extraction. The river has a perennial flow to the lagoon due to rising groundwater and water treatment plant discharges.

2.6.2.1 Surface Flow Conditions

The factors controlling surface streamflow differ considerably during the high-flow season or wet years from those that occur during low-flow seasons or dry years. The following summary of historical conditions presents separate discussions of high and low flows to help clarify the relationship between streamflow conditions and various water resource developments and operations. Several stream gages are located in the Ventura River watershed, and some have a record extending as far back as 1927 (Table 2.6-1). Originally, the U.S. Geological Survey (USGS) operated them all, but starting in the 1980s, the District and Casitas have operated several gages. The operation of some gages has been discontinued for various reasons; for example, the gage above Matilija Dam (11114500) was destroyed in the 1969 flood. The gage locations are shown in Figure 2.6-1 along with their periods of record.

Table 2.6-1 Stream Gages in the Ventura River Watershed

Description	USGS Gage Number	Drainage Area (mi^2)	Period of Record	Data Source
Matilija Creek U/S Reservoir near Matilija Hot Springs	11114500	50.7	1948-1969 (destroyed)	USGS
Matilija Creek at Matilija Hot Springs	11115500	54.7	1927-present	USGS and Casitas
North Fork Matilija Creek at Matilija Hot Springs	11116000	15.6	1928-present	USGS and District
Ventura River near Ojai	11116500	70.7	1911-1984 (not maintained)	USGS
Ventura River near Meiners Oaks	11116550	76.4	1959-present	USGS and Casitas
San Antonio Creek near Ojai	11117000	33.7	1927-1932	USGS
San Antonio Creek at Casitas Springs	11117500	51.2	1949-present	USGS and District
Coyote Creek near Oak View	11117800	9.11	1958-present	USGS and Casitas
Coyote Creek near Ventura	11118000	41.2	1927-1982	USGS and Casitas
Ventura River Diversion near Ventura	11118400	--	1969-present	USGS
Ventura River near Ventura	11118500/ 11118501	188	1929-present, 1932-present, respectively	USGS
Ventura River at Santa Ana Blvd.	Flood warning gage	--	2002-present	District

Table 2.6-1 Stream Gages in the Ventura River Watershed

Description	USGS Gage Number	Drainage Area (mi^2)	Period of Record	Data Source
Thacher Creek at Boardman	Flood warning gage	--	2002-present	District
Matilija Creek upstream of Reservoir	11114495	47.8	2002-present	USGS

Source: District 2007; USGS 2007; Casitas, no date

2.6.2.2 River and Tributary Runoff Production

The production of runoff in various tributaries is generally related to sub-basin area, peak elevations, and variations in vegetation and soil conditions, as well as local storm patterns. Runoff volumes, hydrograph timing, and sediment yield over the period of record has been greatly affected by interaction of fires and floods (refer to Section 2.5, Fire Regime).

Long-Term Averages

The long-term average runoff production for the gauged tributaries and the Ventura River is presented in Table 2.6-2. Matilija and San Antonio creek sub-basins have the largest average annual runoff volumes, with Matilija Creek being the single most important sub-basin for total volume. North Fork Matilija Creek and Matilija Creek are the major water production areas, with long-term average runoff of approximately 500 AF per square mile of watershed area. San Antonio Creek has the lowest runoff production per unit area, but has a larger watershed than either Coyote or Santa Ana creeks. Therefore, the average annual runoff produced from the San Antonio Creek basin is approximately equal in volume to that from both the Coyote and Santa Ana sub-basins upstream of Lake Casitas.

Water Year Types

Annual unimpaired runoff for the Ventura River watershed between 1930 and 2005 varies greatly, with several extremely high years of runoff much higher than the mean value (Table 2.6-3; Figure 2.6-2). The totals range from a low of 1,602 AF in water year (WY) 1961 to a maximum of 277,300 AF in WY 1995. The median annual unimpaired runoff, 18,116 AF, is much lower than the mean due to the statistical effect of a few extremely large runoff years.

The wide range of streamflows from year to year is not unusual for a semi-arid setting, but has important implications as a natural limitation to both the native fisheries resources and water supply management. Over typical planning timeframes (20 to 50 years), such variability creates limitations to water supply management and native fisheries resources. However, when viewed from longer time spans, the conditions are less of a limiting factor than an evolutionary pressure affecting the traits of native fishes. The entire historical record has been analyzed and categorized into WY types. Standard hydrologic methods were used to rank the years and analyze the percent of years with certain ranges of values creating three classes: wet (more than 23 inches of rainfall), normal (16 to 23 inches of rainfall), and dry (less than 16 inches of rainfall. The WY type was determined using the unimpaired runoff for the Ventura River, near Ventura gage (combined record, USGS #8501) (Table 2.6-3).

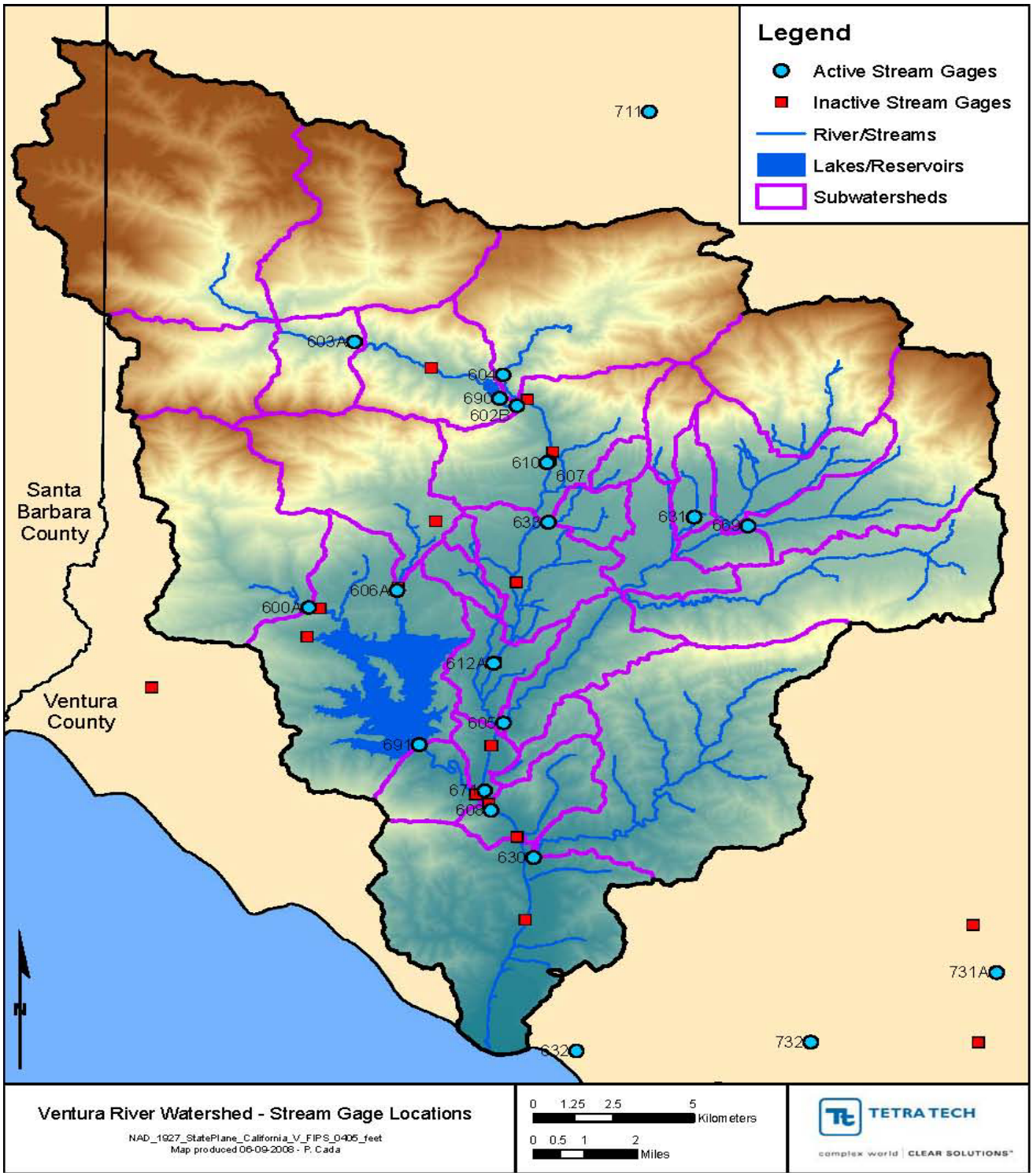


Figure 2.6-1 Ventura River Watershed Stream Gage Locations

Source: Tetra Tech 2008a

Table 2.6-2 Long-Term Average Runoff of the Ventura River Mainstem and Tributaries

Gauging Station	Period of Record	Unit Area (sq. mi.)	Average (mean) Annual Runoff (AF)	Unit Area Production (AF/sq. mi)	Percent of "Ventura River, Combined"
Matilija Creek	1927-present	55	26,442	480.8	55.6
North Fork Matilija Creek	1928-1931 1933-present	16	8,477	529.8	17.8
San Antonio Creek	1949-present	51	11,206	219.7	23.5
Coyote and Santa Ana Creeks	1958-1990	41	9,318	227.3	9.5
Ventura River near Ventura	1912-1913 1930-present	188[a]	42,385	--	89.1
Ventura River near Ventura, combined (unimpaired)	1930-present	188[b]	47,596	253.2	100

Source: USGS gage records; Reclamation 1954; and City of Ventura and Casitas 1991

a. Tributary runoff as a proportion of the unimpaired runoff at Foster Park
b. Includes area of all upstream sub-basins

Although the base number of years differs for the pre-Matilija (1930 to 1947), Matilija-only (1948 to 1958), and post-Casitas/Robles (1959 to 2005) periods, the proportion of water year types in each period can be fairly compared (Table 2.6-3). The post-Casitas period includes 47 years of the total record, and has evenly distributed water year types (approximately 19 percent in each of four classes and 26 percent in the below-normal class). In contrast, over half of the Matilija-only period was below normal or dry. The 18 years of record prior to Matilija had proportionally more wet and above normal years (67 percent) than either of the more recent periods.

High Flows and Flooding

Surface flows in streams of the Ventura River watershed during the wet season are derived almost entirely from rainfall, and generally exhibit variability of flow that parallels the precipitation inputs. The streams have "flashy" storm hydrographs, with sudden rises in discharge immediately following the onset of precipitation, and relatively rapid declines in streamflow after the rainfall ends. On the mainstem, flows can surge from near zero to thousands of cfs within a few hours during major storms (Reclamation 1954).

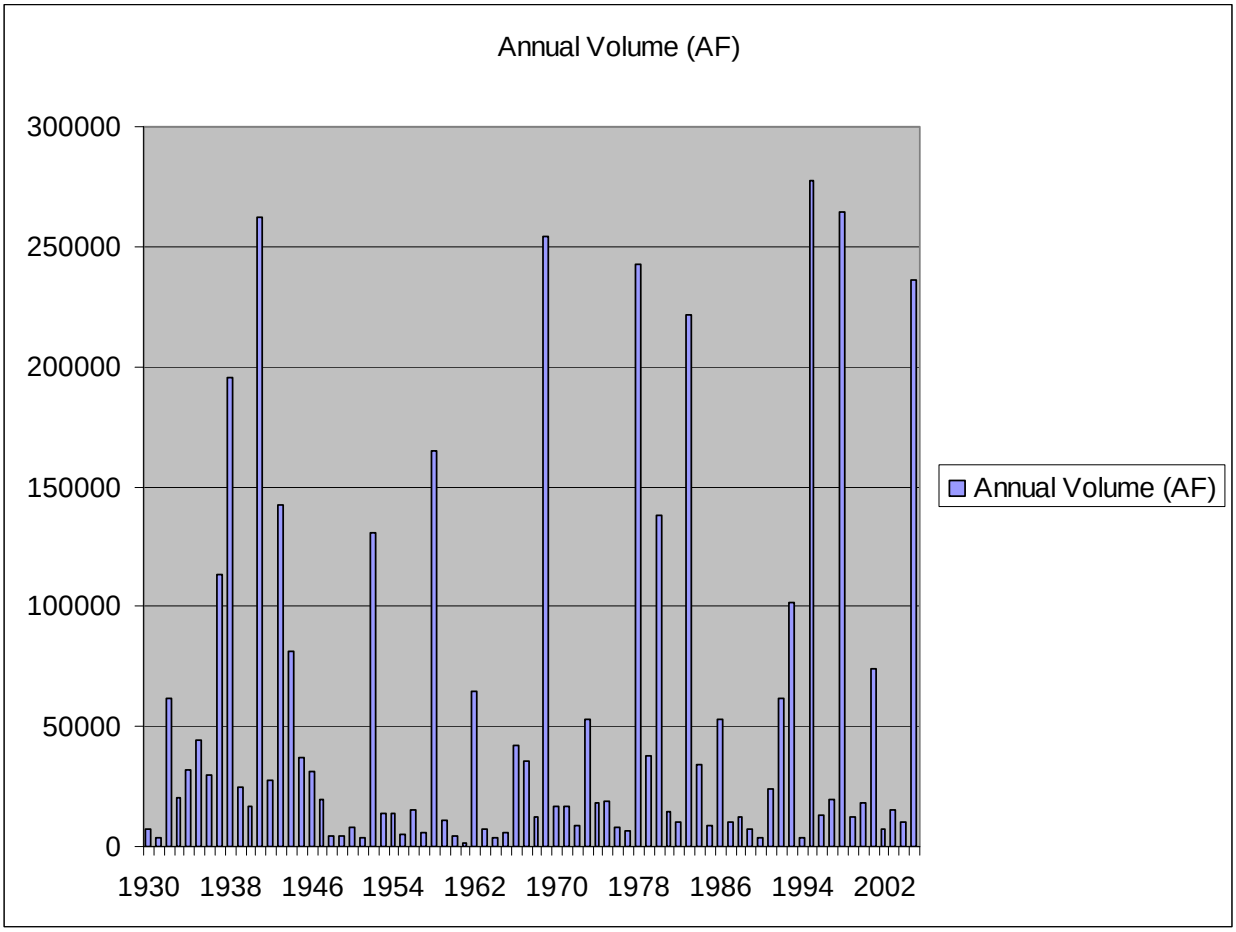


Figure 2.6-2 Annual Unimpaired Runoff 1930-2005

Source: USGS Gage #8501

Table 2.6-3 Water Year Types for the Ventura River Basin Based on Unimpaired Runoff

	Ventura River Runoff*			Ventura River Runoff*	
Water Year	Annual Volume (AF)	Water Year Type**	Water Year	Annual Volume (AF)	Water Year Type**
1930	7,419	Below Normal	1967	35,642	Above Normal
1931	3,322	Dry	1968	12,266	Below Normal
1932	61,808	Above Normal	1969	254,100	Wet
1933	20,141	Normal	1970	16,394	Normal
1934	32,316	Above Normal	1971	16,488	Normal
1935	44,554	Above Normal	1972	8,669	Below Normal
1936	29,550	Above Normal	1973	52,739	Above Normal
1937	113,311	Wet	1974	18,165	Normal
1938	195,303	Wet	1975	18,998	Normal
1939	24,773	Normal	1976	7,731	Below Normal

Table 2.6-3 Water Year Types for the Ventura River Basin Based on Unimpaired Runoff

Water Year	Ventura River Runoff*		Water Year	Ventura River Runoff*	
	Annual Volume (AF)	Water Year Type**		Annual Volume (AF)	Water Year Type**
1940	16,807	Normal	1977	6,558	Dry
1941	262,031	Wet	1978	242,412	Wet
1942	27,751	Above Normal	1979	37,661	Above Normal
1943	142,573	Wet	1980	137,703	Wet
1944	81,338	Wet	1981	14,888	Normal
1945	37,087	Above Normal	1982	10,121	Below Normal
1946	30,919	Above Normal	1983	221,222	Wet
1947	19,268	Normal	1984	34,373	Above Normal
Matilija Dam began storing water in water year 1948			1985	8,820	Below Normal
1948	4,473	Dry	1986	52,680	Above Normal
1949	4,308	Dry	1987	10,523	Below Normal
1950	7,863	Below Normal	1988	12,087	Below Normal
1951	3,574	Dry	1989	7,011	Dry
1952	130,918	Wet	1990	3,672	Dry
1953	14,112	Normal	1991	23,967	Normal
1954	14,102	Below Normal	1992	61,637	Above Normal
1955	4,909	Dry	1993	101,855	Wet
1956	14,972	Normal	1994	3,683	Dry
1957	5,804	Dry	1995	277,300	Wet
1958	165,177	Wet	1996	13,009	Below Normal
Casitas Dam, Robles Diversion began functioning in water year 1959			1997	19,513	Normal
1959	10,847	Below Normal	1998	264,364	Wet
1960	4,238	Dry	1999	12,141	Below Normal
1961	1,602	Dry	2000	18,068	Normal
1962	64,884	Above Normal	2001	73,788	Wet
1963	7,087	Dry	2002	7,299	Below Normal
1964	3,960	Dry	2003	15,466	Normal
1965	6,155	Dry	2004	9,901	Below Normal
1966	42,424	Above Normal	2005	235,817	Wet

* The Water Year Type was determined using the unimpaired runoff for the Ventura River, near Ventura gage (combined record, USGS #8501).

** Water Year Type is defined as the surface-water supply for the 12-month period October 1 through September 30. The water year is designated by the calendar year in which it ends and which includes 9 of the 12 months. Thus, the year ending September 30, 1990, is called "water year 1990."

Floods on the Ventura River occur relatively frequently, with 13 major floods between WY 1938 and WY 2005 (Table 2.6-4). The largest flood occurred in February 1978, with a peak discharge of 63,600 cfs at the Ventura River, near Ventura gage. The storage available at Matilija and Casitas reservoirs to regulate peak flows from major storms has varied over the years. Matilija Dam was capable of appreciably lowering (by 50 percent) flood flows in the river for the first decade or two after construction. The original design included a probable maximum flood peak inflow of 60,000 cfs. However, it presently has little effect on reducing the peak of major flood flows. The available capacity at Casitas Reservoir and the rate of flow above the Robles Fish Passage Facility have become more important factors during major storms, even though they are not designed as flood control facilities. The 500 cfs diversion at Robles Fish Passage Facility has little effect on large peak flows. However, the 500-cfs diversion likely reduces the "moderate" peak events (flows at or near the capacity of the diversion). From the 1970s until the present, floods have occurred relatively frequently and several have been quite large (Reclamation 2003). The 2005 water year was officially one of the wettest years in the century and high flows significantly altered the streambed morphology and vegetation in the mainstem and tributaries (Leydecker and Grabowsky 2006).

Table 2.6-4 Major Floods and Flow Regulations on the Ventura River

Year	Flood Month	Ventura River Peak Discharge (cfs)	Matilija Reservoir Storage Capacity[a] (AF)	Casitas Reservoir Available Storage[b] (AF)
1938	March	39,200	None	None
1943	January	35,000	None	None
1952	January	29,500	7,020	None
1969	January	58,000	2,500	137,000
1969	February	40,000	2,500	37,000
1978	February	63,600	2,500	76,000
1980	February	37,900	2,000	17,000
1983	March	27,000	1,400	40,000
1992	February	46,700	1,000	110,000
1993	January	12,500	990	42,000
1995	January	43,700	990	30,000
1998	February	38,800	990	26,000
2005	January	41,000	990	86,000

a. Maximum storage capacity, based on historic reports; storage available would be less than the maximum.
b. Available storage, based on the difference between the 254,000 acre-feet capacity and reported "first of year" storage (data received from Casitas Municipal Water District 2006).

Low Flows

Under summer low flow or drought conditions, surface streamflow at various locations in the watershed are governed by a complex interaction of precipitation input; discharge from springs; groundwater levels; the effects of water diversions, water storage, water supply releases, and treated wastewater discharge and groundwater extraction.

It is not unusual for streams in Southern California that are rainfed, and lack groundwater support, to dry up in summer months, in both average and below average precipitation years. In the Ventura River watershed, however, several of the smaller tributaries, and even the mainstem, have short perennial reaches that are fed by springs and/or the perched groundwater over shallow bedrock. Perennial flows are present in San Antonio Creek, and in the Casitas Springs/Foster Park reach, defined as the portion upstream of, and including, Foster Park and including lower San Antonio Creek from SR 33 to its confluence with the Ventura River. The presence of year-round flow in this reach of the river is due to high groundwater levels in the shallow alluvium over bedrock, which is artificially raised at Foster Park by the City's subsurface dam (URS Corporation 2003).

Small summer streamflows maintained by springs were documented by both Reclamation (1954) and EDAW et al. (1981) in the upper reaches of the larger sub-basins. EDAW reported typical summer base flows of 1 to 2 cfs in North Fork Matilija Creek, 1 to 3 cfs in Matilija Creek, and less than 0.5 cfs in San Antonio Creek and Coyote Creek below Casitas Dam. Since the 1960s, effluent discharge from the OVSD Wastewater Treatment Plant provides summer flows of approximately 1.9 cfs (2002 data) from the OVSD Wastewater Treatment Plant downstream to the lagoon.

2.6.3 Groundwater

Groundwater has been an important water source for irrigation, domestic, and municipal supplies in the Ventura River watershed for many decades. In general, groundwater in the Ventura River system occurs under unconfined conditions. However, in some localized areas (where fine-grained overbank deposits form a relatively low permeability cap over old channel deposits with higher permeability), semi-confined conditions may exist, especially during periods of high water levels (Fugro 2002). The primary source of recharge to the alluvial aquifer system is direct infiltration of precipitation. Two other sources of recharge include direct infiltration of surface flows, and downvalley underflow through alluvial sediments.

The Ventura River system is composed of five major groundwater basins: the Upper Ojai basin; the Ojai basin; the Upper Ventura River basin; the Lower Ventura River basin; and the San Antonio Creek basin (ENTRIX 2001c). Of primary importance to this report are the Upper Ventura River, Ojai, and San Antonio Creek basins because local agencies operate and maintain water supply facilities in these areas (Figure 2.6-6). A description of the major groundwater basins is provided below.

2.6.3.1 Groundwater Basins

Upper Ventura River Basin

The Upper Ventura River Basin has a partial downslope along the Arroyo Parida fault to the north (ENTRIX 2001b). The upper basin extends from the confluence of Matilija Creek and North Fork Matilija Creek (RM 16.2) to the City's subsurface dam at Foster Park (RM 5.9), which delineates the boundary between the Upper and Lower Ventura River groundwater basins. The basin is believed to have a capacity of approximately 14,000 AF when full (USACE 2004). The boundary between the Ojai Basin and the Upper Ventura River Basin is situated between Camp Comfort to the south and Arbolada to the north. The depth to bedrock decreases in the vicinity of this boundary resulting in a decrease in thickness of the aquifer materials.

The Upper Ventura River is underlain by alluvial deposits with a maximum thickness of approximately 200 feet and an average thickness of 60 to 100 feet. A natural subsurface obstruction blocks subsurface flow below the Ventura River just above San Antonio Creek causing groundwater to rise as springs. Therefore, the groundwater beneath the Ventura River is divided into an upper cell and a lower cell (Reclamation 2003).

The thickness of aquifer materials is generally shallow, but varies along the river due to the geologic structure of the basin (variations in the depth to bedrock and faulting). Along the Upper Ventura River, the water-bearing units increase in thickness downstream of the confluence of Matilija and North Fork Matilija creeks, attaining a maximum thickness of approximately 200 feet on the north (down dropped) side of the Arroyo Parida-Santa Ana fault (Figure 2.6-7). Downstream of the Santa Ana fault, in the Mira Monte area, the alluvium thickness is controlled by the folded bedrock surfaces and is approximately 65 feet thick. In the Foster Park area, north of the subsurface dam and in the vicinity of the City's Nye Wells, the aquifer materials are 45 to 60 feet thick, providing a saturated thickness ranging from 35 to 45 feet (Fugro West 2002). The total storage capacity of about 14,000 AF typically empties during a 1 to 3-year critical dry period. The dominant source of recharge is direct infiltration or precipitation and percolation from local streambeds (ENTRIX and Woodward Clyde Consultants 1997).

Ojai Groundwater Basin

The Ojai Groundwater Basin (Ojai Basin) is located within the Ventura River watershed, within the western portion of Ventura County, California. The Basin is bordered by the Topa Topa Mountains and Santa Ynez Mountain Range on the north and east, Black Mountains on the south, and the Upper Ventura River Groundwater Basin to the west. Ground surface elevations across the alluvial surface of the Basin range from over 1,300 feet above mean sea level (amsl) at the northeastern portion of the Basin, to approximately 700 feet amsl. The drainage area for the basin comprises 36 square miles and rises to elevations over 4,500 feet amsl. The alluvial groundwater Basin is 10.7 square miles (Kear 2005, as cited in Daniel B. Stephens & Associates [DBS&A 2010b]). A large fraction of land within the basin is dedicated to orchards, with the remaining area composed of residential, pasture, commercial and vacant land uses. Municipal and agricultural water requirements of the basin have historically been supplied by both surface water and groundwater sources.

The Ojai Basin is composed of alluvium deposits within a structural depression, and the lateral boundaries of the basin are defined by the contact between the alluvial deposits and the underlying sedimentary rocks (SGD 1992, as cited in DBS&A 2010b). The alluvial aquifer consists of undifferentiated and poorly consolidated deposits of clay, sand, gravel, and boulders. Confining clay units exist within the alluvium, and Kear (2005, as cited in DBS&A 2010b) reported that the units are thickest in the southern portion of the basin.

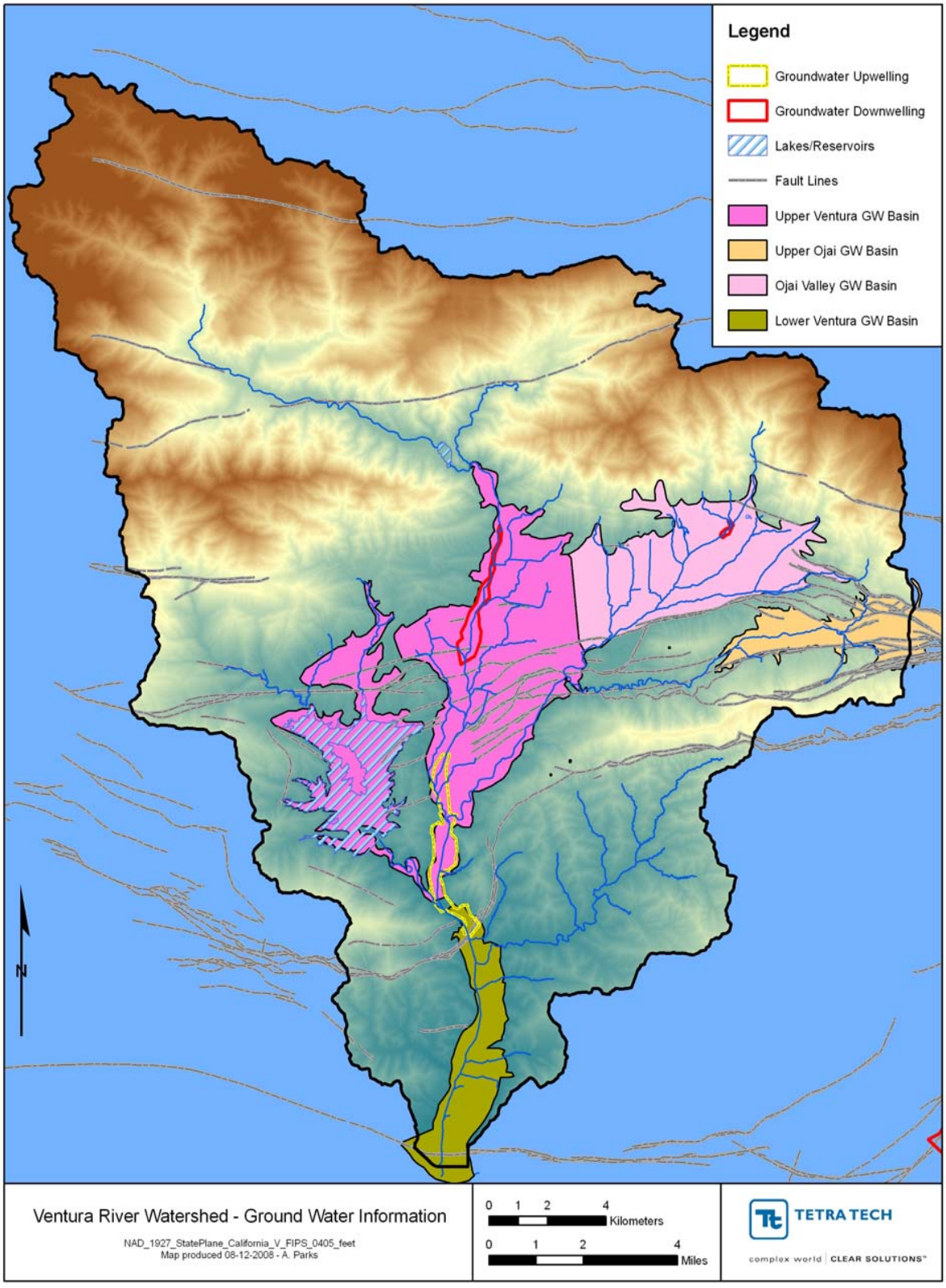


Figure 2.6-6 Groundwater Basins, Upwelling and Downwelling Areas, and Fault Lines

Source: Tetra Tech 2009a

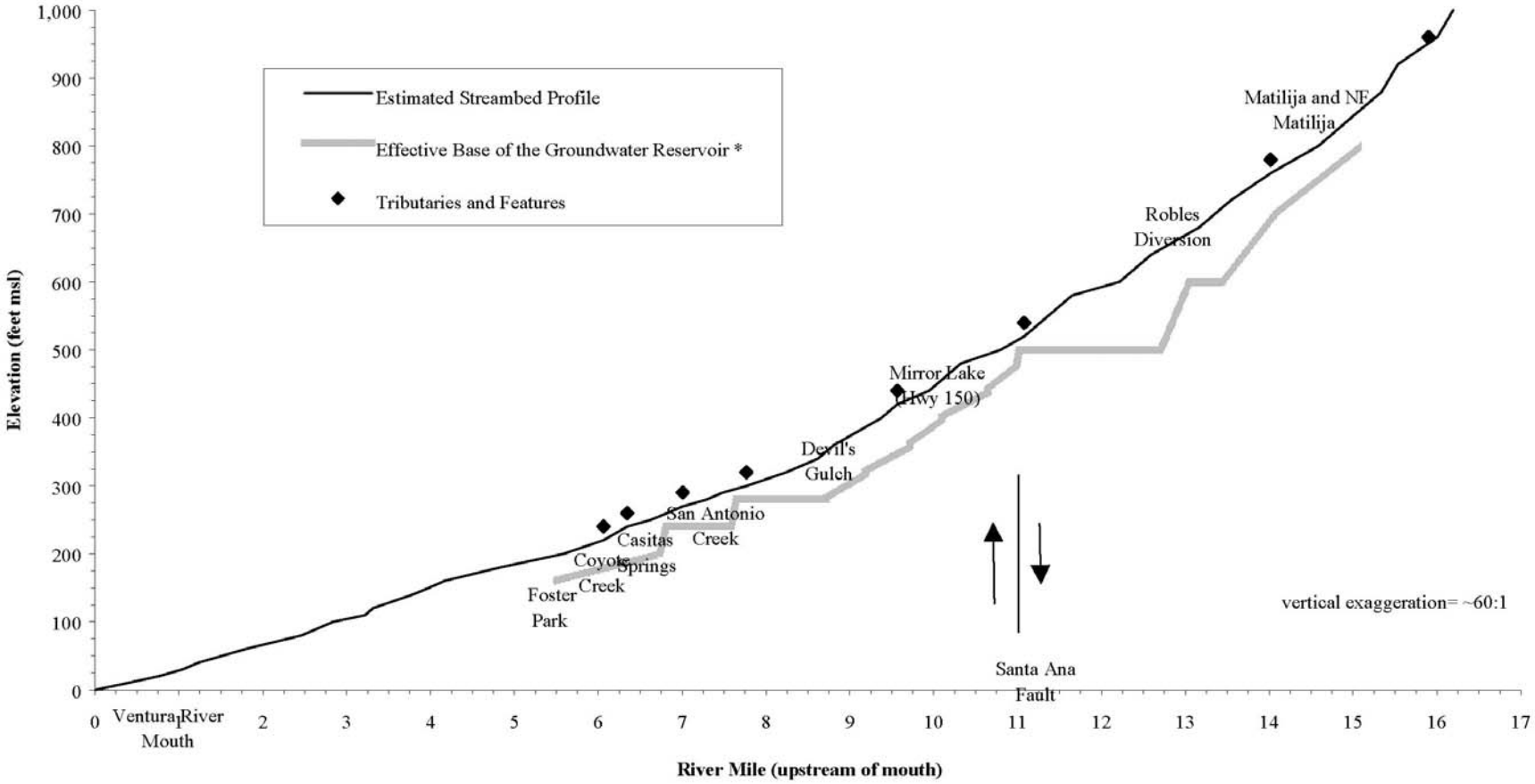


Figure 2.6-7 Ventura River and Effective Base of Groundwater Profiles

Source: ENTRIX 2001c

Depth to groundwater varies spatially and temporally within the basin. Near the alluvial fan heads, depths to water can be on the order of 300 feet below grade with seasonal variations between 50 and 90 feet. In the southern and western portions of the basin, however, the typical depths to water are less than 50 feet and show seasonal fluctuations on the order of 15 feet. Artesian conditions are common in the Ojai Basin in the winter and spring months of years with significant local precipitation. Recent water level monitoring has also indicated that significant static water level differences exist between the stratified aquifers of the Ojai Basin.

Historically, groundwater levels have declined following relatively dry periods (e.g., late 1940s, mid 1960s, late 1980s), and have been restored in subsequent years with relatively heavy rains. SGD (1992, as cited in DBS&A 2010b) reported that, since the early 1970s, decreases in groundwater demand and increases in recharge (through infiltration of excess applied irrigation water) have generally resulted in higher water levels within the basin. In 1971, Turner (1971, as cited in DBS&A 2010b) reported that, spatially, groundwater flow directions generally follow topographic trends, with groundwater flowing from alluvial fan heads in the northern and eastern portions of the basin towards the southwestern portion of the basin. Similarly, surface waters within the basin drain to the southwest towards the Ventura River, exiting the Basin via San Antonio Creek.

San Antonio Creek Basin

The water-bearing materials underlying San Antonio Creek consist of alluvial sediments of Recent Age. The average thickness of the sediment ranges from approximately 20 to 30 feet. The aquifer is generally unconfined and has a limited storage capacity and is used primarily for agricultural and domestic purposes (ENTRIX 2001c). As is typical for alluvial deposits, the aquifer is composed of sand, gravel, cobbles, boulders, silt, and clay, often with interstratified, lenticular, and discontinuous sediment units. Sedimentary structures include channel fill deposits, point bars, and overbank deposits. As a result of these complex depositional features, the aquifer parameters can vary greatly over short distances.

2.6.3.2 Groundwater Trends

Groundwater levels in the Upper Ventura River Basin, the Ojai Basin, and the Lower San Antonio Creek Basin fluctuate annually and seasonally, with the highest water levels occurring in the winter and early spring and the lowest levels occurring in the late summer and early fall. In general, groundwater levels in these basins recover rapidly following periods of precipitation and decline slowly under natural conditions, which is characteristic of unconfined groundwater basins. In the Upper Ventura River basin, groundwater levels in the vicinity of Meiners Oaks appear to fluctuate less than groundwater levels in the vicinity of Casitas Springs, which may be related to differences in groundwater extraction (District 1971).

Water levels in the two major groundwater basins, Ojai and Upper Ventura River, experienced dramatic drops during periods of dry years with low recharge and high extraction, such as the period from 1944 to 1951 (Reclamation 1954), and more recently from 1986 to 1990 (Casitas 1993). A study in 1978 conducted by EDAW, Inc. reviewed groundwater production in the Upper Ventura Basin from 1947 to 1973. In 1961, a particularly dry year, water in the basin was nearly depleted and some wells in the basin went dry (CRWQCB-LA 2002). The water level in the key District well 04N22W05L08S in the Ojai Basin was reported to have declined 31.1 feet

in 2009 after increasing 26.5 feet in 2008, and declining a total of 75.5 feet in 2006 and 2007 (District 2009, as cited in DBS&A 2010b).

A rapid rise of the groundwater levels occurred immediately following drought-breaking wet seasons in both 1952 (Reclamation 1954) and 1992 (Casitas 1993). This response illustrates the high degree of interaction between groundwater and surface water hydrology, and suggests that groundwater extraction use during droughts has not exceeded recharge capability. The provision of supplemental surface water supplies from Casitas has contributed to the stability of the groundwater storage and water levels in the Ojai Basin over the last 25 years.

2.6.3.3 Surface-Groundwater Interaction

A surface water-groundwater interaction evaluation study based on available empirical data was conducted to develop an improved understanding of the hydrologic system dynamics, and determine the likelihood of groundwater pumping impacts on surface flows (ENTRIX 2001b). This effort involved collecting and evaluating available surface flow and groundwater data and prior analyses of the surface and groundwater system. The data reviewed as part of the evaluation included seasonal changes in groundwater levels and groundwater storage, groundwater flow relationships, and estimated contributions from groundwater to surface water.

The findings of this study can be summarized as follows:

- The Santa Ana/Arroyo Parida fault is likely a major influence on downvalley movement of groundwater. Improved knowledge of physical properties and flow processes of the groundwater aquifer in this critical area should provide the basis for developing groundwater management of upstream nodes that considers resultant water table impacts, not simply extraction volumes.
- The rate and ability of the groundwater system to recharge from surface water infiltration/percolation under water year types other than wet years should be evaluated as part of a "safe-yield" assessment, due to the climatic cycles in the region.
- The surface flow in the vicinity of Foster Park reflects augmentation from downvalley contribution of groundwater, over a wide range of water year types.
- Further quantification of groundwater pumping impacts on surface flows would require two critical datasets: (1) site-specific observations of the extent, duration, and magnitude of surface flows in the Casitas Springs/Foster Park reach and other locations of concern; and (2) concurrent information on groundwater pumping rates or volumes.
- An improved understanding of the historical water budget data, even without detailed historical observations of surface flows in the Casitas Springs/Foster Park reach could be developed if groundwater pumping data for some of the dry and wet years in the water-budget study period (WY 1970 to 1982) were obtained.

2.7 Surface Water Quality

In recent years, the RWQCB has taken on the task of reviewing and interpreting data by watershed and subwatershed that were collected by different agencies and programs to establish a general baseline of the water quality in the Ventura River watershed. Most of the available data

is in the form of water column chemistry. There are also a limited amount of sediment chemistry, sediment toxicity, and bioaccumulation data available.

In January 2001, the Santa Barbara Channelkeeper, along with the Ventura section of the Surfrider Foundation launched the Ventura Stream Team water quality monitoring program. Over the past five years, more than 350 local volunteers have collected valuable water quality data including dissolved oxygen (DO), DO percent (%) saturation, pH, total dissolved solids (TDS), temperature, turbidity, conductivity, flow, nitrate (N-NO3 and NH3), phosphate, and dichloro-diphenyl-trichloroethane (DDT) at 15 sites on the Ventura River and its major tributaries including San Antonio, Stewart, Thacher, Cañada Larga, and Matilija creeks (Table 2.7-1). There are four Lower Ventura River sites, two Cañada Larga sites, four San Antonio Creek sites, and four Upper Ventura River sites.

Results of the first 5 years of studies are posted on the Channelkeeper website (www.channelkeeper.org) and a summary was reported in the Ventura River Stream Team Report – 2001-2005 (Leydecker and Grabowsky 2006). The report notes elevated average nitrate and phosphate levels at a number of sites, particularly in the Lower Ventura River (below the OVSD Treatment Plant) and along San Antonio Creek downstream of two golf courses and a number of equestrian stables. Although these sites have somewhat elevated levels, recorded measures for these sites are far below Public Health limits and the limits set in OVSD's Nationwide Pollutant Discharge Elimination (NPDES) discharge permit.

Table 2.7-1 Ventura Stream Team Water Quality Sampling Sites

Station Name	Location	Description
VRW001	Main Bridge	Ventura River (VR) just below the Main Street Bridge
VRW002	Stanley Drain	VR just at the confluence with the Stanley Drain
VRW003	Shell Road	VR at the Shell Road Bridge
VRW004	Lower Cañada Larga	Off of Ventura Ave, just south of the Cañada Larga Bridge
VRW005	Upper Cañada Larga	3.5 miles up Cañada Larga Road, at a small bridge over the creek
VRW006	Foster Park	Along the VR, just downstream from Foster Park at the Casitas Vista Drive Bridge
VRW007	San Antonio Creek	On Old Creek Rd, just off of Highway 33
VRW008	Lion Canyon	On Lion Canyon, just above the confluence with San Antonio Creek
VRW009	Stewart/Fox	Adjacent to site 10, where the Stewart and Fox drainages combine
VRW010	Thacher/San Antonio	Adjacent to site 9, where the upper San Antonio and Thacher drainages combines
VRW011	Santa Ana	VR at the Santa Ana Rd bridge
VRW012	Highway 150	VR at Highway 150 bridge
VRW013	Matilija	Approximately 1 km downstream of the Matilija Dam
VR014	North Fork Matilija	Along the North Fork Matilija
VR015	Upper Matilija	Approximately 1.5 miles above the Matilija Dam in Matilija Canyon

Source: Leydecker and Grabowsky 2006

Additionally, the City of Ventura collects water quality samples at 11 sites located throughout the watershed. Since 2002, the City has monitored water quality along the Ventura River and San Antonio Creek at these sites for *Cyptosporidium*, *Giardia*, bacteria, nutrients, bromide, total organic carbons, chloride, and conductivity.

The Ventura River and San Antonio Creek Watershed Sanitary Survey 20010 Update (Kennedy/Jenks 2011b) confirmed the previous sanitary survey findings that horse manure, sewer overflows, septic tanks near Casitas Springs, illegal dumping, oil wells, and tanks were the primary sources of surface water contaminants. The survey cited the 2009 Ventura County Storm Water Monitoring Mid-Year Sampling report, which indicated that sample events in November 2008 – February 2009 showed exceedances of bacteriological water quality objectives. These wintertime bacteriological increases are consistent with winter storms in surface waters. Giardia and Cryptosporidium were below detection limits in the City of Ventura's water sampling program during the 2005 to 2010 period. Monitoring of general mineral, general physical, radionuclide, and inorganic chemicals stayed within the historical range found in previous surveys (Kennedy/Jenks 2011b).

The Sanitary Survey Update also notes actions since 2000 that have reduced the risk of contamination including:

- New OVSD siphons that reduce the risk of spilling untreated wastewater.
- Horse manure public awareness program.
- Successful operation of the permanent Household Hazardous Waste Collection Facility.
- Improvements to the City's Avenue Water Treatment Plant.

Casitas also prepared a 2011 Watershed Sanitary Survey Update (Casitas 2011c), which concluded:

- The Lake Casitas water supply has not been adversely affected by activities or conditions in the watershed within the last 5 years.
- Casitas' water supply continues to meet the current state and federal Drinking Water Standards.
- The watershed receives many protections through Casitas' ordinances, as well as federal, state, and county policies, plans, and regulations.

2.7.1 Summary of Water Quality Conditions in the Subwatersheds

Above Foster Park, surface water quality in the Ventura River is controlled in large part by the tributary water quality. In the upper tributaries, boron is contributed by hot springs in the Santa Ynez Mountains. Boron can be as high as 6.5 ppm in Matilija Creek above the reservoir during low flow conditions. The high boron is diluted in the reservoir so that water downstream is of higher quality. Turbidity in the watershed can rise as high as 600 turbidity units following storms (Casitas and City of Ventura, 1984).

Uncontrolled stockpiling and storage of horse manure has been observed at some locations within the watershed which could lead to nutrient loading and coliform problems (URS 2002).

Organic chemical analysis of raw water by the City of Ventura in 1997 and 1999 did not find organic chemicals at detectable levels (URS 2002). The excessive growth of vascular plants, particularly the non-native water primrose, is prevalent in the lower Ventura River. Below the discharge point from the Ojai Valley Wastewater Treatment Plant, DO generally remains above 7.0 mg/l, but seasonally in the late summer and early fall DO levels fall. With the first major winter or spring storms and corresponding increased flows in the Ventura River, the DO levels tend to return to desirable levels. Actually, DO levels in the river have improved dramatically to about 11 mg/l. Nitrate levels continue to be considerable in San Antonio Creek, which drains much of the Ojai area. According to the Ventura Stream Team, slightly elevated levels of nitrate are also seen in the lower river.

2.7.2 Impaired Water Bodies in the Ventura River Watershed

The Clean Water Act requires each state to assess the status of water quality in the state (Section 305(b)) and provide a list of impaired water bodies (Section 303(d)) to the U.S. Environmental Protection Agency (USEPA) every 2 years. Impaired water bodies are those that have been determined to not achieve designated beneficial uses. A finding of impairment is made through use of decision rules specified in the State Board Listing Policy, which considers data on chemical-specific water quality standards; bacterial water quality standards; health advisories; bioaccumulation of chemicals in aquatic life tissues; nuisances such as trash, odor, and foam; nutrients; water and sediment toxicity; adverse biological response; and degradation of aquatic life populations and communities. For water quality limited segments included on the 303(d) list, the state is required to develop a Total Maximum Daily Load (TMDL) or take other action to address the impairment. The 2008 update to the Section 303(d) list (CRWQCB-LA 2009, Appendix F) identifies a number of waterbody segments in the Ventura River watershed as water quality limited and requiring a TMDL. These listings are shown in Table 2.7-2. A TMDL for trash has already been developed for the Ventura River Estuary (Tetra Tech 2009b).

Table 2.7-2 2010 Section 303(d) List of Water Quality Limited Sections in the Ventura River Watershed Requiring Development of a TMDL

Waterbody Name	CALWATER Watershed	Estimated Size Affected	Impairment
Cañada Larga (Ventura River watershed)	40210010	8.01 miles	Fecal coliform Low DO TDS
Casitas Lake	40220032	2,069 acres	Mercury
Matilija Creek, Reach 1 / Reach 2	40220010 / 40220012	15.6 miles (combined)	Fish passage
Matilija Reservoir	40220012	121 acres	Fish Passage
San Antonio Creek (tributary to Ventura River Reach 4)	40220023	9.79 miles	Indicator bacteria Nitrogen TDS
Ventura River Estuary	40210011	0.2 miles	Algae Eutrophic Total coliform
Ventura River Reach 1 and 2 (Estuary to Weldon Canyon)	40210011	4.49 miles	Algae
Ventura River Reach 3 (Weldon Canyon to	40210011	2.82 miles	Indicator bacteria

Table 2.7-2 2010 Section 303(d) List of Water Quality Limited Sections in the Ventura River Watershed Requiring Development of a TMDL

Waterbody Name	CALWATER Watershed	Estimated Size Affected	Impairment
Confl. w/ Coyote Cr.)			Pumping Water diversion
Ventura River Reach 4 (Coyote Cr. to Camino Cielo Rd.)	40220021	19.22 miles	Pumping Water diversion

Source: Tetra Tech 2009b and CRWQCB – LA 2011

2.8 Groundwater Quality

Historically, the Upper Ventura River and Lower Ventura River sub-basins both have had generally good water quality, with the exception of concentrations of TDS that are elevated above the USEPA's secondary maximum contaminant level (MCL) of 500 milligrams per liter (mg/L) and nitrate concentrations in excess of the state MCL of 45 mg/L (as nitrate). TDS concentrations within the Upper Sub-Basin are reported to range from 500 to 1,240 mg/L (California Department of Water Resources [DWR] 2004 and District 2009, as cited in DBS&A 2010b). For the Lower Sub-Basin, TDS concentrations are reported to typically range from 760 to 784 mg/L, but become elevated to as high as 3,000 mg/L during extended dry periods when there is less recharge of lower-TDS surface waters. Nitrate concentrations reach a maximum approaching 70 mg/L in the central portion of the Upper Sub-Basin. The Lower Sub-Basin also has exhibited elevated levels of hydrogen sulfide, hydrocarbons associated with oil seepage, sulfate, iron, and nitrate (DWR 2004 and District 2009, as cited in DBS&A 2010b). In sampling conducted by District in 2009, no samples from either of the sub-basins exhibited levels of metals (i.e., Title 22 metals) above the USEPA or state MCLs (District 2009, as cited in DBS&A 2010b).

The District has historically collected groundwater level and groundwater quality data within the Ojai Basin. Summaries of monitoring data collected by District, the Ojai Basin Groundwater Management Agency (OBGMA), and several state agencies, are found in various reports (e.g., DWR 1933, DWR 1953, Turner 1971, and SGD 1992, as cited in DBS&A 2010b). Annual reports prepared by the District also summarize groundwater quality data collected within the basin (e.g., District 2008, District 2009, as cited in DBS&A 2010b). Average TDS was 888 mg/L and ranged from 631 to 1,680 mg/L. Chloride has been a major anion of concern in the basin and has been observed to be significantly elevated in the deeper stratified aquifers of the Ojai Basin (Kear 2010, as cited in DBS&A 2010b). In production well blends, however, chloride concentrations exceeded the USEPA secondary MCL of 250 mg/L in one well (DBS&A 2010b).

2.9 Water Management

2.9.1 Debris and Detention Basins

The steep headwaters of the Ventura River watershed present a risk of flooding and debris flows. To address these risks, five debris basins have been constructed that collect sediment from drainages before they enter the mainstem Ventura River. Live Oak, McDonald, and Dent Canyon basins are on direct tributaries of the Ventura River. One is located in Stewart Canyon, a

tributary to San Antonio Creek, and the other basin is on upper San Antonio Creek (Table 2.9-1 and Figure 2.9-1) (District 2011b).

Table 2.9-1 Debris Basins in the Ventura River Watershed

	Watershed Area Acres	Maximum Debris Storage Capacity (cy)	Annual Sediment Production (cy)	Expected Debris Production for 100-Year Storm (cy)
Dent Debris Basin	27	4,100	263	1,624
Live Oak Basin	794	28,700	NA	NA
McDonald Detention Basin	565	23,400	NA	NA
San Antonio Creek Debris Basin	6,280	30,000	4,586	455,700
Stewart Canyon Creek Debris Basin	1,266	328,300	2,781	209,000

Source: URS 2005

The San Antonio Debris Basin was constructed in 1986 as an emergency structure in response to the Wheeler Fire, which had burned the watershed the previous year. The basin was constructed entirely of earth and rock with a maximum capacity of 30,000 cubic yards and accumulated 26,600 cubic yards of debris the first year of operation. The basin was cleaned and subsequently refilled over the next few years and was cleaned out again in 1992 (Hawks & Associates 2005). The San Antonio Creek Spreading Grounds Rehabilitation Project would rebuild an abandoned diversion works, rehabilitate existing infiltration basins, and construct passive percolation recharge wells adjacent to San Antonio Creek. The proposed project received grant funding Proposition 50 Integrated Regional Water Management Grant, which was awarded to the Watersheds Coalition of Ventura County. The project will capture 25 cfs of surface flow (when available) from San Antonio Creek and enhance groundwater storage and recharge in the Ojai Valley Groundwater Basin (District 2011c).

In terms of the flow of water, the basins function as dry detention basins (Tetra Tech 2008a) (Figure 2.9-2). The major dams also function to intercept storm peak and debris flow, and some of the diversion structures are used for this purpose as well.

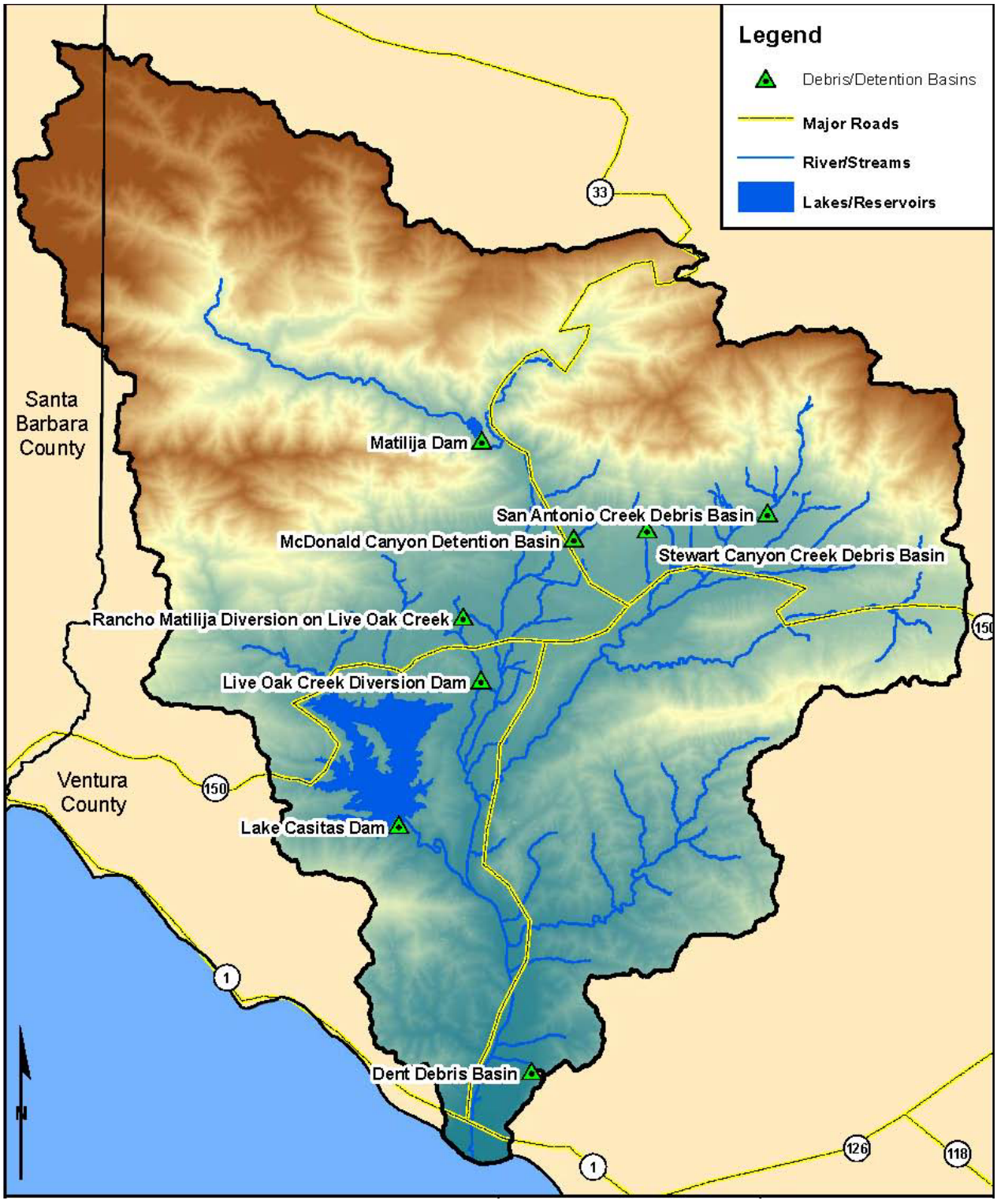


Figure 2.9-1 Dams and Debris and Detention Basins in the Ventura River Watershed

Source: Tetra Tech 2008a



Figure 2.9-2 Stormwater Detention Basin in the Ventura River Watershed

Source: Tetra Tech 2008a

2.9.2 Diversion Structures

Four major on-stream diversion structures and conveyances have been identified in the Ventura River watershed (Figure 2.9-3). Three canals are represented spatially in the GIS; the fourth (Foster Park) is shown only as a point. Water stored in Casitas Reservoir is in large part derived from the Ventura River via the Robles Diversion Dam and the Casitas-Robles Canal (Tetra Tech 2008a).

Surface water from the Ventura River is collected via surface diversion, subsurface collector, and shallow wells and delivered to the Avenue Treatment Plant through the City's Foster Park facilities. Currently, the surface intake structure at Foster Park is unused due to the natural channeling of the active river channel bypassing the structure. Each year the flows can change the position of the active river channel in relation to the intake structure. The Foster Park facilities produce groundwater throughout the year. However, due to storm flows, the wells are subject to inundation and erosion. The early 2005 winter storms destroyed or damaged, some of which were repaired between 2006 and 2009 (RBF 2011).

2.9.3 Flood Protection Levees

There are three major levees along the Ventura River. The most downstream levee, the Ventura Levee (District ID VR-1) is located along the east bank and protects the City of Ventura. The Casitas Springs Levee (VR-2) is located along the east bank and protects the town of Casitas Springs. The most upstream levee (VR-3) is near the Santa Ana Boulevard Bridge. It protects the Live Oak community along the west bank of the river (USACE 2004b).

The Ventura River (VR-1) Levee (VCWPD ID No: VR-1) is located in the city of San Buenaventura and extends from the Pacific Ocean inland to Canada de San Joaquin. The VR-1 levee system is located along the left side of the Ventura River. The levee system consists of embankment levees, side drainage penetrations, and a stop-log structure in the levee at a bike trail crossing. The length of the levee along the Ventura River is approximately 2.65 miles, with an embankment height up to 10 feet above natural ground on the landward side. The levee's earthen berm is protected by loose riprap and grouted riprap with an access road that runs along the top which is approximately 18 to 26 feet wide (Tetra Tech and AMEC 2009a).

The Casitas Springs (VR-2) was improved in 2007 to raise the existing levee by 4 to 6 feet to provide 100-year flood protection to the community of Casitas Springs (ENTRIX and Woodward Clyde 1997, Ventura County Star 2007).

The Live Oaks Levee and Floodwall (VR-3) is located in the community of Oak View, at Live Oaks along the right side of the Ventura River. The levee system consists of embankment levees, floodwalls, high ground and side drainage penetrations. The levee system begins at the Santa Ana Boulevard Bridge in Ventura County, continues upstream to the confluence with the Live Oaks Creek Diversion, and ends along the Live Oaks Creek Diversion at Burnham Road. The length of the levee is approximately 1.28 miles. The levee's earthen berm is protected throughout by riprap that is grouted along certain portions. An access road runs along the top which is approximately 10 feet wide (Tetra Tech and AMEC 2009b).

2.9.4 Water Supply and Use

Surface water and groundwater diversions have been developed for use along the Ventura River for over 200 years. As of 1981, approximately 45 known entities withdrew water from the Ventura River system (EDAW et al. 1981). These entities include irrigators, domestic users, industrial users, and water purveyors or suppliers.

2.9.4.1 Matilija Dam

Matilija Dam was constructed in 1946 to 1947 by the USACE –Los Angeles District to provide water storage for agricultural needs and for limited flood control. The structure is a concrete arch dam with an average height of 190 feet and a crest length of 616 feet, located approximately 0.6 miles upstream of the confluence of Matilija Creek and North Fork Matilija Creek. The original storage capacity of the dam and reservoir was 7,020 AF, but structural modifications to address concrete deterioration and siltation since 1947 have reduced the water storage capacity to less than 500 AF at present. Matilija's current operations are primarily for optimizing diversions at the Robles Diversion Dam, using a release valve with a maximum capacity of 250 cfs (Reclamation 2000).

In July 2004, the District and the USACE – Los Angeles District completed the public draft of The Matilija Dam Ecosystem Restoration Feasibility Study, a study of the feasibility of removing Matilija Dam and restoring the ecosystem above and below the dam location. The report presents the findings of the alternatives analysis and the selection of a recommended preferred alternative. The study focuses on ecosystem restoration in the Ventura River watershed to benefit native fish and wildlife (including the federally listed endangered southern steelhead trout) of the Ventura River and Matilija Creek in the vicinity of Matilija Dam, and improvement to the natural hydrologic and sediment transport regime to support coastal beach sand replenishment from the Ventura River. In September 2004, the Final Environmental Impact Report/Environmental Impact Statement for this project was completed (USACE 2004).

In 2005, the Project Management Plan was developed specifically for the Matilija Dam Ecosystem Restoration Project, Preconstruction Engineering and Design Phase for the purpose of setting forth the management strategy to be employed by both the USACE – Los Angeles District and the District (Sponsor/Partner/Non-Federal Interest). Currently, grant applications and congressional funding is being sought to fund project components outlined in the feasibility study.

2.9.4.2 Casitas Dam

Casitas Dam was constructed in 1959 and is located approximately 2.5 miles upstream of the Ventura River on Coyote and Santa Ana creeks (near RM 6.2). Lake Casitas has a maximum storage capacity of 254,000 AF and is supplied by inflow from the Robles Diversion via the Robles-Casitas canal in addition to watershed runoff from the Coyote and Santa Ana basins.

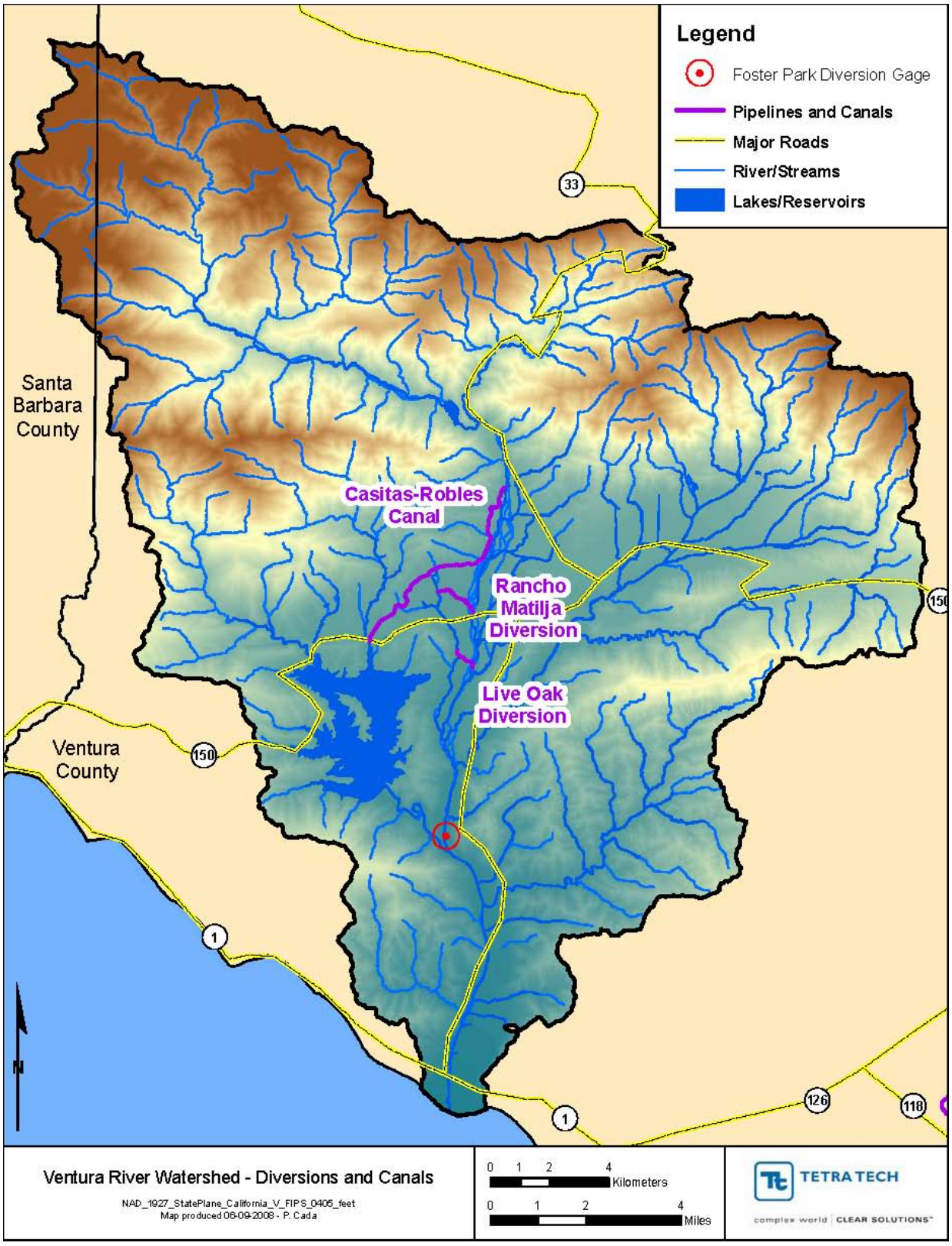


Figure 2.9-3 Diversions and Pipelines in the Ventura River Watershed

Source: Tetra Tech 2008a

2.9.4.3 Robles Fish Passage Facility

The Robles Diversion Dam was first built in 1958 and is located approximately 1.5 miles downstream of the confluence of Matilija Creek and North Fork Matilija Creek (RM 14). Since 1960, the diversion has been used to transfer water to Lake Casitas via a canal. The surface water diversions primarily occur in January, February, and March, and the mean monthly diversions during these months range from 2,183 to 3,489 AF (Reclamation 2003). The annual total diversion volume varies with available runoff and storage capacity remaining in Casitas Reservoir, averaging 13,095 acre-feet per year (AFY), with a median diversion volume of 6,335 AFY (Reclamation 2003). In dry years, there are often almost no diversions.

Since 2003, the Diversion Dam has been referred to as the Robles Fish Passage Facility due to the construction of a fish ladder at the facility. Prior to construction, The National Oceanic and Atmospheric Administration Marine Fisheries Service (NOAA Fisheries) issued a Biological Opinion on southern steelhead for the construction, operations and maintenance of the Robles facility (NOAA Fisheries 2003).

2.9.4.4 Foster Park Surface Diversion and Subsurface Dam

The City of Ventura's water supply facilities at Foster Park consist of a surface and subsurface water collection system. These facilities operate in conjunction with an underground dam (a weir that is 973 feet long and maximum of 65 feet deep and stops short by 300 feet from extending the full breadth of both streams) that was constructed between 1906 and 1908 at the confluence of Coyote Creek and the Ventura River. The underground dam and confining bedrock surfaces increase groundwater levels in the vicinity of Foster Park to produce enhanced surface flows. These flows are captured by a surface diversion (which is currently awaiting repair) and a subsurface collector system consisting of two perforated concrete pipes situated on the upstream side of the dam (Kennedy/Jenks 2006).

2.9.4.5 Groundwater Wells

Several public and private groundwater supply wells are located within the Upper Ventura River basin in the vicinity of the mainstem of the river. The largest groundwater extraction entities are Meiners Oaks County Water District (CWD), Casitas Springs Mutual Water Company, the Ventura River CWD, and the City of Ventura. Meiners Oaks CWD operates two wells located approximately 1 mile downstream of Matilija Dam and two wells in the vicinity of Meiners Oaks, one of which is adjacent to Rice Road. Meiners Oaks CWD produces approximately 1,150 AF of water per year from these wells. The Ventura River CWD operates three wells located between Meiners Oaks and the SR 150 crossing. The Ventura River CWD produces approximately 1,320 AF of water per year from these wells. Casitas Springs Mutual Water Company operates at least one water supply well north of the City's property at Foster Park. The location and annual production from that well is unknown (URS Corporation 2003). The City of Ventura operates four wells located in the Foster Park area. The City of Ventura produces approximately 4,000 AFY from these wells (ENTRIX and Woodward Clyde Consultants 1997; Ventura County Water Purveyors' database 2000; updated by City of Ventura 2006). Production from the City's Foster Park facilities varies greatly from year to year due to effects of weather, local hydrology, the storage capacity of the Ventura River alluvium, and upstream diversions (URS Corporation 2003). The City's wells and pipelines are subject to damage by erosion from heavy storm flows.

More than 300 wells have been installed along the Ventura River and its tributaries, extracting groundwater from the Ventura River Alluvial Basin, outside of the Ojai Basin. Records of groundwater wells were examined at the Ventura County Public Works Agency, Water and Environmental (W&E) Division. A summary of the wells recorded and mapped is provided in Table 2.9-2. Data are unavailable for most wells. However, based on the limited data, it appears that most of the wells are shallow (less than 200 feet), drilled for domestic use, and potentially intact. The available data do not indicate how many wells are still in operation. A large number of the wells appear to have been installed during the 1986 to 1991 drought period. Because the vast majority of the wells are private, there is no monitoring of extractions and, therefore, no estimate of annual private pumping from the alluvial basin.

Table 2.9-2 Summary of Wells Adjacent to the Ventura River Mainstem and Tributaries

	No. of Wells				Type of Well			
Area	Active	Inactive or Abandoned	Unknown	Total	Domestic or Municipal	Irrigation	Unknown	Total
A. Estuary area, including Seaside and Emma Wood Parks	?	?	7	7	?	?	7	7
B. Lower river, between Main Street bridge and Foster Park	2	1	7	10	5	?	5	10
C. Foster Park area	7?	1	22	23	3	?	20	23
D. Coyote Creek below the dam	?	?	6	6	1	?	5	6
E. Casitas Springs area	?	?	9	9	1	1	7	9
F. San Antonio Creek, below Soule Park	?	1	49	50	4	1	45	50
G. Santa Ana Creek watershed above Lake Casitas	?	?	18	18	10	?	8	18
H. Oak View, Live Oak Acres, and western Mira Monte	?	1	139	140	10	2	128	140
I. Mira Monte (western Ojai Valley)	?	?	25	25	4	2	19	25
J. Upper River, between Meiners Oaks and Matilija Ck.	?	?	24	24	4	2	18	24
K. N. F. Matilija Creek	?	?	12	12	10	?	2	12
L. Matilija Creek	?	?	1	1	1	0	0	1
Total				325				325

Source: Ventura County Public Works Agency, Water Resources Division and RBF 2011

? = Current Status Unknown.

The greatest concentration of wells is in the Oak View, Live Oak Acres, and western Mira Monte area where there is significant residential development. A high number of wells are also located along San Antonio Creek in the Ojai Basin. Golden State Water Company has five wells on San Antonio Creek in the City of Ojai. The OBGMA was formed in 1991 to manage the groundwater within the Ojai Basin for the protection and common benefit of agricultural, municipal and industrial water users within the Ojai Basin. Approximately 150 wells have been monitored by

the OBGMA, but the agency recently adopted a requirement for metering of all wells in the Ojai Basin and reporting of extractions to the OBGMA.

2.9.5 Reservoir Management

Dams and reservoirs directly alter the natural flow of streams, allowing water to be stored rather than transferred downstream. Two significant on-stream reservoirs are in the Ventura River watershed: Casitas and Matilija (Figure 2.9-1) (Tetra Tech 2008a).

Casitas Reservoir, completed in 1959, is part of Reclamation's Ventura River Project and supplies the majority of water for human use in the watershed. Casitas Dam impounds Coyote Creek; however, the major source of water for the reservoir is a diversion from the Ventura River mainstem via the Robles Diversion. Lake Casitas has an active capacity of 251,000 AF and a storage capacity of 254,000 AF. Lake Casitas provides irrigation, municipal, and industrial water to urban and suburban areas with the Casitas Municipal Water District (Tetra Tech 2008a).

The outlet works of Lake Casitas have a maximum capacity of 570 cfs. There is an uncontrolled spillway with a 50-foot crest at elevation 567 feet. Six off-stream balancing reservoirs, Oak View, Villanova, Ojai East, Upper Ojai, Rincon Control, and Rincon Balancing, are filled from the Casitas main conduit during the off-peak hours and are used to help supply the full requirement of water during peak hours and as a carryover supply in case of an emergency.

The water balance in Lake Casitas is closely monitored, and record keeping of the water balance for Lake Casitas is available from the date of the first impoundment of water behind the dam in 1959.

Matilija Dam was constructed in 1947 by the USACE, Los Angeles District as both a flood control and water supply facility. The dam originally provided 7,018 AF of storage. The available storage volume was, however, rapidly depleted by sedimentation. The concrete in the dam also experienced corrosion, and the dam was lowered by cutting a notch in 1965, followed by another notch in 1977 (Tetra Tech 2008a).

Records for Matilija are more problematic than Casitas. Daily records of elevation and percent opening of the outlet works are available (but electronically only from 2001 on). A stage-storage curve was supplied for 1994, but this has likely changed over time due to sedimentation. A USGS gage has been operated below Matilija Dam at Hot Springs (11115500) with daily flows from 1927. It is likely that this record can be used to create an approximate discharge record and stage-discharge curve for Matilija Dam (Tetra Tech 2008a).

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Chapter 3

Summary of V-1 Projects

This chapter summarizes the studies funded by the Proposition 50 grant (V-1 projects), which are intended to help meet the objectives of the Ventura River Watershed Protection Project (i.e., to address water supply, water quality, and habitat issues in the Ventura River watershed).

3.1 Ventura River Watershed Hydrology Model

As part of the funded V-1 projects, the District guided the development of a watershed simulation model for the Ventura River. The simulation model provides a mathematical representation of the physical characteristics of the watershed, including the land area and characteristics (e.g., slope and vegetative cover), land management, the length and character of stream reaches, the location of reservoirs and detention basins, and water diversion structures. The simulation model uses precipitation and other weather inputs to generate predictions of streamflow and water quality throughout the watershed in 15-minute increments. This "continuous" model provides the ability to produce real-time estimates of flow during storm events and thereby identify locations that could be subject to flooding; evaluate the effects of development or changes in land use practices on water supply or runoff volumes; and evaluate the effects of BMPs on surface water quality in the watershed.

The Ventura River watershed model was developed using the Hydrological Simulation Program–FORTRAN (HSPF)—a comprehensive flow and water quality simulation model supported by the USEPA and the USGS. The model represents 228 square miles of land area and 94 individual stream reaches, covering the entire area of the Ventura River watershed. The model also represents various land uses within the watershed. The HSPF model incorporates both the effects of surface and groundwater; and, therefore, can be used to evaluate water supply reliability and basin yield in water supply studies. The HSPF model has been calibrated and validated for the Ventura River Basin.

The following sections describe the reports prepared to date that led to the development and testing of the hydrologic model.

3.1.1 Data Summary Report

The Data Summary Report (Tetra Tech 2008a), summarizes existing data and reports relevant to model development, providing an initial summary of background reports, spatial coverages, and data to support model development and calibration. In addition, data gaps and potential data quality issues were identified where appropriate. This data report summarizes the background information and data that were used to develop a Simulation Plan, which described the detailed approach for applying the HSPF model to the Ventura River watershed.

3.1.2 Simulation Plan

The Simulation Plan (Tetra Tech 2008b) served as the draft modeling Work Plan and Quality Assurance Project Plan (QAPP) for model calibration and validation and describes the proposed

approach to applying the HSPF model to the Ventura River watershed. The major sections of the report discuss (1) meteorological representation, (2) hydrologic response representation, (3) hydraulic routing network development, and (4) a summary of special modeling considerations made in preparation for water quality modeling.

3.1.3 Calibration and Validation Baseline Report

The Calibration and Validation Baseline Report (Tetra Tech 2009a) is the third in the series and covers model calibration and validation. This report was designed as a standalone document that incorporates relevant material contained in the two earlier reports, with relevant changes as necessary. This report provided the following conclusions and recommendations.

The performance of a model is judged by a weight of evidence approach, recognizing that some discrepancies are likely to be unavoidable at specific locations and times. The Ventura River Watershed Model performs well across a variety of measures and is judged ready for use, despite certain caveats: During the calibration period, it was evident that there are problems with the flow gage records for Coyote Creek and Santa Ana Creek, neither of which appear to have been measured and calibrated during the last decade. Excluding these gages, 92 percent of the pre-specified performance criteria for the various components of the water balance are met. In addition, the coefficient of determination (R2) between observed and predicted daily flows are high, ranging from 86.4 to 93.5 percent.

Performance during the validation period is also good, although some degradation in fit is noted (and is expected due to less precise information on high-elevation precipitation, diversions, and withdrawals). On the other hand, discrepancies are not present relative to the Coyote and Santa Ana Creek gage records during most of this period when the gage rating tables originally developed by USGS were likely a closer representation of actual conditions. The R2 values between observed and predicted daily flows range from 84.4 to 91.4 percent during the validation period.

Model prediction of storm event peaks is also generally good. Some individual events are not well predicted, presumably because the available point rainfall measurements do not accurately reflect the total rainfall across the upstream watershed. Tetra Tech's conclusion is that the model is fully usable; however, it will be important to consider the range of uncertainty revealed in the model validation relative to specific uses of the model.

Areas where the model might be further improved are discussed in Chapter 6, Data Gaps.

3.1.4 Natural Conditions Report

The Natural Conditions Report (Tetra Tech 2009b) addresses the question of natural flows in the Ventura River system. Natural flows are those flows that would be present without human intervention. Both high and low flow regimes are of interest. To evaluate natural condition flows, the calibrated model is rerun with all developed land use converted to natural land use and all dams, diversions, irrigation, water withdrawals, and discharges removed. The natural condition scenario is run over the same meteorological input (October 1967 through September 2007) as was used for the calibrated existing conditions model, enabling a direct comparison of results.

Because much of the Ventura River watershed remains undeveloped, substituting natural land use has a relatively small effect on flows. On the other hand, the dams, diversions, and water withdrawals currently in place have a large effect, and tend to reduce flows under existing conditions. However, irrigation of agricultural land does serve to increase instream flows somewhat under dry conditions.

3.1.4.1 Water Balance Results

Detailed water balance summaries were constructed for WY 1997 through 2007 (the model calibration period). Inputs are predominantly precipitation, although some water is also added by irrigation under existing conditions, and by depletion of soil and shallow groundwater storage. Differences in the upland water balance between existing and natural conditions are small, but include the elimination of irrigation input (4 percent of the total) and changes in evapotranspiration and storage due to different land cover. Total precipitation to the uplands is a little higher under natural conditions because of the additional land area present due to the removal of Lake Casitas and Matilija Reservoir. Under both existing and natural conditions, about 60 percent of this input is returned to the atmosphere via evapotranspiration, and one-third becomes runoff, while the residual enters deep groundwater. This deep groundwater is a source of irrigation water and also interacts with the stream; however, a complete water balance of the groundwater component is not possible because a groundwater model has not been completed.

The waterbody balance has a number of inputs, beginning with runoff from the land surface, but also including upwelling groundwater, point sources, and direct precipitation (the tables show net precipitation, the difference between precipitation and evaporation, which is an input for some reaches and an output for others). Output from the stream reaches and reservoirs includes downstream flow, diversions for consumptive use from Lake Casitas (existing conditions only), evaporation, and losses to groundwater. Under existing conditions, downstream flow to the Pacific Ocean constitutes 69 percent of the water entering stream reaches or about 25 percent of precipitation on the watershed. About 16 percent of the surface water flow is diverted for consumption, while the remainder is lost to groundwater or evaporation. Under natural conditions, there are no diversions to consumptive use, nor are there reservoir evaporation losses. As a result, the outflow from the Ventura River to the Pacific Ocean increases from 933,677 to 1,199,780 AF over the simulation period, or about 33 percent of the precipitation that falls on the watershed.

3.1.4.2 Flow Duration-Frequency Analysis

The complete distribution of flows was analyzed for WY 1968 to 2007. As a first step, the average flows over the simulation period were compared for each of the gage locations, plus the mouth of the Ventura River. Little difference is estimated in results for those stations that gage predominantly undeveloped land (Matilija Creek, North Fork Matilija Creek, Coyote Creek, and Santa Ana Creek), although average flows under natural conditions are slightly higher. For San Antonio Creek, the average flow under natural conditions is slightly lower as this watershed contains significant amounts of irrigated lands. The most dramatic changes are seen in the Ventura River mainstem; average flows in the river near Meiners Oaks are almost 50 percent higher, due to removal of both Matilija Dam and the Robles Diversion to Casitas. They are also about 50 percent higher under natural conditions for Ventura River near Ventura, reflecting the influence of Casitas Dam. The difference is slightly smaller at the mouth of the Ventura River, as

existing conditions add in the flow from the Ojai wastewater treatment plant (approximately 3 cfs).

For those watersheds that are predominantly undeveloped under existing conditions, the flow-duration curves for existing baseline and natural conditions are very similar. Low flows of a given frequency are slightly lower under natural conditions, reflecting the shift from forest to chaparral without fire suppression, as discussed above.

San Antonio Creek drains an area with substantial amounts of developed land and irrigated agriculture. Groundwater pumping, with associated losses from stream reaches, is removed under the natural conditions scenario; however, irrigation is also removed, resulting in a net reduction in low flow magnitude under natural conditions. Flows above the median value are also higher under existing baseline conditions because of the presence of impervious surfaces that promote runoff rather than infiltration.

The mainstem stations are strongly affected by the removal of dams and diversions. Below the site of Matilija Dam, median and lower frequency flows are higher under natural conditions due to the removal of storage and evaporation losses from the dam. Flows are dramatically different for Ventura River near Meiners Oaks because existing baseline conditions include both diversions to Casitas above this location and significant alluvial pumping that causes the channel to frequently go dry.

Natural condition flows are much higher at Ventura River near Ventura. This gage location is downstream of the confluence with Coyote Creek and Lake Casitas, so the absence of Casitas Dam under natural conditions is the major factor here. Finally, at the mouth of the Ventura River, natural condition flows are generally higher than under existing conditions, except at the lowest flows. Under existing conditions, low flows are maintained at a higher level by the Ojai wastewater treatment plant discharge.

3.1.4.3 Storm Event Peaks

Human influences impact peak runoff in the watershed in a number of ways. Impervious surfaces associated with development cause increased runoff, although the amount of impervious area in the watershed is relatively small. On the other hand, the storage capacity provided by Lake Casitas, Matilija Reservoir, and several smaller detention basins significantly reduces peak flows. A variety of other modifications to the natural drainage pattern have also been made.

The USGS PeakFQ program provides flood-frequency analyses according to Bulletin 17-B methodology (USGS 1982, as cited in Tetra Tech 2009b). This analysis was applied to both existing and natural condition simulated annual peak series for water years 1968 to 2007. For consistency with the model calibration report, the Bulletin 17-B procedure was applied to the complete annual peak series without any corrections for low outliers.

In general, the differences in estimated peaks between existing and natural conditions are small for watersheds without significant flow modification. Peaks under existing conditions are higher for Fox Canyon Drain and Happy Valley Drain as routing modifications have diverted additional area to these drains. On the other hand, peak flows are predicted to be much higher under natural conditions for the Ventura River mainstem, reflecting the removal of the Casitas and Matilija

dams. In general, the presence or absence of reservoirs is the dominant factor differentiating between peak flow estimates for existing and natural conditions.

3.2 Surface Water Quality Monitoring Program

The Surface Water Quality Monitoring Program is designed to help fill gaps in the data required to achieve the water quality objective of the Ventura River Watershed Protection Project. The information collected will be used in watershed modeling efforts, to characterize pollutant loading, and to evaluate the effectiveness of projects implemented in the Ventura River watershed.

The collected data will be incorporated into a hydrologic and water quality model that can simulate historic conditions on a continuous basis. The continuous hydrologic model can then be used to evaluate the effects of land use in the watershed on runoff, as well as the effects of BMPs on improving water quality in the basin. HSPF will be the framework for the hydrologic model.

The V-1 Surface Water Quality Monitoring Program can be used to assess the water quality effects of projects implemented in the Ventura River watershed and will be coordinated with other monitoring efforts to create a more sophisticated and accurate picture of surface water quality throughout the watershed. Long-term goals include using the data resulting from this monitoring program to identify priority water quality issues and develop additional implementation projects to enhance and protect water quality within the watershed.

3.2.1 Water Quality Modeling Plan (Draft), Ventura River Watershed Model

This discussion is drawn from the Water Quality Modeling Plan (Draft), Ventura River Watershed Model, prepared by Tetra Tech (2009b).

The waterbody segments of the Ventura River that are listed as impaired, requiring the development of a TMDL, are discussed in Section 2.7.3 above. As discussed in Section 3.1, a simulation model of the Ventura River watershed (HSPF) has recently been completed, calibrated, and validated for hydrology (Tetra Tech 2009a). In addition to hydrology, HSPF can simulate a full suite of water quality responses, and is frequently used to develop TMDLs.

The Draft Water Quality Modeling Plan discusses options for water quality simulation to address impairments associated with nitrates and algae within the Ventura River (excluding the estuary). Specifically, it addresses the impairment of Ventura River Reaches 1 and 2 for algae and the impairment of San Antonio Creek for nitrogen.

3.2.1.1 Critical Conditions

Impairment due to algae in the Ventura River is associated with dense growths of attached algae (Figure 3.2-1). In addition to creating unsightly conditions and poor habitat, dense algal growths lead to large diurnal swings in stream pH and DO concentration (with supersaturation during daytime photosynthesis and depletion at night). Like other plants, algae require light, warm temperatures, and a supply of nutrients to maximize growth. Excess algal growth is a common problem in the warm, shallow, and relatively unshaded streams of coastal southern California. However, the problem is exacerbated by human activities that increase nutrient loads. Algae require both nitrogen and phosphorus for growth, and a shortage of either constituent can limit

growth; however, nitrogen is often a key factor in determining density of attached algae in flowing streams in Southern California (Tetra Tech 2009b).



Figure 3.2-1 Algae in Ventura River at USGS Gage 11118500, April 29, 2008

Source: Tetra Tech 2009b

The 303(d) listings for algae in the Ventura River are based on older determinations for which detailed factsheets are not available. The Santa Barbara Channelkeeper (2007) provides additional information in their comment letter on 303(d) listings in the Ventura River:

> "Ventura River Reach 1: Historical photographic evidence submitted. 24 of 70 dissolved oxygen samples exceed 120% saturation. 19 of 52 observations indicate the presence of greater than 30% algae coverage. Ventura River Reach 1 has elevated levels of nitrate and phosphate." Ventura River Reach 2: "Historical photographic evidence submitted. 45 of 138 dissolved oxygen samples exceed 120% saturation. 36 of 103 observations indicate the presence of greater than 30% algae coverage. Ventura River Reach 2 has elevated levels of nitrate and phosphate."

Although the Regional Board has not yet done so, the Channelkeeper also suggested that Ventura River Reaches 3 and 4, San Antonio Creek, and Matilija Creek be listed as impaired for algae,

based on visual observations showing 51, 43, 34, and 51 percent of observations, respectively, showing greater than 30 percent coverage of the bottom by algae.

While excess nitrogen may be a contributor to excess algal growth, the 303(d) listing for nitrogen in San Antonio Creek is based on comparison to a target of 5 mg/L nitrate in the CRWQCB-LA Basin Plan, which in turn is based on human health standards. Considerably lower concentrations of nitrogen (in the presence of adequate phosphorus) would likely be needed to control algal growth to acceptable levels. The Channelkeeper (2007) compared observed nitrate and phosphorus concentrations to target values of 1 mg/L and 0.01 mg/L established in the Malibu TMDL (CRWQCB-LA 2004, as cited in Tetra Tech 2009b), and recommended that Ventura River Reaches 1 to 3, Cañada Larga, and San Antonio Creek be listed for nitrate, and that Ventura River Reaches 1 to 4, Cañada Larga, San Antonio Creek, Matilija Creek, and North Fork Matilija Creek be listed for phosphate.

For similar studies in Southern California, nutrient and algae impacts and resulting water quality impairments are often assumed to be most critical during dry conditions when flows are reduced. These conditions lead to greater light availability and higher summer temperatures. Nitrogen availability also tends to be higher during dry conditions, when stream flow is dominated by groundwater discharges (as inorganic nitrogen is highly soluble and dominantly transported via groundwater) and dilution of point source loads is at a minimum. Wet weather flows are generally accompanied by lower light availability (due to turbidity in the water column) and can lead to scour and sloughing of attached algae.

A significant body of water quality data has been collected since 2000 by USGS, Ventura County, and the Ventura River Watershed Monitoring Program (Stream Team, a joint project of Santa Barbara Channelkeeper and Surfrider, Ventura Chapter). The counts for these data are summarized in Table 3.2-1, while the results of these efforts are available on the Stream Team's website (http://www.stream-team.org/venturaalgae.html). Data collection has focused primarily on nutrients, and should provide a good basis for calibrating a model of these components. Data on suspended solids are very limited, while quantitative results are not available for algal density.

Field data collected with the Stream Team sampling include DO and pH measurements. Sample locations are shown in Figure 3.2-2. Both DO and pH respond to algal density, but point-in-time grabs are difficult to interpret in that context. While no quantitative measures of algal density are available therein, these data do include visual estimates of percent algal cover.

The percent cover estimates are plotted against model simulated flow for stations in the lower Ventura (the impaired reaches) in Figure 3.2-3. There is not a strong relationship to flow, and indeed the percent cover tends to increase with increasing flow, regardless of whether samples are examined for one or multiple stations or for summer or whole-year conditions. However, samples are not reported for flows greater than 180 cfs, likely too low for scour. Within this small range, increasing flow may aid algal growth by providing greater mixing into the algal mats and preventing desiccation. In any case, it does not appear that lowest flow conditions clearly lead to greater algal growth. There is also no clear relationship to air temperature. Thus, use of a single critical condition may not be appropriate.

Table 3.2-1 County of Ventura River Laboratory Water Quality Samples (mg/L), 2000-2007

Sampling Location	Ammonia As N	Dissolved Organic N	Nitrate + Nitrite as N	Nitrate as N	Nitrite as N	Ortho-phosphate	Soluble Reactive P	Total Dissolved N	Total Dissolved P	Total Kjeldahl N	Total Dissolved Solids	Total Suspended Solids	Total P	Turbidity
Canada Larga @ Ventura Ave	38	33	38				38	34	34					
Lion Creek	65	61		65			65	62	62					
Lower Matilija Creek	8		8	8	8	8			7	8	7	8	8	
Matilija above dam	73	66		73			73	68	68					
Matilija Cr. below dam	74	67		74			74	69	69					
N. Fork Matilija @ gauge	77	65		77			77	72	72					
San Antonio @ Lion Creek	49	42		49			49	47	47					
San Antonio @ Old Creek Rd.	74	65		74			74	70	70					
Stewart/Fox	68	61		68			68	65	65					
Upper Canada Larga	24	22	24				24	22	22					
Upper Matilija Creek	8		8	8	8	8			7	8	7	8	8	
Upper San Antonio	75	56		75			75	71	71					
Ventura @ Foster Park	125	111	125				125	120	120					
Ventura River at Ojai Valley Sanitation	20			20	20				10	19	20	20	10	20

Source: Tetra Tech 2009b

Quantitative measures of benthic algal biomass (as chlorophyll a density) were collected in 2008 by researchers from the University of California, Santa Barbara (Klose et al., 2009, as cited in Tetra Tech 2009b).These data established a strong relationship between algal density and total N concentration. Unfortunately, the samples were collected after the end of the model simulation period (September 2007), so they were not used to calibrate the model.

The water quality impairments addressed in this study are overgrowth of algae (eutrophication) and elevated levels of nitrates, which contribute to excess algal growth. Completing a TMDL requires a linkage that connects sources of nutrient loading (land sources, atmospheric deposition, point sources) to instream concentrations of nutrients and thence to predictions of

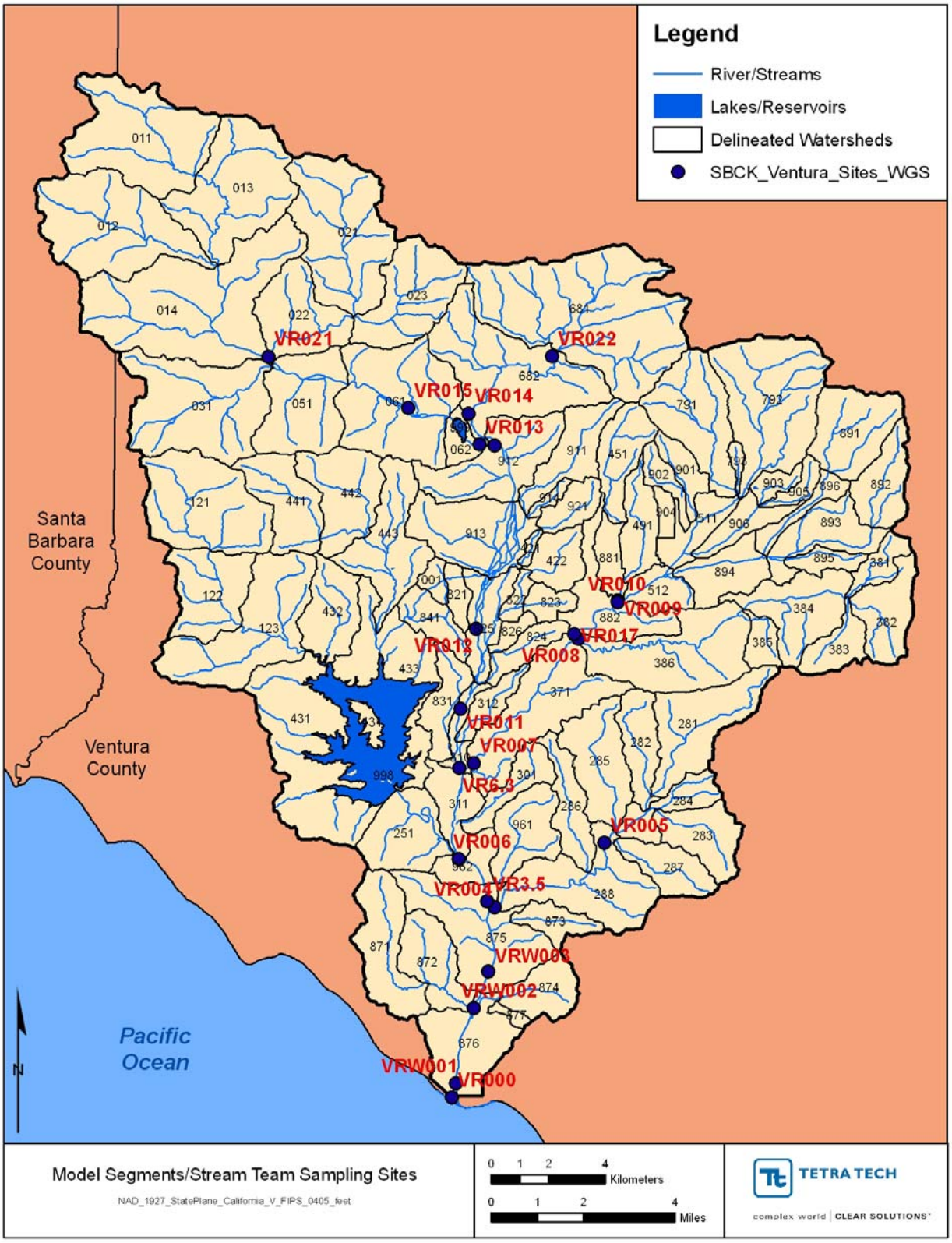


Figure 3.2-2 Location of Ventura Stream Team Sampling Sites

Source: Tetra Tech 2009b

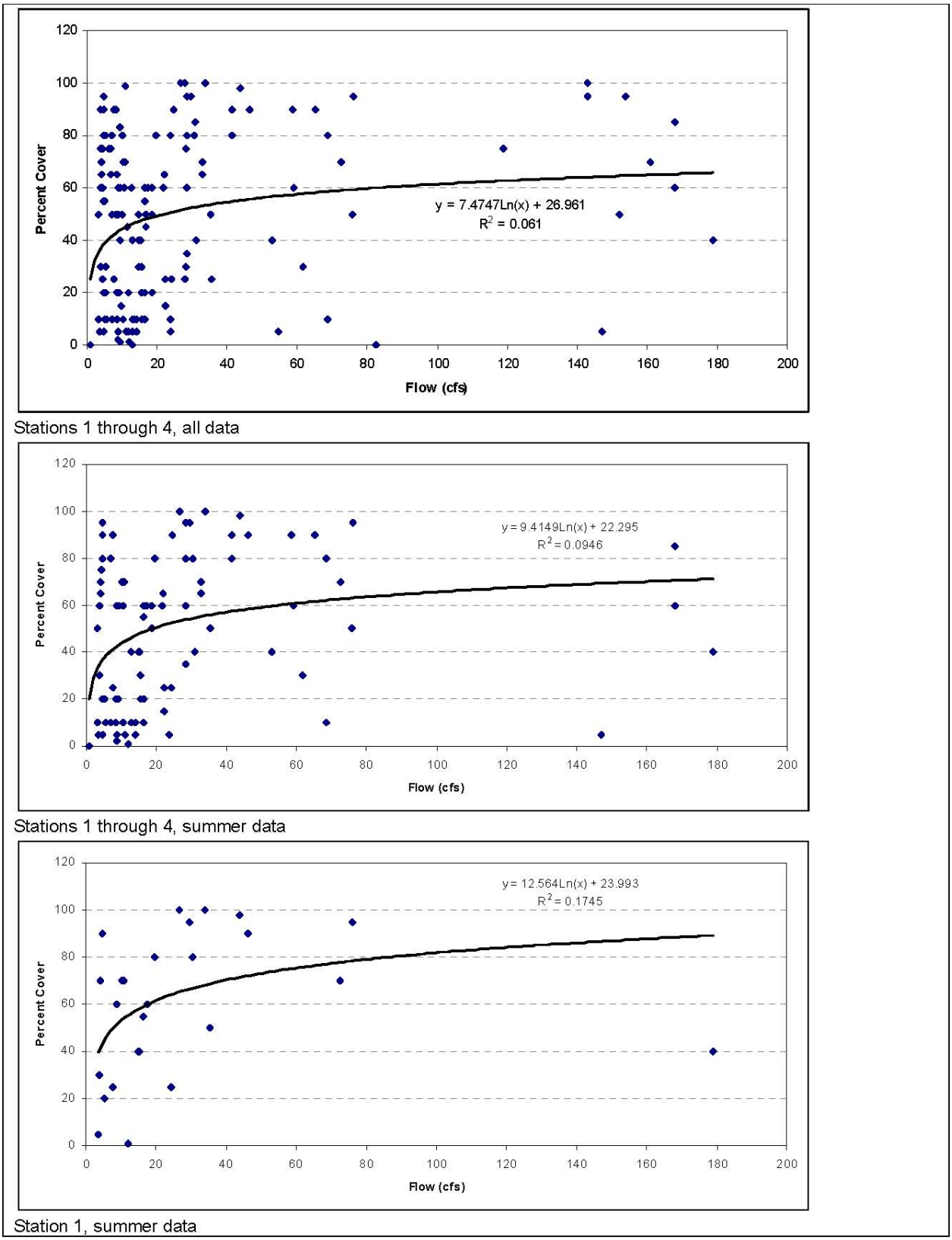


Figure 3.2-3 Algal Percent Cover versus Flow, Stream Team Data 2001-2007

Source: Tetra Tech 2009b

algal biomass. This is often accomplished entirely through simulation models, implemented in either a dynamic (time-varying) or steady-state mode. Dynamic models simulate the time series of responses, while steady-state models would be implemented to address critical conditions.

The HSPF model itself is capable of addressing all necessary aspects of the simulation, from nutrient load generation to algal response. A primary limitation is that it treats stream reaches in one-dimensional, linear form, and is not applicable to situations in which flows reverse or in which the lateral and vertical distribution of algae need to be addressed. For multi-dimensional situations, dynamic models like the Environmental Fluid Dynamics Code hydrodynamic model or the Water Quality Analysis Simulation Program can be employed. These types of models simulation waterbody response only, and would thus need to be linked to a watershed loading model (e.g., HSPF). Steady-state response models are also often employed to address responses under critical conditions of dry-weather flows and nutrient loads.

Regardless of the model that may be chosen, accurate prediction of benthic algal biomass will be difficult because it depends on a large number of factors, including some, such as grazing and sloughing, which are not well represented in any of the available models. Further, such models typically require intensive site-specific calibration – but quantitative data on algal densities in the Ventura River are largely lacking.

For practical implementation, the following approach can be used:

- Modify the upland hydrologic response unit (HRU) models to provide additional time series of generic pollutant surface and subsurface loads.
- Separate the process of "integrating" the unit flows for input to the reaches into a new, intermediate integrator model. This would take the HRU output and rewrite it as a function of the current land use table. The same process can be used for the pollutant loads, with conversion from generic to specific form (i.e., by multiplying times the appropriate buildup rates and subsurface concentrations). Load reduction factors applicable to individual land uses can also be inserted at this point to represent management scenarios. Several sequential runs can be used to account for land use changes over time, as is done in the current reach model.
- Run the reach model using input from the integrator model. As the land use change function has been segregated to the integrator model, the reach model can now be run as a single, continuous simulation. The reach model would also add time series of point source loads and atmospheric deposition.

Within the reach model Tetra Tech recommends that nitrogen and phosphorus be simulated as general quality constituents subject to first-order decay, rather than undertaking a detailed representation of uptake, transformation, and sediment sorption. This is recommended because sufficient data are not available to calibrate the reach model for sediment or algae at this time.

While these modifications involve some complexities, they can be accomplished in an efficient manner using the existing model user input code, which sets up the transfer for flows. Once set up, model calibration for nutrients would proceed in two areas: (1) pollutant-specific

accumulation rates on the land surface and associated groundwater concentrations (at the integrator model step), and (2) first-order decay rates in the reach model.

This calibration approach is well suited to the available data, which is strong on nutrients. The resulting framework is sensitive to land use, land management (which can be assumed to alter either buildup rates or pollutant delivery at the integrator level), and changes in flow, and can thus be used to investigate the sensitivity of nutrient concentrations in the river to a variety of scenarios.

3.2.2 Surface Water Quality Monitoring Plan 2010 and Quality Assurance Project Plan

3.2.2.1 Overview

As part of the V-1 grant-funded project, water quality and quantity data were collected from two surface water monitoring stations, laboratory analyses of the field measurements, and automated measurements. Collected data were assembled in a database and then evaluated using the water quality standards established in the California Toxics Rule and Los Angeles Water Quality Control Plan (or Basin Plan); they were then summarized in report that gives an overall view of the surface water quality in the Ventura River watershed.

The data collected from this effort can be integrated with data from a previously established monitoring station on the Ventura River and incorporated into the hydrologic simulation model developed for the Ventura River watershed (discussed above).

Water quality sampling included coordinating monitoring events to take place during various weather conditions; documenting all aspects of the water quality monitoring events including calibration of monitoring equipment; assembling hydrologic information including rainfall and flow; taking field measurements for DO, conductivity, specific conductance, salinity, temperature, and pH; and collecting grab and composite water quality samples during monitoring events and submitting them to the appropriate certified laboratory to be analyzed for the requested parameters. Monitoring events occurred four times per year − three times during wet weather and once during dry weather − to provide water quality information during various weather conditions. Laboratory analyses were conducted using approved EPA or Standard Methods and tests were conducted at California and/or National Environmental Laboratory Accreditation Program certified laboratories.

DO, conductivity, specific conductance, salinity, temperature, and pH were measured in the field using calibrated measuring equipment. Stream flow was measured using Bubbler Flow Meters programmed with appropriate rating tables. Grab samples were collected for total coliform, fecal coliform, E. coli, oil and grease, total petroleum hydrocarbons, cyanide, volatiles, and mercury (for one year). Composite samples were collected using automated samplers. All constituents are important to the project with a particular emphasis on nutrients and metals.

The project schedule and deliverables are shown in Table 3.2-2.

Table 3.2-2 Project Schedule and Deliverables

Activity	Anticipated Date of Initiation	Anticipated Date of Completion	Deliverable	Due Date
Determine monitoring locations	December 2005	January 2009	None	N/A
Design monitoring stations	December 2008	August 2009	None	N/A
Order and install equipment	June 2009	October 2009	None	N/A
Start sample collection	October 2009	August 2011	None	N/A
Enter data into database	November 2009	November 2011	None	N/A
Produce annual water quality report	November 2010	January 2011	Annual Report	N/A
Produce annual water quality report	November 2011	January 2012	Annual Report	N/A
Produce final water quality report	January 2012	March 2012	Final Report	N/A

Source: District 2010d

3.2.2.2 Monitoring Sites

The monitoring sites were selected to be representative of urban runoff in the Ojai Valley. Urban runoff rates are unpredictable during dry weather because they are dependent on usage upstream. Minimal amounts of urban runoff are desirable for the objective of pollution reduction. Public Outreach has been conducted in the Ojai Valley to encourage residents and business operators to reduce their contributions to urban runoff. These factors all contribute to the difficulties in sampling storm drains during the dry season. The Project has opted to overcome this obstacle by predominantly monitoring during rain events, which are more representative of the overall contributions of urban runoff to the watershed because accumulated material is washed into the storm drain system where it can be sampled and quantified. The locations of the monitoring sites are shown in Figure 3.2-4.

Meiners Oaks – Happy Valley Drain

The Meiners Oaks monitoring site (MO-MEI) is located on the southeast side of Rice Road, southwest of the intersection of Rice Road and W. Lomita Avenue, on the Happy Valley Drain. The Meiners Oaks monitoring site is positioned low in the watershed and receives runoff from an estimated 1.6 square mile drainage area of mixed land use (open space, residential, and agricultural).

Ojai – Fox Canyon Barranca

The Ojai monitoring site (MO-OJA) is located on the Fox Canyon Barranca, east of Fox Street, south of Highway 150 (E. Ojai Avenue), near the Ojai Valley Athletic Club. The Ojai monitoring site is positioned low in the watershed and receives runoff from an estimated 1.2 square mile drainage area of mixed land use (open space, residential, and agricultural).

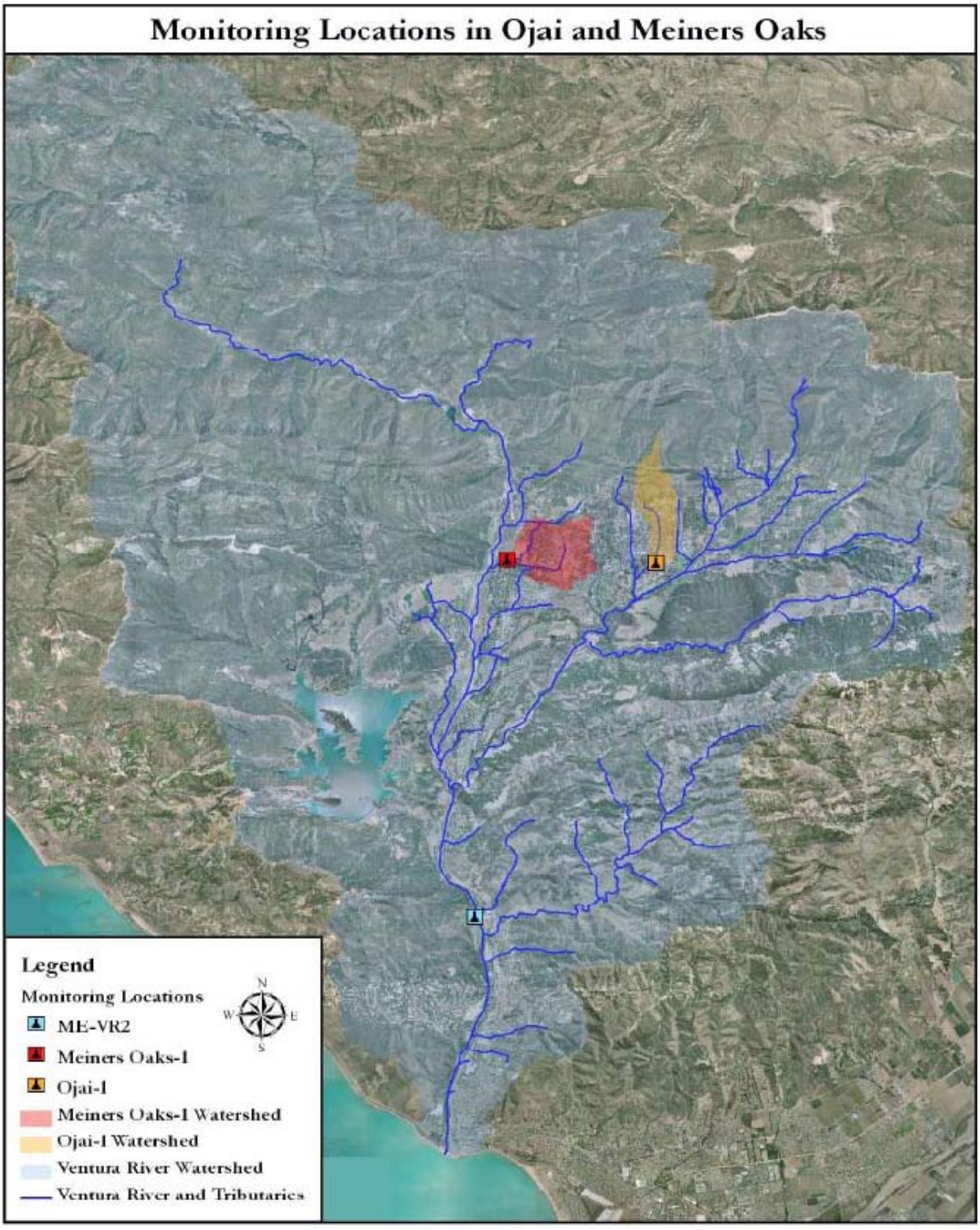


Figure 3.2-4 Monitoring Site Locations

Source: District 2010b

3.2.3 Ventura River Watershed Model – Aluminum

To demonstrate the viability of the hydrologic model (described above) to simulate water quality conditions, the District requested a pilot demonstration for the presence of aluminum in surface water. This effort included the identification of sources of aluminum (which are primarily natural), estimation of the contribution (or loading) of aluminum from those sources and the use of the model to estimate the resulting concentrations in surface waters. In addition, water quality sampling and analysis was conducted to allow a comparison of model predictions to observed concentrations in the water quality samples. A technical memorandum was prepared to describe the setup, calibration, and results of the water quality modeling for aluminum (Tetra Tech 2011).

3.2.3.1 Aluminum

Sources of Aluminum

Aluminum (Al) is ubiquitous in the environment and is the most abundant metal in the earth's crust. The primary source of aluminum in the Ventura River watershed is from natural geology and soils. Many clay minerals (kaolinite, montmorillonite, illite, and chlorite) contain a certain percentage of aluminum silicate (Al2SiO5) as a natural component of the chemical matrix (~ 5 to 15 percent). Other potential sources of elevated aluminum load include mining, accidental discharge from oil and gas exploration, certain agricultural chemicals, and point source discharge.

Mine drainage is a possible source of aluminum load, particularly acid mine drainage. There has been historic gold mining in Ventura County, but little documented activity within the Ventura River watershed. There are only two known mining operations in the Ventura River watershed. One is an inactive sand and gravel operation a few hundred yards north of Hwy 101 above the estuary, and the other is an active rip-rap operation near the confluence of Matilija Creek. Neither of these sites is known to have had any aluminum discharges or runoff.

The watershed does include an area of oil and gas exploration. The wells themselves are not expected to be sources of aluminum, but drilling muds can be a source. Drilling mud/additive manufacturers use a typical Bentonite clay for well drilling (for both oil and water wells) that contains a relatively consistent 18 percent Al2SiO2. Significant amounts of drilling muds would have to be spilled or leached and reach surface water to be a significant source of aluminum within the Ventura River. It is believed that such spills have occurred very infrequently.

Agricultural uses of aluminum sulfate can be another potential source of aluminum (e.g., used for crops that require a low pH like blueberries). However, excess soil aluminum is deleterious to many crops and this is not a typical amendment in the Ventura River watershed.

The Ojai Valley Sanitary District discharges treated wastewater to the Ventura River. This point source discharge is considered a minor source of aluminum load. The facility monitors aluminum infrequently.

In sum, anthropogenic sources of aluminum load appear to be of limited importance. The most widespread and likely source for aluminum is the natural soil and parent geology, especially the Eocene-age rock types in the upper portion of the Ventura River watershed. The Cozy Dell Shale formation exists in an east-west band that crosses the upper watershed. Rock types here are

classified as argillaceous and contain aluminosilicates as a major chemical component along with a host of possible clay minerals. The adjacent Coldwater Sandstones and Matilija Sandstones also contain such clay minerals.

Monitoring Data

Only limited amounts of ambient monitoring data for aluminum are available from the Ventura River watershed. Ventura County has collected aluminum data at four sites within the Ventura River watershed (Figure 3.2-5). Data are available from two sites – Ventura River at Foster Park and Ventura River at Ojai Valley Sanitation – since 2004 to 2005 (Table 3.2-3). Monitoring occurred at two additional sites – Fox Canyon Drain and Happy Valley Drain more recently.

Table 3.2-3 Ventura River Watershed Sites with Aluminum Data

Site	Site ID	Samples	Sample Dates
Fox Canyon Drain	MO-OJA	6	10/14/09 -11/21/10
Happy Valley Drain	MO-MEI	6	10/14/09 -11/21/10
Ventura River at Foster Park	ME-VR	10	2/3/04 -1/11/05
Ventura River at Ojai Valley Sanitation	ME-VR2	32	5/4/05 -10/30/10

Source: Tetra Tech 2011

Concentrations are elevated during wet periods dominated by stormwater runoff relative to dry, baseflow conditions (Table 3.2-4). The overall average of all the wet condition data was 3012 µg/L (median equal to 878 µg/L). During dry conditions the average was 103 µg/L (median of 11 µg/L).

Table 3.2-4 Summary of Total Aluminum Data (Storm and Non-Storm)

	Dry (Non-Storm)		Wet (Storm)	
Site	Average (µg/L)	Samples	Average (µg/L)	Samples
Fox Canyon Drain	3.2	1	3,060	5
Happy Valley Drain	22.0	1	3,120	5
Ventura River at Foster Park	7.6	3	5,560	7
Ventura River at Ojai Valley Sanitation	141.5	12	2,081	20

Source: Tetra Tech 2011

Based on data gaps identified in an earlier report, a water-quality monitoring plan was developed. Water quality parameters identified for further monitoring includes nutrients, bacteria, metals, organics, pesticides, temperature, pH, total suspended solids, DO, and conductivity. A water quality monitoring plan will provide data for watershed modeling efforts, characterize pollutant loading, and evaluate effectiveness of projects implemented in the watershed.



Figure 3.2-5 Ventura River Monitoring Stations

Source: Tetra Tech 2011

The scope of the project included the planning, and construction of two water quality monitoring stations, water quality sampling and analysis, and data management and analysis. The first phase of implementing the water quality monitoring plan consisted of determining the appropriate locations for the monitoring stations, and selecting the suitable equipment for the automated collection of composite water quality samples. Tasks for the second phase included purchase of monitoring equipment, the installation of station enclosures and equipment, and calibration of monitoring equipment. Tasks for the third phase included coordination of monitoring events that took place during various weather conditions, collecting composite water quality samples during monitoring events and analyses of appropriate parameters, assembling hydrologic information associated with each monitoring event, documenting all aspects of the water quality monitoring events (including interrogation of monitoring equipment and submitting water samples to an appropriate state-approved laboratory for chemical analysis).

Additional tasks in this effort included assembling the data in an database, reviewing the data for QA/QC, evaluating data using water quality standards established in the California Toxics Rule, L.A. Basin Plan, the Ocean Plan, and producing a final water quality report based on the data summarizing water quality conditions within the Ventura River watershed.

3.2.3.2 Point Source Representation

One point source was simulated in the model: the OVSD wastewater treatment plant (CA0053961). Available discharge monitoring data for aluminum consisted of nine samples collected from 2006 to 2010. The range in aluminum concentration was 130 to 360 µg/L, with an average concentration of 225.7 µg/L. The loading series was created using the flow time series developed during the hydrology calibration with a constant concentration applied equal to the average concentration of the observed discharge data.

3.2.3.3 Calibration Results

Calibration focused on the two stations where observed data coincided with the model simulation period of 1996 to 2007: Ventura River at Foster Park and Ventura River at Ojai Valley Sanitation. The Ojai Valley station had 50 percent more observed data to compare to so it received greater focus. Adjustments were made to accumulation load by land use category and subsurface (interflow and groundwater) concentrations during calibration to obtain a fit to observed, instream data. A series of diagnostic graphs and statistics were prepared for both load and concentration to facilitate the process. Select graphs and statistics are shown below and demonstrate a reasonable fit to monitored aluminum in the Ventura River watershed.

The calibration largely relies on comparisons of continuous model output to point-in-time and point-in-space observations. Time series of observed and simulated aluminum concentration show that the trends in observed values are tracked reasonably well, particularly given limits on the amount of data available for comparison (i.e., 10 to 15 paired data points).

The deviations do not appear to have a strong bias of under-or over-prediction. The average concentration is underpredicted slightly at both stations with average errors of -15.32 percent and -3.68 percent. At both stations, this statistic is strongly influenced by one high, observed concentration that was underpredicted: in March 2006 at Ojai Valley and in January 2005 at Foster Park. Accordingly, median errors, which are not as heavily influenced by just a few large deviations, are positive. And at Ojai Valley, median error is less than 1 percent.

A comparison of model predictions of load to observed load plotted against flow also shows a reasonable agreement. Regression lines developed for both sets of data nearly coincide. While additional data for calibration would likely strengthen this relationship, the agreement provides evidence that trends in, and distribution of, load at these two sites are similar over the range of flows.

Total aluminum load at the outlet of the watershed over the full simulation period (10/1/1996-9/30/2007) was 624.15 tons/year (Table 5). The OVSD wastewater treatment plant represented a very small fraction of this load: 0.76 tons/year.

3.3 Ojai Basin Groundwater Monitoring Plan

The District plans to conduct routine monitoring of groundwater levels and groundwater quality from select wells within the Ojai Basin. To clarify the effort required for this process, a groundwater monitoring plan was developed to describe the collection of data on groundwater levels and quality, estimate the budget for sampling events, and propose a reporting format for the collected information. The information developed from this monitoring plan can be used to gauge the effectiveness of the Ojai Basin Groundwater Model, developed by OBGMA, and recharge projects such as the San Antonio Creek Spreading Grounds Rehabilitation Project (described above in Section 2.6).

The following information is excerpted from the report entitled Ojai Basin Groundwater Monitoring Plan by DBS&A (2010b). The objective of the monitoring program is to assess groundwater levels and groundwater quality on a semi-annual basis in the various stratified aquifers of the Ojai Basin. As documented below, several wells have been identified to meet this objective without the need for drilling or converting a significant number of production wells to depth discrete monitoring wells. The acquired data will be combined with existing well data and surface stream gauging stations throughout the larger area. The results of groundwater quality/level monitoring will be documented in semi-annual reports.

3.3.1 Monitoring Wells

Of the dozen stratified aquifers in the Ojai Basin that can be correlated, most wells have been drilled and perforated through multiple zones. The following wells, however, are perforated through only a few of the zones and can be used to focus on the conditions of individual aquifers; locations of these wells are shown on Figure 3.3-6:

- 2010 San Antonio Creek Spreading Grounds Rehabilitation Project Depth Discrete Monitoring Well: This is a County-owned monitoring well that has five perforated casings intervals ranging in depth from 95 to 295 feet. The deepest of these is perforated in the Sespe formation, while the four shallower zones are perforated in zones that comprise the more permeable strata of Ojai Valley alluvium. Not all zones are perennially saturated. Designed as part of the San Antonio Spreading Grounds Rehabilitation Project, this well will be monitored under the basin-wide monitoring program as well.
- Rusin East Well: This privately-owned well was designed and constructed in 2008 to extract groundwater only from an intermediate series of aquifers. Importantly, the two sets of perforations in the well extend only from 320 to 440 and the upper aquifers are sealed off via a cement annular seal that extends to 130 feet below ground surface. Water levels in this well

are typically higher than other nearby wells due to the confined pressure of the intermediate aquifer system.

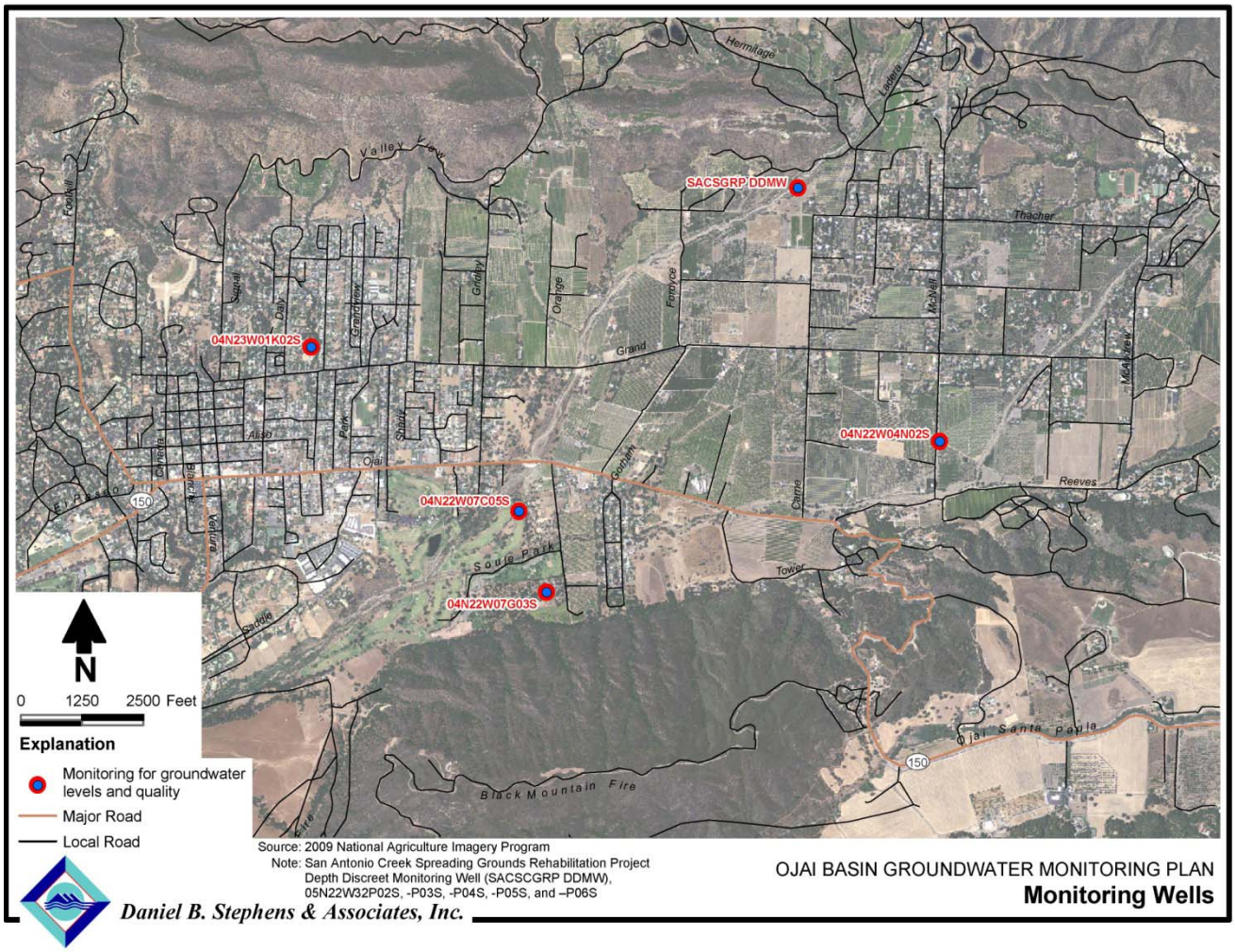


Figure 3.3-1 Monitoring Wells

Source: DBS&A 2010b

- Soule Park older well: This 14-inch-diameter steel cased well, owned by the County-affiliated Soule Park Golf Course, has been recently replaced by a well drilled a few hundred feet to the north. Similar perforation intervals exist in this older well compared to the new well, and this well may be used for monitoring during pumping of the new well to understand aquifer parameters. This well may also be a candidate for modification due to the presence of well defined aquitards in this portion of the basin.
- Mollan Well: This privately owned well is currently monitored for water levels by the District, but due to its limited and shallow perforations (90 to 130 ft), the well will be included in the monitoring program.

- Ruch Well: This privately owned well is perforated only in the upper zones of the Basin, from approximately 70 to 140 feet below ground surface. This well has been documented to be one of the first in the basin to flow artesian in any given year.

3.3.2 Water Level Measurements

Water level measurements provide a measure of water potential (hydraulic head) at specific geographic locations and depths. The primary purpose for measuring water levels in monitoring wells is to determine depth-to-water, horizontal and vertical groundwater flow directions, and gradients. These measurements, when converted to elevation relative to a standard datum (such as mean sea level or the North American Vertical Datum) and posted on a map, can be contoured to prepare potentiometric surface maps, and used to evaluate where and at what rate groundwater is moving in specific aquifers in the Basin.

Water levels were measured on a semi-annual basis in the above wells to provide water level data to evaluate groundwater gradients and flow directions. March and September were targeted as the months in which monitoring events will occur to coincide with the historic highs and lows of groundwater levels, based on most available data in the Basin. The water level measurements were conducted over a one to two day period to represent static conditions as amenable to well owners pumping and irrigation schedules. Well owners were asked to deactivate or idle well pumps for a period of 24 hours, if possible, before water level measurements commence to allow for pre-measurement water level recovery and stabilization.

Measurements within geographic areas were collected in the shortest possible time so that the data can be assumed to have been collected under comparable conditions. Water level measurements were made using an electric sounder, and performed in accordance with procedures described in the DBS&A standard operating procedures (DBS&A 2010b, Appendix A). Where wells are equipped with an airline or pressure transducer, and obtaining static water levels with an electric sounder is not feasible, the existing infrastructure was used for obtaining depth to water measurements.

3.3.3 Water Quality Sampling and Analysis

Water quality samples were collected on a semi-annual basis from the wells specified on Figure 3.3-1. Permanent production well pumps already present at each well were used to collect groundwater samples, as applicable. Temporary pumps/and/or bailer(s) were used to extract groundwater samples from wells without permanent pumps. In coordination with well owners' pumping schedules, as applicable, each well pumped for a 24-hour period before sampling to reach a steady pumping water level. If typical pumping periods were not at least 24-hours in length, a maximum pumping period was targeted.

Near the end of each pumping period, a pumping water level was obtained and water samples collected. Field personnel followed standard operating procedures as applicable for well purging and sample collection (DBS&A 2010b, Appendix A). Field parameters measured during well purging include pH, temperature, oxidation reduction potential, electrical conductivity, DO, and turbidity. All water quality meters were calibrated at the beginning of each sampling day using factory-recommended calibration solutions. If turbidity was present in excess of 5 nephelometric turbidity units, the samples were field-filtered using a manually operated positive-displacement pump equipped with a nominal 0.45 micron disposable filter.

Fruit Grower's Laboratory, Inc., located in Santa Paula, CA, performed laboratory analyses. The analytical suite for groundwater monitoring events are listed below:

- Field measurements.
- Irrigation suitability (alkalinity, bicarbonate, boron, calcium, carbonate, chloride, copper, electrical conductivity, fluoride, gypsum requirement, hydroxide, iron, magnesium, manganese, nitrate, pH, potassium, sodium, sodium absorption ratio, sulfate, TDS).
- Perchlorate.

Irrigation suitability was selected to provide a good representation of general water chemistry, and an incentive for well owners to cooperate with the monitoring program. Perchlorate was selected as an analyte due to its detection during the GAMA program in the two wells included in the Ojai Basin in 2007 sampling (Montrella and Belitz 2009, as cited in DBS&A 2010b).

Field quality control measures implemented during the quarterly groundwater sampling events will be performed according to the standard operating procedures (DBS&A 2010b, Appendix A) and QAPP (DBS&A 2010a, as cited in DBS&A 2010b). The required quality control sample frequencies and field quality control measures include but are not limited to:

- Collection of 1 field duplicate, 1 equipment blank, and 1 matrix spike.
- Providing accurate, detailed field documentation.
- Proper sample packaging and shipment.

3.3.4 Reporting Format

On a semi-annual basis, the acquired data was combined with existing well data and data from surface stream gauging stations throughout the larger area (collected by others), and these results documented in formal reports. All data analysis, interpretation, and report preparation was directed and reviewed by a DBS&A senior scientist and State of California Professional Geologist.

Section 1.0 of each report presents introductory information pertaining to the project history and hydrogeology, purpose and scope, and report organization. Section 2.0 summarizes the monitoring event activities including groundwater level measurements, sample collection, QA/QC procedures, and the analytical program. Section 3.0 presents the groundwater monitoring data including groundwater conditions and analytical results. Section 4.0 presents recommendations for program modifications, extensions, or reductions. The laboratory analytical report, including chain-of-custody forms, is attached as Appendix A to the report.

Measurements within geographic areas were collected in the shortest possible time so that the data can be assumed to have been collected under comparable conditions. Water level measurements were made using an electric sounder, and performed in accordance with procedures described in the DBS&A standard operating procedures. Where wells were equipped with an airline or pressure transducer, and obtaining static water levels with an electric sounder is not feasible, the existing infrastructure was used for obtaining depth to water measurements.

3.4 Upper and Lower Ventura River Basin Groundwater Budget and Approach to a Groundwater Management Plan

To improve the understanding of the groundwater basins along the Ventura River, a groundwater budget was developed based on available data and a hydrogeologic analysis performed to estimate the groundwater inputs and outputs in the Upper and Lower Groundwater basins (or sub-basins) which are generally located above and below Foster Park. In addition, the report also proposed an approach for the development of a groundwater management plan for the basins to insure a long-term sustainable, reliable, and good-quality water supply.

Information in this discussion is excerpted from the report entitled Groundwater Budget and Approach to a Groundwater Management Plan, Upper and Lower Ventura River Basin by DBS&A (2010a).

The sub-basins extend along the Ventura River Valley from the mouth of the river at the Pacific Ocean to just south of Matilija Canyon. Water users in the Ventura River watershed have no access to imported water and are therefore dependent upon maintaining an adequate supply of usable quality local water resources. For this reason, protection of local groundwater is vital, and an adequate understanding of groundwater storage volume and water quality trends is necessary. This report presents a groundwater budget for the sub-basins and an approach to a groundwater management plan (GWMP), as the first steps in planning for long-term protection.

The general approach for the groundwater budget is to estimate, based on available data and hydrogeologic analyses, the magnitude of all groundwater inputs and outputs within each of the sub-basins. Inputs include infiltration from precipitation, infiltration from irrigation, surface water recharge to groundwater, recharge from domestic septic systems, inflow from bedrock to the alluvial aquifer, and groundwater inflow from upgradient sub-basins. Groundwater outputs include municipal groundwater extractions, domestic groundwater extractions, agricultural groundwater extractions, industrial groundwater extractions, groundwater discharge to surface water, groundwater outflow, and groundwater consumption by riparian vegetation.

The resulting budget provides an estimate of the net gain or loss of the volume of groundwater in storage within the sub-basins per year. For the Upper Sub-Basin, a net gain of 1,466 AFY (Table 3.4-1) is estimated for the budgeted time period (WY 1997 through 2007). The primary inputs to groundwater in this sub-basin are infiltration and surface water recharge from Lake Casitas and the Ventura River, while the primary outputs are municipal and agricultural extractions. The estimated net gain in groundwater storage is relatively small and is consistent with long-term hydrographs of wells within the Upper Sub-Basin that indicate stable groundwater levels with 5 to 10-year rise and decline cycles.

Table 3.4-1 Groundwater Balance Upper Ventura Sub-Basin

Category	Parameter	Upper West (AFY)	Upper East (AFY)	Upper (Combined)[a] (AFY)
Groundwater Inputs	Infiltration from precipitation	893	4,181	5,073
	Infiltration from irrigation	222	2,891	3,113
	Net surface water to groundwater	2,003	2,290	4,293

Table 3.4-1 Groundwater Balance Upper Ventura Sub-Basin

Category	Parameter	Upper West (AFY)	Upper East (AFY)	Upper (Combined)[a] (AFY)
	Septic system recharge	18	120	139
	Bedrock to alluvial [b]			113
Groundwater Outputs	Extractions (domestic)	1	16	17
	Extractions (municipal)	0	7,385	7,385
	Extractions (agricultural)	0	1,898	1,898
	Groundwater outflow to Lower Sub-basin [b]			535
	Consumption by riparian vegetation [b]			1,430
			Final Balance [c]	+1,466

Notes:
a: Numbers may not add exactly because of rounding
b: Values not calculated independently for East and West Sub-basins
c: Sum of groundwater inputs minus sum of groundwater outputs
Source: Daniel B. Stephens & Associates 2010

For the Lower Sub-Basin, a net loss of 2,423 AFY (Table 3.4-2) is estimated for the budgeted time period. The primary inputs are infiltration and inflow from the Upper Sub-Basin, while the primary outputs groundwater discharge to surface water and discharge to the Pacific Ocean. There are currently no water levels monitored by Ventura County within the Lower Sub-Basin for comparison to the budget.

Table 3.4-2 Groundwater Balance Lower Ventura Sub-Basin

Category	Parameter	AFY[a]
Groundwater Inputs	Infiltration from precipitation	616
	Infiltration from irrigation	655
	Net surface water to groundwater	5
	Septic system recharge	319
	Bedrock to alluvial [b]	535
Groundwater Outputs	Extractions (domestic)	1,254
	Extractions (municipal)	1
	Extractions (agricultural)	522
	Groundwater outflow to Lower Sub-basin [b]	2,412
	Consumption by riparian vegetation [b]	365
	Final Balance [b]	-2,423

Notes:
a: Numbers may not add exactly because of rounding
b: Sum of groundwater inputs minus sum of groundwater outputs
Source: Daniel B. Stephens & Associates 2010

The intention of a GWMP is to provide a framework to manage groundwater to ensure a long-term, sustainable, reliable, good-quality water supply suitable to the political, legal, institutional, hydrogeologic, and economic conditions and constraints that exist in a groundwater basin. This report presents an approach to development of a GWMP for the sub-basins, including specifications for public participation, interagency involvement, coordination with the Ventura River Watershed Council, literature review and technical analysis, establishment of management objectives, and development of a monitoring program. The following outline provides an approach to development of a GWMP.

Component 1. Develop a map showing the area of the Basin, with the area that will be subject to the GWMP, as well as the boundaries of other local agencies that overlie any portion of the Basin. As a delineated groundwater basin with two delineated groundwater sub-basins, maps of the basins have been developed by both state and county agencies.

Component 2. Provide a written statement to the public describing the manner in which interested parties may participate in development of the GWMP. The statement should be provided to the public via local newspapers and/or other media, with distribution throughout the Basin. Documentation of public notification will be included in the GWMP.

Component 3. Establish a plan to involve other agencies whose boundaries overlie the Basin in development of the GWMP. This may include involvement via agency representative participation in the Ventura River Watershed Council (see Component 4).

Component 4. Establish a process for the Ventura River Watershed Council to serve as the designated advisory committee of stakeholders (interested parties) within the plan area that will help guide the development and implementation of the GWMP and provide a forum for resolution of controversial issues.

Component 5. Describe, in detail, the area to be managed under the GWMP, including (1) the physical structure and characteristics of the aquifer system underlying the plan area in the context of the overall basin; (2) a summary of the availability of historical data; (3) issues of concern; and (4) a general discussion of historical and projected water demands and supplies.

Component 6. Establish management objectives (MOs) for the groundwater basin that is subject to the plan. MOs are intended to contribute toward a more reliable supply for long-term beneficial uses of groundwater in the plan area.

Component 7. For each MO in Component 6, describe how meeting the MO will contribute to a more reliable supply for long-term beneficial uses of groundwater in the plan area, and describe existing or planned management actions to achieve MOs.

Component 8. Adopt monitoring protocols for the monitoring and management of groundwater levels, groundwater quality, potential inelastic land surface subsidence, and changes in surface flow and surface water quality that directly affect groundwater levels of quality.

Component 9. Describe the monitoring program, including the following:

- A map indicating the general locations of any applicable monitoring sites for groundwater levels, groundwater quality, subsidence stations, or stream gages.
- A summary of monitoring sites indicating the type (groundwater level, groundwater quality, subsidence, stream gage) and frequency of monitoring. For groundwater level and groundwater quality wells, indicate the depth interval(s) or aquifer zone monitored and the type of well (public, irrigation, domestic, industrial, or monitoring).
- A QAPP for monitoring in the basin.
- Standard operating procedures for monitoring in the basin.

Component 10. Describe any current or planned actions by the local managing entity to coordinate with other land use, zoning, or water management planning agencies or activities.

Component 11. Provide for periodic report(s) summarizing groundwater basin conditions and groundwater management activities. The report(s) prepared annually or at other frequencies and should include the following:

- Summary of monitoring results, including a discussion of historical trends.
- Summary of management actions during the period covered by the report.
- Discussion, supported by monitoring results, of whether management actions are achieving progress in meeting MOs.
- Summary of proposed management actions for the future.
- Summary of any plan component changes, including addition or modification of MOs during the period covered by the report.
- Summary of actions taken to coordinate with other water management and land use agencies and other government agencies.

Component 12. Provide for the periodic reevaluation and updating of the plan by the Ventura River Watershed Council.

3.5 Upper San Antonio Creek Watershed Giant Reed Removal Project

Giant reed (*Arundo donax*) is an invasive plant that consumes large quantities of water; displaces native vegetation and wildlife; disperses readily during floods; and exacerbates flooding, erosion, and fire intensity. The Upper San Antonio Creek Watershed Giant Reed Removal Project was implemented to substantially reduce the abundance and distribution of giant reed from the Upper San Antonio Creek Watershed, including Upper San Antonio, McNell, Thacher, and Reeves Creeks.

The distribution of giant reed within these creeks is patchy; overall, its percent cover relative to other vegetation is fairly low (less than about 20 percent). However, there are a few locations where its percent cover is as much as 76 percent. Figure 3.5-1 provides a giant reed distribution map of the project area. The project also involved the opportunistic removal of castor bean (*Ricinus communis*) in areas where it occurs in close proximity to the giant reed. The intended

outcome of the Project is the re-colonization of native vegetation and the restoration of native habitats. A total of 212 acres were targeted for giant reed removal (District 2010c)

The "cut and daub" method was used to remove the giant reed and treatments only occurred when surface water was not present. The method involved manually cutting off the canes of the giant reed and painting the freshly cut surface with a glyphosate-based herbicide that is approved and labeled for use near and in open water, such as Aquamaster®. Treatment began in June 2010 and ended in December 2011.

Glyphosate is a broad-spectrum, non-selective, post-emergent herbicide that readily and completely biodegrades in soil and has little potential for leaching into groundwater. The primary MCL for glyphosate in drinking water sources or water bodies with a MUN (municipal and domestic supply) beneficial use designation has been set by the USEPA at 700 parts per billion (ppb). This is the equivalent of 700 parts of glyphosate to 999,999,300 parts of water and is the level of protection that the USEPA believes would not cause potential short-term or long-term health effects. Therefore, as a protective measure, the threshold for glyphosate for this project was also set at 700 ppb.

Aminomethylphosphonic acid (AMPA) is a breakdown product of glyphosate as the result of microbial metabolism. The laboratory method used to analyze for AMPA also measured glyphosate and glufosinate. Glufosinate is similar to glyphosate in its chemical structure and use. There are no regulatory limits for AMPA or glufosinate.

The District and the Stream Team routinely monitored for glyphosate within the treatment area to ensure that the water quality BMPs used during the Project were effective. The District also periodically monitored for AMPS. All sampling was constrained by the need for surface water to be present for collection of samples. Periodic stormwater monitoring also occurred.

Four routine sampling sites were monitored for the term of the project (Figure 3.5-2). Site 1 was southwest of Soule Park above the confluence of San Antonio Creek and Stewart/Fox Canyon (Pirie Creek), and downstream of the densest giant reed population to be targeted in this project. Site 2 was at the San Antonio Creek Crossing on Ojai Avenue near the entrance to Soule Park Golf Course. Site 3 was downstream of the Thacher Creek crossing of Ojai Avenue just south of the bridge. Site 4 is at the Reeves Creek crossing on McAndrew Road on the eastern (upstream) side of the bridge. Water quality data will be stored by the District for a period of at least 20 years from the date of sampling. Laboratory results were posted online within 1 month of receipt from the laboratory. Water quality data from certified laboratories were periodically uploaded to California Environmental Data Exchange Network and posted online on the District's website. Water quality data were entered and evaluated on a monthly basis or more frequently, as required. Monitoring results are shown in Tables 3.5-1 and 3.5-2.

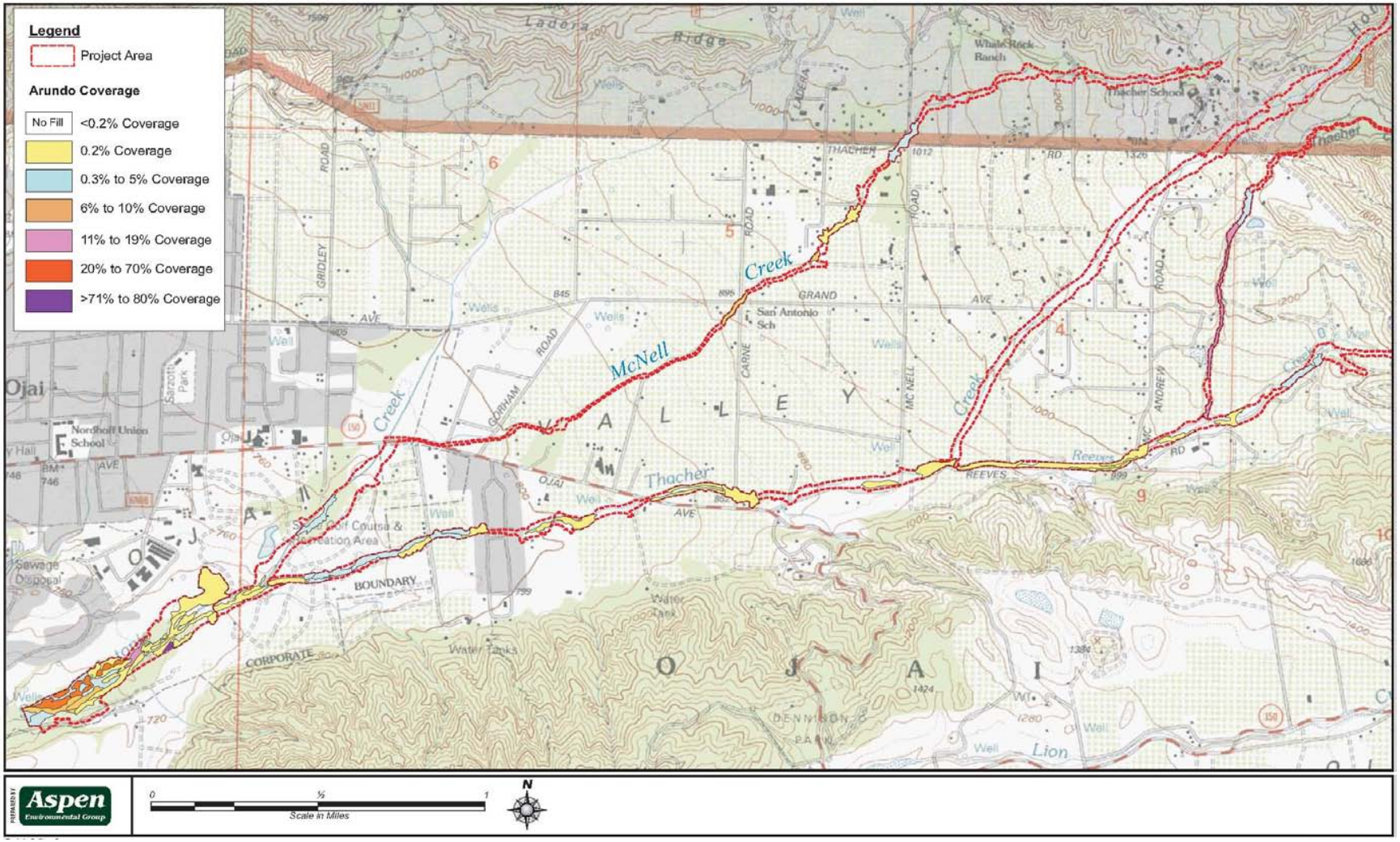


Figure 3.5-1 Giant Reed Percent Cover and Distribution

Source: District 2010c

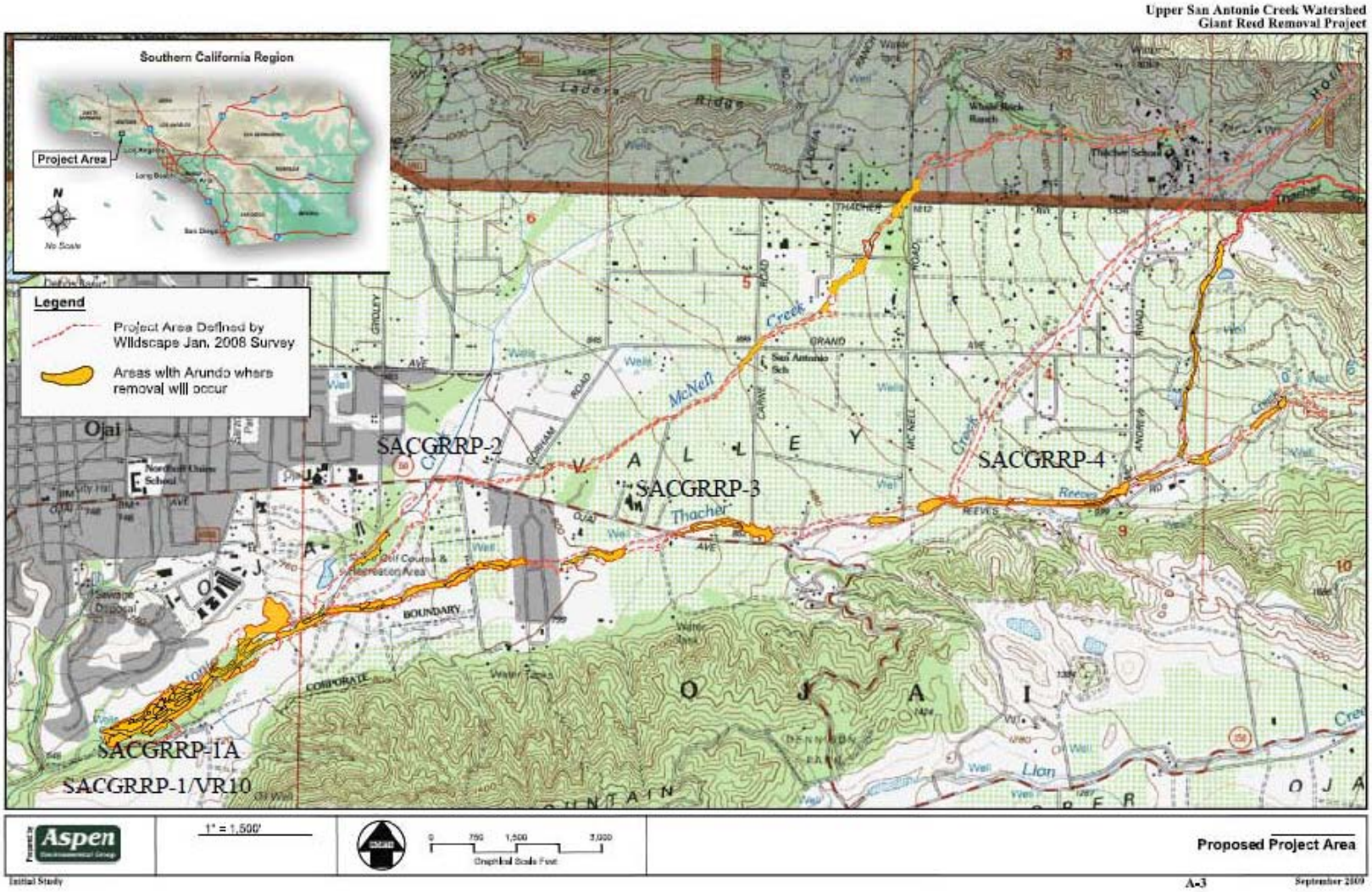


Figure 3.5-2 Project Area and Monitoring Sites

Source: District 2010c

Table 3.5-1 Routine Glyphosate Monitoring – Sites 1 to 4 and Soule Park

Sample Date	Organization	Site 1/VR10 (ug/l)	Site 1A (ug/l)	Site 2 (ug/l)	Site 3 (ug/l)	Site 4 (ug/l)	Soule Park (ug/l)
03/06/2010	Stream Team	ND	—	—	—	—	—
04/26/2010	VCWPD	ND	—	Dry	Dry	ND	—
05/03/2010	Stream Team	ND	—	—	—	—	—
06/07/2010	VCWPD	ND	—	Dry	Dry	Dry	—
06/09/2010	Stream Team	ND	—	—	—	—	—
06/30/2010	VCWPD	—	ND	Dry	Dry	Dry	—
07/14/2010	Stream Team	ND	—	—	—	—	—
08/04/2010	VCWPD	-	ND	Dry	Dry	Dry	—
08/09/2010	Stream Team	ND	—	—	—	—	—
08/30/2010	VCWPD	—	ND	Dry	Dry	Dry	—
09/15/2010	Stream Team	ND	—	—	—	—	—
09/29/2010	VCWPD	—	ND	Dry	Dry	Dry	—
10/02/2010	Stream Team	ND	-—	—	-	—	—
11/01/2010	VCWPD	—	ND	Dry	Dry	Dry	—
11/09/2010	Stream Team	ND	—	—	—	—	—

Source: District 2010e

Table 3.5-2 Special Testing – Site 1/1A

Sample Date	Organization	AMPA (ug/l)*	Glyphosate (ug/l)*	Glufosinate (ug/l)*
04/26/2010	VCWPD	0.03	ND	ND
12/20/2010	VCWPD	0.81	0.79	<0.02
04/26/2010	VCWPD	0.03	ND	ND

* The special testing method detection limit (MDL) for AMPA, glyphosate, and glufosinate is 0.02 ug/l. The MDL is the minimum concentration of a substance that can be identified, measured, and reported with a 99-percent confidence that the concentration is greater than zero.

ND = Not Detected

ug/l = micrograms per liter, equivalent to parts per billion

Dry = sampling could not occur because no water was present at the site

Source: District 2010e

Chapter 4

Water Demand and Water Budget

4.1 Introduction

This section provides a summary and analysis of water demand for the Ventura River watershed, which relies entirely on local water resources for water supply. Data collected from various previous investigations has been compiled and presented in a combined form to illustrate both the level of understanding of water demand and the types of data that will need to be addressed to improve the accuracy of a water budget for the watershed.

Wholesale and retailed water service within the watershed is provided by:

- Casitas (Municipal Water District) provides service within a 150-square mile area that includes the Ojai Valley and much of the lower Ventura River watershed. Casitas operates and maintains the Casitas Dam, Robles Diversion, and Robles-Casitas Canal (collectively referred to as the Ventura River Project) under contract with the U.S. Bureau of Reclamation to supply surface water from the Ventura River and Coyote Creek. Additionally, Casitas operates a single groundwater well in Mira Monte. Casitas provides water to retail customers, as well as several other public and private retail water operations.
- Golden State Water Company (Golden State) provides service to an area that is approximately the limits of the City of Ojai. Golden State relies on groundwater extractions from the Ojai Basin and supplements the groundwater supply with additional water from Casitas' service connections.
- Hermitage Mutual Water Company provides service to a limited area in the foothills north of the Ojai Valley. It relies on wells in the Ojai Basin and a supplemental connection to Casitas.
- Meiners Oaks Water District provides service in Meiners Oaks. It relies primarily on two wells in the Ventura River and has relied on Casitas only during infrequent system emergencies.
- Senior Canyon Mutual Water Company provides service in the east end of the Ojai Valley. It relies on three wells in the Ojai Basin and surface water diversions, with Casitas as a secondary source of water to buffer peak demands and as a drought contingency supply.
- Siete Robles Mutual Water Company services a single housing development located southeast of the City of Ojai. It relies on a well in the Ojai Basin and one service connection to Casitas that is used occasionally.
- Sisar Mutual Water Company provides service in the northeast area of the Upper Ojai Valley. It relies on groundwater wells and on a connection to Casitas as an emergency water source.
- Tico Mutual Water Company provides service in Mira Monte. It relies on one well in the Mira Monte area and one 2-inch service connection to Casitas as a backup supply.

- Ventura (City) provides service to the entire city and some adjacent unincorporated areas. Its water portfolio includes shallow wells in the Ventura River near Foster Park, rights to reclaim water from the OVSD Wastewater Treatment Plant, several connections to a Casitas pipeline, and groundwater sources from the east end of Ventura.
- Ventura River County Water District provides service to Casitas Springs, Rio Via, Monte Via and Oak View, and relies on four wells in the Ventura River and supplemental water from Casitas.

4.2 Water Demand

4.2.1 Municipal and Industrial (M&I) Demand

The overall M&I water usage (demand) for an average water year can be calculated from deliveries reported by Casitas along with the groundwater extractions for municipal and domestic uses in the Upper and Lower Ventura sub-basins, the Ojai Basin, and the Upper Ojai Basin, as provided in Table 4-1 below. These cumulative water deliveries are representative of the basin as a whole because Casitas provides water service to a large portion of the watershed, and the remaining areas receiving M&I supplies are supported by Golden State (City of Ojai) and the City of Ventura, and the various smaller water providers (which primarily rely on groundwater with supplemental supplies from Casitas).

Table 4-1 Estimated 2010 Municipal and Industrial Water Demand

Source/Location	Amount (AF)	Note
Casitas	9,674	Sum of 2010 urban water demand and sales to other retail agencies, not including City of Ventura[1]
Golden State	1,741	2010 (groundwater) demand, not including sales from Casitas[2]
Ventura (City)	3,085	Pro-rated share of 2010 Ventura City demand within watershed[3]
Upper and Lower Ventura Sub-Basins	8,657	Estimated annual domestic & municipal extractions, 1997-2007[4]
Upper Ojai Basin	11	Extractions in 2008 by Sisar Mutual Water Company[5]
Total	23,169	Total of all extractions within watershed for M&I use

Sources:

1: Casitas 2011, Tables 6 and 9, not including 300 AF of groundwater from Mira Monte well.

2: Kennedy/Jenks 2011c, Table 4-1, not including supplemental water delivered by Casitas.

3: Pro-rated estimate based on population residing within the Ventura River watershed. Total 2010 water demand in service area for the City of Ventura (including residential, commercial, industrial, institutional/government, landscape and other uses) is 16,983 AF (Kennedy/Jenks 2011a, Table 2-5). Population within the Ventura River watershed is estimated at 18,121 (for Ventura County census tracts 21.02, 22, 23 & 24, per census tract data from California Department of Finance 2011), which is 16 percent of total service area population (of 113,478, per Kennedy/Jenks 2011a, Table 2-1). Water demand for Petroleum Recovery Operations (of 368 AF) was added to the pro-rated total, as it is assumed that this demand occurs entirely within the watershed.

4: DBS&A 2010a, Tables 13 and 14.

5: Casitas, 2011, Table 8.

It should be noted that the available data does not allow development of an estimate for a consistent timeframe (as the estimate in Table 4-1 is primarily for 2010, except for groundwater extractions). Thus some variations in the estimate are likely due to annual variations in climatic conditions. In addition, the OBGMA assumes that all water extractions outside the Golden State service area are for irrigation use (as discussed below).

An alternate estimate of M&I demand could be generated to reflect the potential that some of the water extracted from the Ventura River is utilized outside the watershed (e.g., in areas located east of downtown Ventura). The City of Ventura reports 4,200 AF of extractions (in 2010) from the river (and associated basins) for M&I use. If the estimate of City's extractions were pro-rated, based on estimate of 16.0 percent of population that resides in the watershed (Table 4-1, Note #3), then total M&I water demand could be adjusted downward by approximately 3,228 AF, if that proportionate share of water was assumed to be utilized within the service area of the City of Ventura but outside the Ventura River Watershed.

4.2.2 Agricultural

Although extensive portions of the watershed are occupied by agricultural land uses, the water supply requirements for these lands is not well documented, as much of the agricultural uses are supported by groundwater, and pumping for that purpose is not reported outside the Ojai Basin.

Casitas reports:

> "[Casitas] provides water directly to 3,445 acres and supplements groundwater use on approximately 2,168 acres of irrigated crop lands. The total irrigated lands which are receiving [Casitas] water is 5,613 acres which is primarily avocado and citrus orchards, and a limited amount of flowers, strawberries, apples and walnuts. Agricultural water demand will fluctuate depending on weather conditions, but generally demands an annual average of two and a half acre-feet per acre for inland areas and two acre-feet per acre on the coast" (Casitas 2010).

For 2010, Casitas estimated agricultural water demand at 6,398 AF. Note however, this estimate does not account for groundwater extractions on the estimated 2,168 acres of agricultural lands for which Casitas provides supplemental water.

The Groundwater Budget and Approach to Groundwater Management Plan, Upper and Lower Ventura River Basin, provides an estimate of groundwater extractions for agricultural uses that overlay the upper and lower groundwater basins in the watershed, including those areas serviced by Casitas:

> "…agricultural extraction was estimated from existing SCAG land use data… and the locations of active agricultural wells within the Sub-basins... Those land use areas designated as irrigated agriculture or orchard/vineyard, for which active agricultural wells were either co-located or reasonably proximal, were assumed to provide all irrigation via groundwater extraction. These land use areas were then multiplied by water application rates for the land use types available from [the California Department of Water Resources]…" (DBS&A 2010a).

Using this methodology, DBS&A estimated agricultural water use at 2,420 AFY for an irrigated area of 1,429 acres (in the areas overlying the Upper and Lower Ventura sub-basins).

The OBGMA reports:

> "Beginning in 1993, the Ojai Basin Groundwater Management Agency has kept a record of reported groundwater extractions in the basin… [including] extractions by the Golden State Water Company for residences and businesses in the City of Ojai, primarily domestic… and extractions from private wells, primarily for irrigation use..." (OBGMA 2011).

For 2010, total groundwater extraction for irrigation use (which is herein assumed to be agricultural use) was 3,229 AFY, although the acreage of irrigated lands is not reported.

The Golden State Water Company, which serves the City of Ojai, does not identify any agricultural water use within their service area (Kennedy/Jenks 2011c). In addition, no agricultural water use estimates were available for the Upper Ojai Valley area.

The total estimated agricultural water demand for an average water year is summarized in Table 4-2.

Table 4-2 Estimated 2010 Agricultural Water Demand

Source/Location	Amount (AF)
Casitas	6,398[1]
Golden State	0
Ventura (City)	0
Upper and Lower Ventura Sub-Basins	2,420[2]
Ojai Basin	3,229[3]
Upper Ojai Basin	689[4]
Total	12,736

1: Casitas 2011

2: DBS&A 2010a

3: OBGMA 2011

4. DWR 2004, reduced by 11 AF to account for reported M&I use

4.2.3 Total Water Demand

Table 4-3 combines M&I and agricultural demand and provides an estimate of the total water demand within the Ventura River watershed.

Table 4-3 Estimated 2010 Total Water Demand

Source/Location	M&I Demand (AF)	Agricultural Demand (AF)
Casitas	9,674	6,398
Golden State	1,741	0
Ventura (City)	3,085	0
Upper and Lower Ventura Sub-Basins	8,657	2,420
Ojai Basin	0	3,229

Table 4-3 Estimated 2010 Total Water Demand

Source/Location	M&I Demand (AF)	Agricultural Demand (AF)
Upper Ojai Basin	11	689
Subtotals	23,169	12,736
Total Water Demand (AF)	35,905	

Sources: Tables 4-1 and 4-2

4.3 Water Budget

A water budget for the Ventura River watershed would sum all of the water inputs and outputs and permit the identification whether the net effect is a surplus or a deficit in water resources. To identify long-term trends, a long period of historical record (e.g., 20 to 30 years) would be needed, to account for changes in annual precipitation patterns, particularly to assess conditions during drought periods.

A comprehensive water budget could address whether the water resources in the Ventura River watershed are sufficient to meet total water demand (Table 4.3), particularly during drought conditions. If water demand exceeds available resources, then some sources would be expected to decline over time (e.g., groundwater levels).

Table 4.4 provides a watershed-wide water balance developed by Tetra Tech (Tetra Tech 2009a) for the purposes of calibrating the HSPF model. However, the input and output categories are very broad and don't provide an opportunity to corroborate these results with other data sources, many of which address portions of the watershed (e.g., the tributary area for Lake Casitas or the Ventura River groundwater sub-basins). For example, the average annual evaporation and rainfall loss in Lake Casitas is estimated at 2,630 AF (Casitas 2011b).

Table 4-4 Ventura River Watershed Water Balance

	Parameter	AFY1	Percent
Upland Balance			
Input	Precipitation	322,008	93%
	Irrigation	14,349	4%
	Change in storage	8,723	3%
	Total Input	345,080	
Output	Evapotranspiration	215,414	62%
	To stream	113,275	33%
	To deep groundwater	16,391	5%
	Total Output	345,080	
Waterbody Balance			
Input	Runoff	113,275	94%
	Diversions in	0	0%
	Upstream in	0	0%

Table 4-4 Ventura River Watershed Water Balance

	Parameter	AFY1	Percent
	Groundwater in	4,252	4%
	Point source	2,491	2%
	Net precipitation	198	0%
	Total Input	120,216	
Output	Downstream out	84,880	71%
	Diversions out	19,691	16%
	Stream to groundwater	7,375	6%
	Net reach and reservoir loss	8,270	7%
	Total Output	120,216	

1: The original source summed values for an 11-year period from 1997-2007, so those values have been averaged for a single year.

Source: Tetra Tech 2009a

DBS&A developed a groundwater budget model for the Upper and Lower Ventura sub-basins, which identified a potential surplus in the Upper Basin (Table 3.4-1) and a potential deficit in the Lower Basin (Table 3.4-2) for the period between 1997 and 2007. However, the lack of some groundwater data (e.g., water levels in the Lower Basin, outflows to the ocean, and extractions for agriculture) limits the applicability of the results for other purposes, such as a water budget.

The possible elements of a comprehensive water budget are listed in Table 4-5. For each element, a brief description is provided, along with an assessment of the availability of this information for the watershed.

Table 4.5 Key Elements of Water Budget

Inflows	
Surface Water	Groundwater
Total Precipitation Consists of rainfall measurements Data are widely available from rain gauge records	Inflow from Precipitation Consists of recharge to groundwater Estimates are widely available.
Surface Runoff Consists of surface flows in rivers and creeks Data are generally available from stream gage records, although not all records are complete.	Recharge from Irrigation Consists of the deep percolation of irrigation water from farmland and pastures Estimates are widely available, but rely on inadequate records for agricultural irrigation amounts
M&I Return Flow Consists of flows from wastewater treatment plants and miscellaneous runoff (e.g., urban runoff, including flows from over-irrigation of landscaped areas). Data are available for wastewater discharge, but other flows are not generally available.	Inflow from Rivers, Lakes & Septic Systems Consists of the deep percolation of water from rivers, lakes, and septic system return flows. Estimates are generally available for Lake Casitas, but only marginally available for the Ventura River, due to incomplete understanding of subsurface geology. Estimates are generally available for septic systems.

Table 4.5 Key Elements of Water Budget

Inflows	
Surface Water	Groundwater
Groundwater Accretions Consists of surface water in streams and creeks that infiltrates into groundwater basins. Estimates are generally available.	Surface Water Accretions Consists of inflows to creeks and rivers from subsurface groundwater, via seeps, springs, and baseflow. Estimates are generally available, but limited by incomplete understanding of subsurface geology
Outflows	
Agricultural Diversions Consists of surface water that is diverted to irrigate pastures and farmland. Data are not available, but estimates can be developed based on crop usage information	Agricultural Pumping Consists of water used for irrigation of farmland and pastures. Aggregate data are available for the Ojai basin, but unavailable for other areas. Estimates generally available based on crop types and climatic data.
M&I Diversions Consists of surface water diversions by water districts Data are widely available from Casitas and City of Ventura	M&I Pumping Consists of groundwater pumping by water suppliers. Data are widely available for public agencies, but generally not available for private water companies.
Evapotranspiration Consists of the sum of evaporation and transpiration by plants Estimates are available based on data provided by D, but relies on aggregating vegetation types into broad categories. More precise estimates are widely available for crop types.	Evapotranspiration-Riparian Consists of the transpiration by plants that can access subsurface water, typically along creeks and rivers. Estimates are generally available, but rely on broad assessments of vegetative cover.
Outflow to Ocean Consists of runoff from the Ventura River at the estuary. Data are generally available based on a stream gage near Foster Park, but the record is not complete because of occasional storm damage to the gauge.	Outflow to Ocean Consists of subsurface flows at the Ventura River Estuary. Estimates are generally available, but based on incomplete understanding of subsurface hydrology.

Notes:

Widely available: data or estimate is available from a variety of accessible sources

Generally available: some data or estimates are available, but not for the entire watershed

Not available: data has not been collected or is not reported.

Sources: Tetra Tech 2009a, 2009b, 2010; DSB&A2010, and Dunne and Leopold 1978

4.4 Safe Yield

The concept of safe yield has been applied to reservoirs and groundwater basins, and traditionally has been interpreted as the amount of water than can be extracted without causing a long term decline in water levels and/or damage to natural or human uses. The concept of safe yield has been widely debated, due to the complex variables involved and the inability to adequately account for all potential losses. As a result, discussions of water yield, particularly for watersheds, more commonly focus on the term "sustainable yield" in recognition of a long term goal to ensure that water extractions can be sustained over time, and thus account for variations in water availability related to changes in precipitation patterns.

No assessments of safe or sustainable yield for the entire watershed have been prepared, and given the data limitations related to development of a water budget, a meaningful estimate cannot currently be prepared without improved data for several components of the watershed

system. Identification of those limitations and recommendations to address them could facilitate development of an estimate of the safe, or sustainable yield; these are provided in Chapter 6.

In 2004, Casitas prepared a report on Water Supply and Use Status (Casitas 2004), which provided an estimate of safe yield for Lake Casitas (including surface water diversions and groundwater extractions from a single well in Mira Monte), based on a period of record from 1945 to 1980, including a critical drought period from 1945 to 1965. The calculation of safe yield was described as:

> "…based on the storage volume of Lake Casitas (the aquifer), the surface water and groundwater supply managed by Casitas, and the length of time that the water supply needs to last (i.e., the longest drought on record). The safe yield is an interpolated value that is held to be consistent of the period of the critical drought, bring the level of storage to the desired minimum volume."

The report concluded that during the critical drought period, the safe yield was 20,840 AF, assuming no storage capacity at Matilija Dam and the ongoing implementation of operating conditions imposed by the Biological Opinion for diversions at the Robles Fish Passage Facility. Casitas' 2010 UWMP uses that estimate (parsed as 20,540 AF for the lake and 300 AF for the single groundwater well) as the water supply for the district.

Daniel B. Stephens & Associates recently completed the Ojai Basin Groundwater Model Report (DBS&A 2011) provides a Groundwater Mass Balance analysis that estimated average groundwater inputs (including precipitation, irrigation, septic systems, and spreading grounds) at 6,780 AFY and average groundwater outputs (including pumping wells, discharge to streams, evapotranspiration, and outflow to bedrock) at 6,816 AFY), which would result in a net change in storage of approximately -30 AFY.

The estimates of the safe yield for Casitas' service area and groundwater mass balance in the Ojai Basin could be a starting point for the calculation of the entire watershed's safe or sustainable yield, if sufficient information can be identified for the other water resources in the watershed.

Chapter 5

Review of Applicable Watershed Management Plans

5.1 Introduction

To provide relevant information to inform development of a comprehensive and integrated Ventura River Watershed Management Plan, this Report includes a summary of other watershed management plans that may be applicable to the Ventura River watershed (based on physical characteristics and location), the identification of lessons learned from those plans, and recommendations that can inform development of a watershed management plan for the Ventura River.

5.2 Identification of Applicable Watershed Plans

In the past decade, one watershed plan and several related studies have been developed within Ventura County. These include the ongoing watershed management effort in Calleguas Creek and various studies related to the management of the Santa Clara River, although those efforts are more focused on the river corridor itself.

Within Los Angeles County, watershed plans and studies have been prepared for Arroyo Seco, Ballona Creek, Compton Creek, Coyote Creek, Dominguez Channel, Rio Hondo, Tujunga Wash, and the Upper San Gabriel River. In addition, a watershed and open space plan was prepared for the Los Angeles and San Gabriel rivers.

Several watershed planning studies also have been conducted in Santa Barbara County, focusing on Carpinteria Creek, Mission Creek (including Arroyo Burro and Sycamore creeks), Rincon Creek, and San Jose Creek, but none of these has resulted in the development of complete watershed plans.

To identify which of these plans or studies are applicable to development of a management plan for the Ventura River watershed, several factors were considered, including location (e.g., within or outside Ventura County); importance of local water supplies (because the Ventura River watershed is entirely dependent on local supplies); major focus on water quality (because both surface and groundwater quality are key issues in the Ventura River watershed); and the extent of involvement of a local watershed group in development of the plan (because it is assumed that the Ventura River Watershed Council will participate in development of a watershed plan).

Based on these factors, three applicable watershed plans were identified:

- Ballona Creek Watershed Management Plan (LACDPW 2004), because surface water quality was a major focus of the plan, and the stakeholder-led Ballona Creek Watershed Task Force guided development of the plan.

- Calleguas Creek Watershed Management Plan (Calleguas Steering Committee 2004), because Calleguas Creek is located in Ventura County, surface water quality is a key issue, and stakeholders were involved in development of the plan.
- Tujunga-Pacoima Watershed Management Plan (The River Project 2008), because this plan is focused on enhancing water supply and improving both surface water and groundwater quality.

5.3 Review of Applicable Watershed Plans

5.3.1 Ballona Creek

5.3.1.1 Purpose

The Ballona Creek Watershed Task Force, composed of stakeholders, adopted the following goal:

> "To develop and facilitate implementation of a Comprehensive Watershed Management Plan for the Ballona Creek Watershed that sets forth pollution control and habitat restoration actions to achieve ecological health."

Thus, this watershed plan is primary focused on the improvement of surface water quality and the enhancement and restoration of habitat.

5.3.1.2 Organization and Content

The plan is organized as follows:

- Executive Summary, which provides a useful overview that can be quickly read and was the basis for a brochure developed after the plan was adopted.
- Chapter 1, Background, which gives an overview of the historical and planning context relevant to plan development.
- Chapter 2, Existing Conditions, which includes a concise summary of existing conditions in the watershed, providing the reader with the context for the subsequent goals and objectives.
- Chapter 3, Goals and Objectives, which includes a list of "issues of interest" that were identified by the task force, and those issues are subsequently reflected in list of "watershed problems" that could be addressed by the plan. The inclusion of the issues and problems in this section provide the reader with a clear understanding of how the Goals and Objectives were derived.
- Chapter 4, Methods and Mechanisms, which includes lists of priority actions, BMPs, and existing and pending projects. The plan also includes 10 demonstration projects that provide multi-purpose examples of projects that would improve surface water quality, enhance groundwater recharge, and provide pockets of native habitat.
- Chapter 5, Community-Based Monitoring, which describes how existing monitoring efforts could be integrated to form a Community-Based Monitoring program (primary for surface water quality) that would assure consistency between both public and private (e.g., non-governmental organizations) monitoring efforts. This chapter includes an analysis of data gaps and provides specific recommendations to address those gaps.

- Chapter 6, Opportunities for Stakeholder Involvement and Funding, which provides a specific list of actions that should be undertaken by federal, state, and local agencies; non-governmental organizations; and individuals. This chapter also discusses funding opportunities, including opportunities to fund the demonstration projects.
- Chapter 7, Next Steps, which identifies next steps for plan implementation, organized according to whether they relate to water, land, and planning.

5.3.1.3 Lessons Learned

The Ballona Creek Watershed Management Plan was completed in 2004 and is the earliest of the three watershed plans identified as applicable to the Ventura River watershed. Development of the plan was funded by a Proposition 13 grant from the State of California, which was administered by the County of Los Angeles. Development of the plan was led by a steering committee, although major elements of the plan (such as the goals and objectives) were derived from a consensus of the stakeholders that were members of the task force. Following adoption of the plan, a watershed coordinator was hired to foster its implementation.

Although the Ballona Creek plan was a broad attempt to address the stakeholder-identified issues and forge a comprehensive vision for the future of the watershed, few of the actions and projects identified in the plan have been implemented. With a wide range of policy recommendations, the plan did not adequately anticipate the issues required to work across jurisdictional boundaries. The demonstration projects were proposed to be located on various public sites, but the entities responsible for those sites were not involved in their selection or conceptual planning, and thus, there was little impetus for project implementation. Because no single entity is responsible for implementation of the plan, many of the recommended actions have not been implemented, or have been implemented in other forums (e.g., TMDL implementation is discussed via a process established by the Regional Water Quality Control Board). The watershed coordinator hired after adoption of the plan did implement some of the plan recommendations, but lack of funding limited the scope of those actions. Most of the projects that have been implemented in the watershed were either driven by regulatory requirements (e.g., TMDLs), or have been relatively small-scale projects that have not generated much public awareness. The Ballona Creek Watershed Task Force recently began meeting again recently (after a hiatus). Many of the watershed-related activities have been subsumed by a non-profit organization (Ballona Creek Renaissance), which is focused on restoration activities along the creek and educating the public about watershed-friendly landscape practices.

5.3.2 Calleguas Creek

Stakeholders first organized to discuss watershed conditions in 1996, and considerable effort was expended to characterize watershed conditions and to evaluate options to address the identified problems. The Phase I Watershed Plan was completed in 2004. An Addendum was completed in 2006, thus creating the Phase II plan, which was proposed to serve as an Integrated Regional Water Management Plan (IRWMP) until that effort was combined with the county-wide IRWMP effort lead by the Watersheds Coalition of Ventura County. Although the watershed plan was completed almost 7 years ago, numerous planning activities are still underway, generally focused on the issues of surface water quality (and TMDL compliance) and flooding and erosion on specific reaches of the creek.

5.3.2.1 Purpose

As described in the watershed plan:

> "The Calleguas Creek Watershed Management Plan is a comprehensive, stakeholder driven effort to work cooperatively and responsibly to develop a comprehensive plan that would guarantee the long term health of natural resources in the watershed. In the first phase, this included development of action recommendations and technical tools to address coordinated environmental and resource management by public agencies and private sector participants. [Phase II focused] on how responsible parties in the watershed can act collectively to address significant water quality improvements and meet the mandatory standards of the federal Clean Water Act and California Porter-Cologne Act."

The objectives of the Phase II Management Strategy (which is distinct from Phase II of the Watershed Management Plan) are to set guiding principles for future stream protection by:

- Identifying and generating a cost-effective, economical, and environmentally friendly programmatic solution.
- Identifying and generating a comprehensive system of concepts and scenarios that will address the flooding and sedimentation issues.
- Promoting a more natural stream condition.
- Providing multiple benefits and opportunities.

5.3.2.2 Organization and Content

The watershed plan is organized as follows:

- Chapter 1, Introduction, which provides a brief summary of the plan contents.
- Chapter 2, Action Recommendations, which includes actions developed by watershed management plan subcommittees that focus on water resources and water quality, habitat and recreation, flood protection and sediment management, agriculture, land use, and public outreach and education.
- Chapter 3, Past Work Products, which summarizes the results of various studies that were conducted prior to development of the watershed plan and include the goals adopted by several of the subcommittees.
- Chapter 4, Watershed Overview, which summarizes of the physical, hydrologic, and biological characteristics of the watershed and synthesis much of the work completed in the past work products described in Chapter 3.
- Chapter 5, Watershed Definitions, which provides a primer on watershed planning and the concepts used in this form of integrated planning.

5.3.2.3 Lessons Learned

The watershed plan reflects the substantive body of work that was completed prior to development of the plan; however, the plan organization could be viewed as somewhat

backwards. What could be considered introductory material (e.g., watershed definitions) appears in the last chapter, the overview of the watershed is in Chapter 4, and the summary of previous work in provided in Chapter 3. Chapter 2 presents a detailed list of actions, but other than acknowledging that those actions were generated by various subcommittees, it is not clear to the reader how those groups formulated those actions.

Although a full range of issues is addressed in the plan, including habitat, recreation, and land use, the emphasis of the recommended actions (seven are related to flooding and stormwater runoff and six are related to TMDLs) suggests that that flooding and surface water quality are the primary emphasis. As noted above, the primary emphasis of Phase II was compliance with federal water quality regulations (e.g., TMDLs), and most of the planning activities that have occurred since completion of the plan relate to TMDL compliance and protection from flooding and erosion. Since many of the plan participants are focused on addressing those issues, it is possible to conclude that the plan was focused on the key issues of many plan participants. The ongoing activity related to those issues suggests that many of those same participants have continued to support implementation of the actions and strategies identified in the plan.

5.3.3 Tujunga-Pacoima

5.3.3.1 Purpose

The watershed plan identifies its purpose as follows:

> "This plan is intended as a resource for anyone interested in working towards a sustainable future in this region. It aims to educate and inspire and to provide local advocates, urban planners, agencies, elected officials, policy-makers, individual property owners, residents, and youth a road map and a toolkit to do the following:
>
> - Develop a more holistic understanding of the our local environment.
> - Facilitate widespread watershed awareness and education.
> - Empower the community to be directly engaged in the decision making process.
> - Catalyze actions to sustain support and implementation of the Plan over the long term.
> - Improve coordination and integration among agencies.
> - Enhance communication and collaboration between agencies and other stakeholders.
> - Bring together key agencies with other stakeholders to plan the financing and implementation of large-scale watershed retrofitting."

5.3.3.2 Organization and Content

The watershed plan is organized as follows:

- Chapter 1, Introduction, which includes a watershed primer ("Watersheds 101"), a discussion of why traditional land use planning models need to be modified, and a description of how the plan was developed and what the plan is intended for (which is summarized as the purpose above).

- Chapter 2, Watershed Conditions, which provides a summary of the existing conditions in the watershed and is based on a much more detailed companion report entitled "State of the Tujunga."
- Chapter 3, Goals and Objectives, which 3 identifies the goals and objectives as having been generated through a collaborative stakeholder process.
- Chapter 4, Projects, which describes the process used to identify a total of 216 projects and subsequently select 37 projects as a "preferred scenario" based on an analysis of the projected project benefits. Each of the preferred projects is described on a two-page fact sheet.
- Chapter 5, Quantifying Benefits, which describes the modeling effort utilized to quantify the benefits of projects on a watershed scale (e.g., the net effect on surface water quality) and the limitations in that approach.
- Chapter 6, Studies and Programs, which identifies a series of studies to address data gaps that were identified during development of the plan and various programs that could expand watershed awareness and provide specific tools that could enhance implementation of watershed concepts.
- Chapter 7, Policy Recommendations, which address land use, water supply, stormwater quality, public safety, parks and open space, habitat and native vegetation, coordination and planning, and funding.
- Chapter 8, Next Steps, which provides specific recommendations for individuals, Los Angeles City Neighborhood Councils, local entities, and state and federal agencies.

5.3.3.3 Lessons Learned

The Tujunga-Pacoima Watershed Management Plan was funded by a grant from the CALFED Watershed Program to The River Project, a non-profit organization. It also relied upon in-kind contributions from various groups and companies to extend the scope and content of the plan. Development of the plan was supported by various stakeholder-focused activities, including a Tujunga "Watershed U" (supported by the University of California Cooperative Extension). The development and subsequent implementation of the plan was not supported by a watershed coordinator. Since completion of the plan, the stakeholder group involved in the plan development has not continued to meet.

As noted in the introduction, the plan is focused on the education of individuals, organizations, neighborhood councils, agency staff, and policy makers. The content of the document included sufficient background information to be accessible to readers with limited understanding of watershed concepts. Several of the projects identified in the plan have been implemented, which suggests that the process of vetting projects to identify those with substantive benefits helped to identify projects that are more likely to be pursued. The discussion of policy recommendations was far reaching, but few, if any, of the policy recommendations have been implemented. This is similar to the experience with Ballona Creek, where agencies or institutions have little incentive and no mandate to consider these policy recommendations. The inclusion of specific recommendations for watershed residents does provide a clear opportunity for individual actions that can improve watershed health.

5.4 Recommendations for Ventura River Watershed Management Plan

Although the scope and content of a watershed management plan for the Ventura River have yet to be articulated, based on a review of the applicable watershed plans, the following recommendations may be informative.

- **Identify the intended audience and provide appropriate content**. If the plan is intended to educate watershed residents, then consider inclusion of information that explains the concepts inherent in watershed planning, and move technical information to an appendix (to demonstrate the plan's technical competence) and provide a summary of that information in the body of the plan.
- **Engage watershed stakeholders**. An active and engaged group of participants may enhance the potential for implementation of plan elements. Because so many participants in the Calleguas Creek watershed have a clear interest in resolution of the identified water quality and flood protection issues, many of those entities have remained engaged in ongoing planning activities. Thus, the recommendation is to focus the Ventura River Watershed Plan on those issues that will keep stakeholders engaged over the long term.
- **Clearly define and state the plan's goals and objectives**. The clarity of goals and objectives in the reviewed watershed plans varied, but those with clearly defined goals and objectives make it easier for the reader to understand the intent of the plan. It would also be helpful to provide sufficient information to make it clear how the goals and objectives were identified.
- **Focus the scope of the plan.** The scope of the applicable watershed plans varied considerably, with Calleguas focused most specifically and Tujunga the broadest. Although watershed planning inherently suggests adopting a holistic approach to land, water, and natural resources, addressing all of those issues equally could result in a plan that is too unfocused. It is recommended that once the goals and objectives are identified, to assess which of those issues are already being addressed by existing programs and which are not being addressed. For issues already being addressed, identify how those programs can be enhanced. For issues that are not being addressed, identify solutions and make specific recommendations on how to implement those solutions.
- **Focus on issues where stakeholders can make a meaningful difference.** The inclusion of land use policy recommendations in the Ballona and Tujunga plans has resulted in little change because the responsible institutions have no mandate to consider the changes and little incentive to change. Thus, the recommendation is to limit the scope of policy recommendations if there is little chance to overcome institutional resistance.
- **Work with regulatory programs.** Some existing regulatory programs (e.g., TMDLs) may benefit from enhancements that make them more efficient and effective. The watershed plan should consider how existing regulatory programs are structured and make recommendations that demonstrate that understanding. For example, instead of suggesting a new process, it is suggested that recommendations focus on changes that can be accommodated within existing structures and programs.
- **Prioritize projects that can meet the plan's objectives.** If projects are included, it is recommended that a clear and open decision-making process be used to identify the projects that respond most directly to the plan's goals and objectives (e.g., high-priority or preferred

projects). It is also recommended to avoid inclusion of projects that are located on land that is not controlled by the project proponents.

- **Identify mechanisms and a process to gauge progress towards plan implementation.** Measuring the success of the applicable watershed plans was difficult, either because no clear monitoring mechanisms were identified or no such monitoring is ongoing. Providing the ability to measure success towards implementation can foster a sense of accomplishment and enhance the potential to keep stakeholders engaged.

Chapter 6

Data Gaps

The reports prepared for the V-1 projects described several data gaps that were identified in the development of the HSPF runoff model for the watershed and the groundwater budget for the Ventura River sub-basins. In preparation of this Report, several other data gaps were identified. This section summarizes the data gaps and recommendations to address them.

6.1 HSPF Model

6.1.1 Study Limitations

The Calibration and Validation Baseline Report (Tetra Tech 2009a) identified the following areas where the HSPF model might be further improved:

- There is uncertainty regarding the model's ability to accurately predict high flow peaks at the North Fork Matilija and Happy Valley Drain stream gages. Some improvement could likely be attained by refining the channel hydraulic representation through development of HEC-RAS models for these subwatersheds, which would require assembly of additional information on channel dimensions and structures. Note that as part of the Federal Emergency Management Agency (FEMA) Cooperating Technical Partners (CTP) Program for Happy Valley Drain, a HEC-RAS model was developed and is available for further refinement of HSPF in this area (District 2011b).
- Simulation of event peaks in Happy Valley Drain also was identified as being particularly problematic. The hydrology in this area is complex, including a diversion and a concrete channel. The report noted that detailed survey and small scale modeling of this area might reveal ways in which the model representation could be improved. This also was done as part of the FEMA CTP for Happy Valley Drain.
- Model fit to the Santa Ana and Coyote Creek gages is uncertain due to the lack of information on gage accuracy and bias. New rating tables have apparently not been developed for these gages in a number of years, and adjustments are likely needed to reflect changes in channel dimensions. Measurements to develop a current-day rating curve would assist in interpretation of records from earlier in this decade.
- As noted above, the quality of gage records for Coyote Creek and Santa Ana Creek is uncertain. These gages are useful for providing a broad basis to evaluate model performance. Tetra Tech suggests that field measurements be made on a regular schedule (at least annually) to provide a basis for calibrating and adjusting the Coyote Creek and Santa Ana Creek rating tables.
- No current gauging exists in the southernmost portion of the watershed, downstream of Foster Park. As a result, this portion of the model cannot be directly calibrated. Tetra Tech suggests that a mainstem gage should be installed at an appropriate location near the outlet of the Ventura River. In addition, the Canada Larga peak flow gage should be operated to provide continuous flow records.

- The present-day precipitation monitoring network appears to provide generally good coverage of the watershed. However, quality assurance can likely be improved for the high elevation ALERT gages. In addition, there are fundamental difficulties in extrapolating from point rainfall measurements to total areal precipitation, particularly in regions of high relief. There is a potential to improve total rainfall estimates through use of integrative techniques, such as Doppler radar interpretation.
- Evapotranspiration is a major part of the overall water balance, and is, of necessity, estimated from a small number of stations (many of which report only monthly totals) for the calibration and validation periods. The recently activated California Irrigation Management System (CIMIS) stations within the watershed provide an opportunity to develop better estimates of potential evapotranspiration in the future. Use of these stations would also provide better estimates of irrigation demand.

6.1.2 Data Gaps and Recommendations

The Calibration and Validation Baseline Report (Tetra Tech 2009a) made the following recommendations for improving data collection for future maintenance and refinement of the HSPF model; in addition, there are a number of research-oriented issues that might lead to significant improvements in the model, but could not be addressed within the current scope:

- The most significant limitation on simulation of the water balance is the lack of a detailed groundwater model of the [Ventura River] basins. As described in the report, there are portions of the stream network that both lose to and gain from groundwater. Pumping in the alluvial aquifers also provides a significant influence on low flows in San Antonio Creek and portions of the Ventura River mainstem. Ideally, a dynamic groundwater flow model (e.g., MODFLOW) would be developed and could be linked to provide the reach losses and deep groundwater discharge time series to the HSPF model. Developing such a model represents a considerable effort. In the absence of funding to develop a dynamic model, a simpler mass balance accounting of inputs and outputs to the alluvial aquifers would also be useful for constraining and improving the surface water model.
- During model calibration it was necessary to reduce the default assumptions of irrigation application rates. This should be investigated further, starting with a survey to better determine the extent of irrigated lands and actual irrigation rates. As much of the irrigation supply in the basin comes from groundwater, this could best be done in conjunction with development of a groundwater model or mass balance accounting.
- As part of the current work, a method was developed to account for the potential effects of high sediment concentrations on runoff volumes and flow values using a sediment bulking approach. The validity of this method has not been tested in the Ventura River watershed. Further investigations and fine-tuning of the sediment bulking approach could be pursued if and when data are available to document extremely high sediment concentrations during specific peak runoff events.
- The current work also developed and incorporated a method to account for the hydrologic effects of severe wildfires, which reduce interception, infiltration, and evapotranspiration, leading to increases in both high flows and low flows. These effects were assumed to persist for two years after a major fire. The method appears to perform adequately in general, in particular providing an improved fit to observed flows following the 1979 and 1985 fires.

However, some of the gage data (e.g., North Fork Matilija) suggest that the fire impacts persist for somewhat longer than two years. Some adjustments to the approach – in particular the period of application – may thus be warranted.

6.2 Groundwater Budget Data Gaps and Recommendations

DBS&A (2010a) identified several limitations and data gaps for the groundwater budget developed for the Upper and Lower Ventura River basins. These are summarized in Table 6-1, along with their recommendations.

Table 6-1 Groundwater Data Gaps and Recommendations

Data Gap	Recommendation
The delineation of the groundwater sub-basins is not consistent among various reports, including DWR Bulletin 118 (DWR 2003, as cited in DBS&A 2010a); the District's annual groundwater reports; and previous modeling reports for the Ventura River watershed (Tetra Tech 2009a).	Determine a unified delineation of the sub-basins based on geologic maps of the extent of alluvium (e.g., Appendix A, Plates 1 and 2 of DBS&A 2010a) along the Ventura River and associated creeks.
Several calculations present in DBS&A 2010a rely on reported results of the HSPF model. As discussed in the Calibration and Validation Baseline Report (Tetra Tech 2009a), the Ventura River Watershed Hydrology Model is prone to uncertainty stemming from assumptions in the mathematical formulation, data uncertainty, and parameter specifications.	Following any revision to the Ventura River Watershed Hydrology Model that reduce model uncertainty, revise the groundwater budgets presented in DBS&A 2010a to reflect those changes.
Uncertainty with the surface water hydrology model can be reduced via development of a groundwater model for the (Ventura River) sub-basins and coupling of the groundwater and surface water models.	Develop a groundwater flow model of the sub-basins and couple the groundwater and surface water models. Development and application of a calibrated groundwater model could also be used to reduce uncertainty with estimation of the groundwater budget within the sub-basins.
The approach used by DBS&A (2010a) for estimation of infiltration from precipitation relies on the Maxey-Eakin method, which is the most often used empirical method for this purpose in the semiarid regions of the southwest. However, this approach has not been field-validated within the sub-basins and does not account for area-specific factors that influence recharge rates, such as soil type and slope.	Output from the Ventura River Watershed Hydrology Model be should be generated that is specific to areas within the sub-basins and that these data be used to reduce uncertainty associated with infiltration from precipitation. Additionally, data from the model could be used to reduce uncertainty with estimation of surface water recharge to groundwater.
The time period used by DBS&A (2010a) is WYs 1997 to 2007, to be consistent with the Ventura River Watershed Hydrology Model and because this period is generally representative of conditions over the last several decades.	Selection of a different time period would result in a different estimated groundwater budget. For instance, a groundwater budget calculated during a period of relatively low precipitation would result in a more negative groundwater budget. Additionally, the decrease in municipal extractions by the City of Ventura since 2005 would result in a more positive groundwater budget for the Upper Sub-Basin.
Estimates of groundwater inflow from the alluvial aquifer are prone to uncertainty due to a lack of hydrogeologic data regarding the bedrock formations. Perhaps most significantly, nested groundwater wells are not present for accurate calculation of a vertical hydraulic gradient. The geologic structure of the bedrock also has not been accounted for in the groundwater budget developed by DBS&A (2010a) because DBS&A has not identified any specific data regarding the influence of geologic structure on groundwater flow in this area.	Install nested groundwater monitoring wells or piezometers in the area of the sub-basins that are screened in both the alluvium and the bedrock formations. These wells maybe used to estimate vertical hydraulic gradients and estimate additional hydrogeologic data.
Groundwater flow calculations using Darcy's Law are dependent on estimated values of hydraulic connectivity, hydraulic gradient, and aquifer cross-sectional area. Resulting uncertainty in these calculations may be significant, particularly for the Lower Sub-Basin, where groundwater discharge to the ocean is a primary component of the groundwater budget.	Obtain additional local measurements of hydraulic conductivity via aquifer tests or other methods. Additionally, development of a calibrated groundwater model, as discussed above, could help reduce uncertainty with groundwater flow calculations.

Table 6-1 Groundwater Data Gaps and Recommendations

Data Gap	Recommendation
Because extraction data from agricultural wells within the sub-basins are not reported to a public agency and are, therefore, not available, agricultural extraction was estimated based on co-location of active wells and agricultural land uses. Alternative methods were also used based on extraction rates per well in the adjacent Ojai Basin and Casitas water delivery trends.	Obtain agricultural extractions from individual well owners within the sub-basins and invite well owners to participate in a groundwater monitoring program.
Groundwater extraction rates associated with oil production or other uses in the Lower Sub-Basin are not currently reported to a public agency and are, therefore, not available.	Encourage well owner participation to obtain extraction rates from wells associated with oil production in the Lower Sub-Basin.
The net groundwater/surface water balances presented for each of the sub-basins rely on estimates of surface water inputs and outputs for sections of the Ventura River watershed that contain the sub-basins.	Obtain output from the Ventura River Watershed Hydrology Model that is specific to model areas within the sub-basins that contain surface water bodies. With model output data specific to these specific reaches, uncertainty of the surface water/groundwater balance will be reduced. Install additional surface water gages along San Antonio Creek within the area of the sub-basins and upstream (including the boundary between the Ventura River Basin and Ojai Basin) in order to better quantify groundwater/surface water interactions along that reach.
The estimated annual groundwater budget cannot be compared to measured changes in groundwater storage, due to a lack of monitoring wells within the sub-basins. There are currently no Ventura County-monitored water levels within the Lower Sub-Basin for comparison to the budget (District 2009, as cited in DBS&A 2010a).	Identify several wells within the Lower Sub-Basin for inclusion in a groundwater level and groundwater quality monitoring program, including abandoned wells. Perform an assessment of the change in groundwater storage for comparison to the budget, as measured from monitoring of groundwater levels.

Source: DBS&A, 2010a

6.3 Other Data Gaps and Recommendations

The discussion of the conceptual elements of a water budget (summarized in Table 4-5) identified various data gaps, many of which are addressed above for the HSPF model and the groundwater budget. However, three additional gaps have been identified:

- Aggregate pumping data for agriculture is reported for the Ojai Basin, but is not available for the Ventura River sub-basins and the Upper Ojai area. However, data recently collected by OBGMA and the Fox Canyon Groundwater Management Agency for agricultural uses that rely on groundwater can be used to provide estimates of crop use that could be applied to agricultural areas within the watershed.
- In addition to the lack of a groundwater model on the Ventura River, a model for the Ojai Basin has just recently been developed, but no model exists for the Upper Ojai basin. Development of models for groundwater basins (and linking them to the HSPF surface water model) would improve the accuracy of the model and enhance understanding of groundwater use and trends throughout the watershed.
- During compilation of habitat BMPs in Chapter 7 (below), it was noted that limited sources of information are available on habitat within the watershed, most notably for terrestrial habitat. Relevant information on aquatic habitat is available from the Matilija Dam Ecosystem Restoration Feasibility Study. Other sources do provide relevant information on terrestrial habitat, but not at the scale of the watershed, such as the Los Padres National Forest Management Plan.

Chapter 7

Applicable Best Management Practices

7.1 Introduction

Development of a watershed management plan could be informed by the identification of best management practices (BMPs) that can be implemented to improve water supply, water quality, and habitat. This chapter provides summary of BMPs that are applicable to the watershed and may be useful in development of a watershed plan.

7.2 Water Quality

7.2.1 County of Ventura Technical Guidance Manual for Stormwater Quality Measures

Although many sources identify BMPs to enhance surface water quality, a relevant source for the Ventura River Watershed is provided by the Ventura County Technical Guidance Manual for Stormwater Quality Measures (Larry Walker Associates/Geosyntec Consultants 2011) developed to meet the Planning and Land Development requirements contained in Part 4, Section E of the Los Angeles Regional Water Quality Control Board's municipal separate storm sewer system (MS4) permit (Order 09-0057) for new development and redevelopment projects.

The goal of the Planning and Land Development Program is to minimize runoff pollution typically caused by land development and protect the beneficial uses of receiving waters by employing a sensible combination of:

- Site Design Principles and Techniques.
- Source Control Measures.
- Low Impact Development (LID) BMPs.
- Treatment Control Measures.

7.2.1.1 Site Design Principles and Techniques

Site Design Principles and Techniques integrate stormwater management throughout the site and emphasize conservation and use of existing site features to reduce the amount of runoff and pollutant loading generated from a project site. These principles and techniques are organized around five main concepts: 1) protect and restore natural areas; 2) minimize land disturbance; 3) minimize impervious cover; 4) apply LID BMPs at the watershed and site scale; and 5) implement integrated water resource management practices.

Protect and Restore Natural Areas

Each project site possesses unique topographic, hydrologic and vegetative features, some of which are more suitable for development than others. Sensitive areas should be protected and/or restored, including streams and their buffers, floodplains, wetlands, steep slopes, and high

permeability soils. Additionally, slopes can be a major source of sediment and should be properly protected and stabilized. Site design criteria include:

1. Identify and cordon off streams and their buffers, floodplains, wetlands, steep slopes.
2. Reserve areas with high permeability soils for either open space or Infiltration BMPs.
3. Incorporate existing trees into site layout.
4. Identify areas that may be restored or revegetated either during construction or later.
5. Identify and avoid or stabilize areas susceptible to erosion and sediment loss.
6. Concentrate or cluster development on least-sensitive portions of a site, while leaving the remaining land in a natural undisturbed state.
7. Slopes must be protected from erosion by safely conveying runoff from the tops of slopes.
   - Slopes must be vegetated with first consideration given to use of native or drought-tolerant species.
   - Slope protection practices must conform to design requirements or standards set forth by local permitting agency erosion and sediment control standards and design standards. The design criteria described in this fact sheet are intended to enhance and be consistent with these local standards.
8. Limit clearing and grading of native vegetation at a site to the minimum amount needed to build lots, allow access, and provide fire protection.
9. Maintain existing topography and existing drainage divides to encourage dispersed flow.
10. Maximize trees and other vegetation at each site by planting additional vegetation, clustering tree areas, and promoting the use of native and/or drought-tolerant plants.
11. Promote natural vegetation by using parking lot islands and other landscaped areas. Integrate vegetated BMPs within parking lot islands and landscaped areas.

Design Criteria to Minimize Land Disturbance

Designing the site to preserve existing hydrology and drainage patterns reduces the need for grading and the disturbance of vegetation and soils. Siting buildings and impervious surfaces away from steep slopes, drainage courses, and floodplains also limits the amount of grading, clearing and disturbance and reduces hydrologic impacts. Design criteria include:

1. Delineate and flag the development envelope for the site by identifying the minimum area needed to build; allow access and provide fire protection; protect and buffer sensitive features such as streams, floodplains, steep slopes and wetlands; and concentrate buildings and paved areas on the least permeable soils, with the least intact habitats.
2. Plan clearing and grading to minimize the compaction of infiltrative soils.

3. Restrict equipment access to the development envelope.

4. Restrict storage of construction equipment within the development envelope.

5. Avoid the removal of existing trees and valuable vegetation, as feasible.

6. For areas in which soil disturbance will occur, consider soil amendments to restore permeability and organic content.

Design Criteria to Minimize Impervious Cover

Minimizing impervious area through site design is an important means of minimizing stormwater pollutants, as impervious areas increase the volume and rate of runoff flow and pollutants deposited on impervious areas tend to be easily mobilized and transported by runoff flow. Design criteria include:

1. Use minimum allowable roadway and sidewalk cross sections, driveway lengths and parking stall widths and lengths.

2. Minimize or eliminate the use of curb and gutter so that roadway runoff drains to LID BMPs is encouraged where slope and density permit.

3. Use two-track/ ribbon driveways or shared driveways.

4. Include landscape islands in cul-de-sac streets.

5. Reduce the footprints of building and parking lots.

6. Utilize permeable pavement to accommodate overflow parking (if overflow parking is needed).

7. Cluster buildings and paved areas to maximize pervious area.

8. Maximize tree preservation or tree planting.

9. Avoid compacting or paving over soils with high infiltration rates.

10. Use pervious pavement materials where appropriate, such as modular paving blocks, turf blocks, porous concrete and asphalt, brick, and gravel or cobbles.

11. Use grass-lined channels or surface swales to convey runoff instead of paved gutters.

Design Criteria to Apply LID BMPs at Various Scales

LID is a decentralized approach to stormwater management that works to mimic the natural hydrology of the site by retaining rainfall onsite. In order to realize the full benefits of water quality protection and runoff volume reduction, LID BMPs should be integrated and considered at the regional/watershed scale and the site scale.

Design criteria at the Regional/Watershed scale include:

1. Consider Density, as higher density development consumes less land and produces less impervious cover per capita than low density development.

2. Identify and Preserve Contiguous Open Space and look for opportunities to link open space preservation with regional open space preservation efforts.

3. Make use of Previously Developed Sites, as this reduces the need for greenfield development, and makes use of existing infrastructure.

4. Locate Development within Close Proximity to Mass Transit to reduce the number of automobile trips, and lessen the water quality impacts associated with transportation.

Design criteria at the Site scale include:

1. Maintain and Restore Natural Flowpaths for Runoff to reduce the amount of clearing and grading and maintain the pre-development hydrology's time of concentration.

2. Maximize Use of Existing Impervious Cover to reduce runoff at a watershed scale.

3. Design Public Spaces and Common Areas to Minimize Stormwater Runoff.

4. Compact Project Design to reduce the amount of impervious cover per capita and increase walkability, and decrease water quality impacts associated with transportation.

5. Encourage Use of Multiple Modes of Transportation.

Implement Integrated Water Resource Management Practices

Integrated Water Resource Management (IWRM) is a process which promotes the coordinated development and management of water, land, and related resources. Many of the concepts of IWRM are documented in the County's IRWMP, a product of an intensive stakeholder process, and address multiple water resource management goals. These practices include:

1. Conserve and Augment Water Supplies: Identify and evaluate the opportunities to recharge groundwater and increase water use efficiency. This can be accomplished through infiltration of stormwater runoff and selection of drought-tolerant landscaping.

2. Protect People, Property and the Environment from Adverse Flooding Impacts: Identify opportunities to utilize BMPs that provide both water quality and water quantity benefits. Provide and maintain setbacks from streams and rivers.

3. Protect and Restore Habitat and Ecosystems in Watersheds: Implement the practices identified in Protect and Restore Natural Areas to integrate habitat and stormwater goals. Landscaping selection for stormwater management practices may also further encourage and attract wildlife.

4. Provide Water-Related Recreational, Public Access and Educational Opportunities: Integrate recreation and stormwater management by creating multi-functional BMPs and designing

courtyards and open spaces that accommodate both people and stormwater runoff. Consider providing educational signage for BMPs located in public spaces, where appropriate.

7.2.1.2 Site-Specific Source Control Measures

Source Control Measures are low-technology practices designed to prevent pollutants from contacting stormwater runoff or to prevent discharge of contaminated runoff to the storm drainage system. Control measures are identified for specific types of sites or activities that have been identified as potential significant sources of pollutants in stormwater. These measures include:

S-1: Storm Drain Message and Signage: Signs are typically stenciled or affixed near the storm drain inlet to inform the public that dumping of wastes into storm drain inlets is prohibited and/or the drain discharges to receiving water. Message markers or placards are required at all storm drain inlets within the boundary of a development project.

S-2: Outdoor Material Storage Area Design: stormwater contamination may be prevented by eliminating the possibility of stormwater contact with the material storage areas either through diversion, cover, or capture of the stormwater, or by minimizing the storage area.

S-3: Outdoor Trash Storage Area Design: construct the storage area base with a material impervious to leaks and spills; install a screen or wall around trash storage area to prevent off-site transport of loose trash; use lined bins or dumpsters to reduce leaking of liquid wastes; use water-proof lids on bins/dumpsters or provide a roof to cover enclosure to prevent rainfall from entering containers; berm or grade the waste handling area to prevent run-on of stormwater; and post signs on all dumpsters informing users that hazardous materials are not to be disposed of therein.

S-4: Outdoor Loading/Unloading Dock Area Design: construct floor surfaces with material that is compatible with materials being handled in the loading/unloading area; cover loading/unloading areas to a distance of at least 3 feet beyond the loading dock or install a seal or door skirt to be used for all material transfers between the trailer and the building; grade or berm storage areas to prevent run-on from surrounding areas; direct runoff from downspouts/roofs away from loading areas; do not locate storm drains in the loading dock area as direct connections to storm drains from depressed loading docks are prohibited; and provide means, such as isolation valves, drain plugs, or drain covers, to prevent spills or contaminated stormwater from entering the storm drainage system.

S-5: Outdoor Repair/Maintenance Bay Design: construct the vehicle maintenance/repair floor area with Portland cement concrete; cover or berm areas where vehicle parts with fluids are stored; cover or enclose all vehicle maintenance/repair areas; berm or grade the maintenance/repair area to prevent run-on and runoff of stormwater or runoff of spills; direct runoff from downspouts/roofs away from maintenance/repair areas; grade the maintenance/repair area to drain to a dead-end sump for collection of all wash water, leaks and spills, as direct connection of maintenance/repair area to storm drain system is prohibited; do not locate storm drains in the immediate vicinity of the maintenance/repair area; provide means, such as isolation valves, drain plugs, or drain covers, to prevent spills or contaminated stormwater from entering the storm drainage system.

S-6: Outdoor Vehicle/Equipment/Accessory Washing Area Design: construct the vehicle/equipment wash area floors with Portland cement concrete; provide a cover that extends over the entire wash area; berm or grade the maintenance/repair area to prevent run-on and runoff of stormwater or runoff of spills; grade or berm the wash area to contain the wash water within the covered area and direct the wash water to treatment and recycle or pretreatment and proper connection to the sanitary sewer system; obtain approval from the governing agency before discharging to the sanitary sewer; direct runoff from downspouts/roofs away from wash areas; do not locate storm drains in the immediate vicinity of the wash area; provide means, such as isolation valves, drain plugs, or drain covers, to prevent spills or contaminated stormwater from entering the storm drainage system.

S-7: Fueling Area Design: fuel dispensing areas must be paved with Portland cement concrete; use asphalt sealant to protect asphalt paved areas surrounding the fueling area; the dispensing area must be covered, and the cover must not drain onto the dispensing area; the dispensing area shall have a 2% to 4% slope to prevent ponding and must be separated from the rest of the site by a grade break that prevents run-on of stormwater to the extent practicable; grade the fueling area to drain toward a dead-end sump; direct runoff from downspouts/roofs away from fueling areas; do not locate storm drains in the immediate vicinity of the fueling area; provide means, such as isolation valves, drain plugs, or drain covers, to prevent spills or contaminated stormwater from entering the storm drainage system.

S-8: Proof of Control Measure Maintenance: To ensure that ongoing inspection and maintenance is provided, the local permitting agency will require a Maintenance Agreement from the owner/operator of stormwater control measures and a Maintenance Plan that provides an operation plan and schedule and a site map and describes: the maintenance and cleaning activities and schedule; equipment and resource requirements necessary to operate and maintain facility; and the responsible party for operation and maintenance.

7.2.1.3 Low Impact Development BMPs

LID BMPs, which are distributed, small-scale stormwater BMPs that are designed to mimic natural hydrologic patterns and retain runoff on the project site. These include Infiltration, Rainwater Harvesting, and Evapotranspiration BMPs.

Infiltration BMPs

INF-1: Infiltration Basin: An infiltration basin consists of an earthen basin constructed in naturally pervious soils (Type A or B soils) with a flat bottom and provided with inlet structure to dissipate energy of incoming flow and an emergency spillway to control excess flows. An optional relief underdrain may be provided to drain the basin if standing water conditions occur. A forebay settling basin or separate Treatment Control Measure must be provided as pretreatment. An infiltration basin functions by retaining the SQDV in the basin and allowing the retained runoff to percolate into the underlying native soils over a specified period of time. The bottoms of infiltration basins are typically vegetated with dry-land grasses or irrigated turf grass.

INF-2: Infiltration Trench: Infiltration trenches are long, narrow, gravel-filled trenches, often vegetated, that infiltrate stormwater runoff from small drainage areas. Infiltration trenches may include a shallow depression at the surface, but the majority of runoff is stored in the void space within the gravel and infiltrates through the sides and bottom of the trench.

INF-3: Bioretention: Bioretention stormwater treatment facilities are landscaped shallow depressions that capture and filter stormwater runoff. These facilities function as a soil and plant-based Filtration device that removes pollutants through a variety of physical, biological, and chemical treatment processes. The facilities normally consist of a ponding area, mulch layer, planting soils, and plantings. As stormwater passes down through the planting soil, pollutants are filtered, adsorbed, and biodegraded by the soil and plants. For areas with low permeability native soils or steep slopes, bioretention areas can be designed with an underdrain system that routes the treated runoff to the storm drain system rather than depending entirely on infiltration.

INF-4: Drywell: A dry well is a shaft or hole or pit whose depth is greater than its width that is filled with aggregate or a prefabricated storage chamber or pipe segment that is designed specifically for the alleviation of flooding and the disposal of storm water. Drywells are similar to infiltration trenches in their design and function, as they are designed to temporarily store and infiltrate runoff, primarily from rooftops or other impervious areas with low pollutant loading. Dry wells can be used to reduce the increased volume of stormwater runoff caused by roofs of buildings. Dry wells can also be used to indirectly enhance water quality by reducing the amount of stormwater quality design storm runoff volume to be treated by other downstream stormwater management facilities.

INF-5: Permeable Pavement: Permeable pavements contain small voids that allow water to pass through to a stone base. They come in a variety of forms; they may be a modular paving system (concrete pavers, grass-pave, or gravel-pave) or poured in place solutions (porous concrete, permeable asphalt). All permeable pavements with a stone reservoir base treat stormwater and remove sediments and metals to some degree. While conventional pavement result in increased rates and volumes of surface runoff, porous pavements, when properly constructed and maintained, allow some of the stormwater to percolate through the pavement and enter the soil below. For porous pavements to function properly over an expected life span of 15 to 20 years, they must be properly sited and carefully designed and installed, as well as periodically maintained.

INF-6: Proprietary Infiltration: A number of vendors offer proprietary infiltration products that use durable prefabricated structures to enhance rates of stormwater infiltration and provide subsurface storage.

Rainwater Harvesting BMPs

RWH-1: Cistern: While rain barrels are less than 100 gallons, cisterns range from 100 to 10,000 gallons in capacity. Cisterns collect and temporarily store runoff from rooftops for later use as irrigation and/or other non-potable uses.

Evapotranspiration BMPs

ET-1: Green Roof: Green roofs (also known as eco-roofs and vegetated roof covers) are roofing systems that include a soil/vegetative cover over a waterproofing membrane. Green roofs rely on highly porous media and moisture retention layers to store intercepted precipitation and to support vegetation that can reduce the volume of stormwater runoff via evapotranspiration.

7.2.1.4 Treatment Control Measures

Treatment Control Measures are engineered technologies designed to remove pollutants from stormwater runoff prior to discharge from the project site. These measures include Vegetated/Multi-use, Proprietary, and Pre-Treatment BMPs.

Vegetated/Multi-Use BMPs

VEG-1: Bioretention with Underdrain: Bioretention stormwater treatment facilities are landscaped shallow depressions that capture and filter stormwater runoff. These facilities function as a soil and plant-based filtration device that removes pollutants through a variety of physical, biological, and chemical treatment processes. The facilities normally consist of a ponding area, mulch layer, planting soils, and plantings. As stormwater passes down through the planting soil, pollutants are filtered, adsorbed, and biodegraded by the soil and plants. Bioretention with an underdrain is a treatment control measures that can be utilized for areas with low permeability native soils or steep slopes. Bioretention may also be designed without an underdrain to serve as a retention BMP in areas of high soil permeability.

VEG-2: Planter Box: Planter boxes are bioretention treatment control measures that are completely contained within an impermeable structure with an underdrain (they do not infiltrate). These facilities function as a soil and plant-based filtration device that removes pollutants through a variety of physical, biological, and chemical treatment processes. The facilities normally consist of a ponding area, mulch layer, planting soils, plantings, and an underdrain within the planter box.

VEG-3: Vegetated Swale: Vegetated swales are open, shallow channels with low-lying vegetation covering the side slopes and bottom that collect and slowly convey runoff to downstream discharge points. Vegetated swales provide pollutant removal through settling and filtration in the vegetation (usually grasses) lining the channels, provide the opportunity for stormwater volume reduction through infiltration and evapotranspiration, and reduce the flow velocity in addition to conveying stormwater runoff.

VEG-4: Vegetated Filter Strip: Filter strips are vegetated areas designed to treat sheet flow runoff from adjacent impervious surfaces or intensive landscaped areas such as golf courses. Filter strips decrease runoff velocity, filter out total suspended solids and associated pollutants, and provide some infiltration into underlying soils. While some assimilation of dissolved constituents may occur, filter strips are generally more effective in trapping sediment and particulate-bound metals, nutrients, and pesticides.

VEG-5: Dry Extended Detention Basin: Dry extended detention (ED) basins have been designed to detain the stormwater quality design volume (SQDV), for 36 to 48 hours to allow sediment particles and associated pollutants to settle and be removed. Dry ED basins do not have a permanent pool; they are designed to drain completely between storm events. By modifying the outlet control structure and providing additional detention storage, Dry ED Basins can also enhance flood protection or reduce downstream hydromodification.

VEG-6: Wet Detention Basin: Wet detention basins are constructed, naturalistic ponds with a permanent or seasonal pool of water (also called a "wet pool"). Aquascape facilities, such as artificial lakes, are a special form of wet pool facility that can incorporate innovative design

elements to allow them to function as a stormwater treatment facility in addition to an aesthetic water feature. Wetponds require base flows to exceed or match losses through evaporation and/or infiltration and must be designed with the outlet positioned and/or operated in such a way as to maintain a permanent pool.

VEG-7: Constructed Wetland: A constructed treatment wetland is a system consisting of a sediment forebay and one or more permanent micro-pools with aquatic vegetation covering a significant portion of the basin. The interactions between the incoming stormwater runoff, aquatic vegetation, wetland soils, and the associated physical, chemical, and biological processes are a fundamental part of constructed treatment wetlands.

VEG-8: Sand Filter: Sand filters operate much like bioretention facilities; however, instead of filtering stormwater through engineered soils, stormwater is filtered through a constructed sand bed with an underdrain system. As stormwater passes through the sand, pollutants are trapped in the small pore spaces between sand grains or are adsorbed to the sand surface.

Proprietary LID BMPs

PROP-1: Proprietary Biotreatment: Proprietary biotreatment devices are manufactured treatment BMPs that incorporate plants, soil, and microbes engineered to provide treatment at higher flow rates or volumes and with smaller footprints than their non-proprietary counterparts. Incoming flows are typically pretreated to remove larger particles/debris, filtered through a planting media (mulch, compost, soil, and plants), collected by an underdrain, and delivered to the stormwater conveyance system.

PROP-2: Cartridge Media Filter: Cartridge media filters are manufactured devices that typically consist of a series of cylindrical vertical filters contained in a catch basin, manhole, or vault that provide treatment through filtration and sedimentation. The basin may be divided into multiple chambers where the first chamber acts as a pre-settling basin for removal of coarse sediment while another chamber acts as the filter bay and houses the filter cartridges.

Pretreatment/Gross Solids Removal BMPs

PT-1: Hydrodynamic Device: Hydrodynamic separation devices (alternatively, swirl concentrators) are devices that remove trash, debris, and coarse sediment from incoming flows using screening, gravity settling, and centrifugal forces generated by forcing the influent into a circular motion. By having the water move in a circular fashion, rather than a straight line, it is possible to obtain significant removal of trash, suspended sediments and attached pollutants with less space as compared to wet vaults and other settling devices. Several types of hydrodynamic separation devices are also designed to remove floating oils and grease using sorbent media.

PT-2: Catch Basin Insert: Catch basin inserts are manufactured filters or fabric placed in a drop inlet to remove sediment and debris and may include sorbent media (oil absorbent pouches) to remove floating oils and grease. Catch basin inserts are selected specifically based upon the orientation of the inlet.

7.3 Water Supply

The California Urban Water Conservation Council was created to increase efficient water use statewide through partnerships among urban water agencies, public interest organizations, and

private entities. The Council's goal is to integrate urban water conservation Best Management Practices into the planning and management of California's water resources. A Memorandum of Understanding was signed by nearly 100 urban water agencies and environmental groups in December, 1991. Since then the Council has grown to 389 members. Those signing the MOU pledged to develop and implement fourteen comprehensive conservation Best Management Practices (BMPs), which as of 2009, were reorganized as follows into two broad categories: Foundational BMPs and Programmatic BMPs.

7.3.1 Foundational BMPs

7.3.1.1 Utility Operations Programs

Water utilities throughout California are implementing water conservation programs and providing services to the customers they serve. There are four subcategories that comprise signatory utility operation program responsibilities.

1) Conservation Coordinator (formerly BMP 12)

Designate a person as the agency's responsible conservation coordinator for program management, tracking, planning, and reporting on BMP implementation.

2) Water Waste Prevention (formerly BMP 13)

a) New Development

Enact, enforce, or support legislation, regulations, ordinances, or terms of service that (1) prohibit water waste such as, but not limited to: single-pass cooling systems; conveyer and in-bay vehicle wash and commercial laundry systems which do not reuse water; non-recirculating decorative water fountains and (2) address irrigation, landscape, and industrial, commercial, and other design inefficiencies.

b) Existing Users

Enact, enforce, or support legislation, regulations, ordinances, or terms of service that prohibit water waste such as, but not limited to: landscape and irrigation inefficiencies, commercial or industrial inefficiencies, and other misuses of water.

c) Water Shortage Measures

Enact, enforce, or support legislation, regulations, ordinances, or terms of service that facilitate implementation of water shortage response measures.

3) Wholesale Agency Assistance Programs (formerly BMP 10)

This section addresses assistance relationships between regional wholesale agencies and intermediate wholesale agencies as well as between wholesale agencies and retail agencies.

a) Financial Investments and Building Partnerships

When mutually agreeable and beneficial to a wholesaler and its retail agencies, a wholesaler will provide financial assistance and help build partnerships to accomplish conservation.

b) Technical Support

When requested, wholesale water agencies will provide conservation-related technical support and information to retail agencies they serve, which may include: workshops and support advice addressing conservation program planning, design, implementation, and evaluation.

c) Program Management

When mutually advantageous, wholesale and retail water agencies will join together to plan, design, implement, manage, and evaluate regional conservation programs.

d) Water Shortage Allocations

Wholesale agencies shall pursue water shortage allocation policies or plans which minimize disincentives to long-term water conservation, and encourage and reward investments in long-term conservation shown to advance regional water supply reliability and sufficiency.

e) Non-Signatory Reporting

To the extent possible, wholesale water agencies will provide reports on BMP implementation within their service area by retail water agencies that are not signatories to the MOU.

f) Encourage CUWCC Membership

Wholesale agencies will encourage all of their retail agencies to become MOU signatories, provide information to assist the CUWCC in recruitment targeting, and may assist in paying CUWCC dues for their retail agencies.

7.3.1.2 Educational Programs

Public Information Programs (formerly BMP 7)

Implement a public information program to promote water conservation and water conservation-related benefits. Implementation shall consist of at least the following actions:

1) The program should include, when possible, but is not limited to, providing speakers to employees, community groups and the media; using paid and public service advertising; using bill inserts; providing information on customers' bills showing use for the last billing period compared to the same period the year before; providing public information to promote water conservation measures; and coordinating with other government agencies, industry groups, public interest groups, and the media.

2) The program should include, when possible, social marketing elements which are designed to change attitudes to influence behavior. This includes seeking input from the public to shape the water conservation message; training stakeholders outside the utility staff in water conservation priorities and techniques; and developing partnerships with stakeholders who carry the conservation message to their target markets.

3) When mutually agreeable and beneficial, the wholesale agency or another lead regional agency may operate all or part of the public information program.

School Education Programs (formerly BMP 8)

School education programs have been implemented to reach the youngest water users at an early age and enforce the need to engage in water conservation as a life-long behavior. Implementation shall consist of at least the following actions:

1) Implement a school education program to promote water conservation and water conservation-related benefits.

2) Programs shall include working with school districts and private schools in the water suppliers' service area to provide instructional assistance, educational materials, and classroom presentations that identify urban, agricultural, and environmental issues and conditions in the local watershed. Educational materials shall meet the state education framework requirements and grade-appropriate materials shall be distributed.

3) When mutually agreeable and beneficial, the wholesale agency or another lead regional agency will operate all or part of the education program.

7.3.2 Programmatic BMPs

7.3.2.1 Residential

Residential water users throughout California depend on a reliable and safe supply of water for their homes. This BMP will define the best and most proven water conservation methods and measures those residents, working in conjunction with water agencies, can implement.

1) Residential Assistance Program (formerly BMPs 1 & 2)

Provide site-specific leak detection assistance that may include, but is not limited to, the following: a water conservation survey, water efficiency suggestions, and/or inspection. Provide showerheads and faucet-aerators that meet the current water efficiency standard as stipulated in the WaterSense Specifications (WSS) as needed.

2) Landscape water Survey (formerly BMP 1)

Perform site-specific landscape water surveys that shall include, but are not limited to, the following: check irrigation system and timers for maintenance and repairs needed; estimate or measure landscaped area; develop customer irrigation schedule based on precipitation rate, local climate, irrigation system performance, and landscape conditions; review the scheduling with customer; provide information packet to customer; and provide customer with evaluation results and water savings recommendations.

3) High-Efficiency Clothes Washers (HECWs) (formerly BMP 6)

Provide incentives or institute ordinances requiring the purchase of high-efficiency clothes washing machines (HECWs) that meet an average water factor value of 5.0. If the WaterSense[1]

[1] The U.S. Environmental Protection Agency created the WaterSense program to help consumers make smart water choices that save money and maintain high environmental standards without compromising performance. Products and services that have earned the WaterSense label have been certified to be at least 20 percent more efficient without sacrificing performance.

specification (WSS) is less than 5.0, then the average water factor value will decrease to that amount.

4) WaterSense Specification Toilets (formerly BMP 14)

Provide incentives or ordinances requiring the replacement of existing toilets using 3.5 or more gpf (gallons per flush) with a toilet meeting WSS.

5) WaterSense Specifications for Residential Development

Provide incentives such as, but not limited to, rebates, recognition programs, or reduced connection fees, or ordinances requiring residential construction meeting WSS for single-family and multi-family housing until a local, state or federal regulation is passed requiring water efficient fixtures.

7.3.2.2 Commercial, Industrial, and Institutional

The goal of this BMP is to implement comprehensive yet flexible best management practices, allowing each water agency to tailor the implementation of each practice to fit local needs and opportunities. The goal is to implement measures to achieve the water savings goal for Commercial, Industrial, and Institutional accounts of 10 percent of the baseline water use over a 10-year period.

1) Implement Commercial, Industrial, and Institutional conservation measures that result in well-documented savings, including:

- Hi-Efficiency Toilets.
- Hi-Efficiency Urinals.
- Ultra Low Volume Urinals.
- Zero Consumption Urinals.
- Commercial High- Efficiency Single Load Clothes Washers.
- Cooling Tower Conductivity Controllers.
- Cooling Tower pH Controllers.
- Connectionless Food Steamers.
- Medical Equipment Steam Sterilizers.
- Water-Efficient Ice Machines.
- Pressurized Water Brooms.
- Dry Vacuum Pumps.

2) Implement unique conservation measures to achieve the agency's water savings goals. Sample measures include, but are not limited to: industrial process water use reduction, industrial laundry retrofits, car wash recycling systems, water-efficient commercial dishwashers, and wet cleaning.

7.3.2.3 Landscape

The goal of this BMP is that irrigators, with assistance from (water agency) signatories, will achieve a higher level of water use efficiency consistent with the actual irrigation needs of the plant materials. Reaching this goal would reduce overall demands for water, reduce demands during the peak summer months, and still result in a healthy and vibrant landscape for California.

1) Accounts with Dedicated Irrigation Meters

a) Identify accounts with dedicated irrigation meters and assign evapotranspiration (ETo) based water use budgets equal to no more than an average of 70% of the annual average local ETo per square foot of landscape area. Recreational areas (portions of parks, playgrounds, sports fields, golf courses, or school yards in public and private projects where turf provides a playing surface or serves other high-use recreational purposes) and areas permanently and solely dedicated to edible plants, such as orchards and vegetable gardens, may require water in addition to the water use budget.

b) Provide notices each billing cycle to accounts with water use budgets showing the relationship between the budget and actual consumption.

c) Offer site-specific technical assistance to reduce water use to those accounts that are 20% over the reference ETo budget.

2) Commercial/Industrial/Institutional Accounts without Meters or with Mixed-Use Meters

a) Develop and implement a strategy targeting and marketing large landscape water use surveys to commercial/industrial/institutional (CII) accounts with mixed-use meters.

b) In un-metered service areas, actively market landscape surveys to existing accounts with large landscapes, or accounts with landscapes which have been determined by the purveyor not to be water efficient.

7.4 Habitat

BMPs to improve habitat functions for the Ventura River watershed have yet to be articulated in a concise format or centralized manner. However, BMPs can be inferred from several sources, including (1) land use policies that regulate future development; (2) policies that govern site planning; (3) goals and policies that govern management of the national forest lands within the watershed; and (4) conditions included in recent permits that regulate construction and maintenance activities within or adjacent to the Ventura River.

7.4.1 Land Use Policies

In 1996, the County Board of Supervisors, all City Councils within Ventura County and the Local Agency Formation Commission adopted revised Guidelines for Orderly Development to maintain the consistent theme that urban development should be located within incorporated cities whenever or wherever practical, which may preserve open space, including those lands which contain native habitat.

The Ventura County General Plan includes several relevant goals for Open Space (in Section 3.2.1):

(1) Preserve for the benefit of all the County's residents the continued wise use of the County's renewable and nonrenewable resources by limiting the encroachment into such areas of uses which would unduly and prematurely hamper or preclude the use or appreciation of such resources.

(4) Retain open space lands for outdoor recreational activities, parks, trails and for scenic lands.

(6) Recognize the intrinsic value of open space lands and not regard such lands as "areas waiting for urbanization."

In addition, Section 3.2.2 identifies the following Open Space policies:

(1) Open Space should include areas of land or water which are set aside for the preservation of natural resources, including, but not limited to, areas required for the preservation of plant and animal life, including habitat for fish and wildlife species; areas required for ecologic and other scientific study purposes; rivers, streams, bays, and estuaries; and coastal beaches, lakeshores, banks of rivers and streams, and important watershed lands.

(2) Open Space should also include areas set aside for managed production of resources, including, but not limited to, forest lands, rangeland, agricultural lands not otherwise designated Agricultural; areas required for the recharge of groundwater basins; bays, estuaries, marshes, rivers, and streams which are important for the management of commercial fisheries; and areas containing major mineral deposits, including those in short supply.

A report on Roads and Biodiversity Project: Guidelines for Safe Wildlife Passage (Ventura County Planning Division, 2005) acknowledges that in the review of future development proposals, the Ventura County Initial Study Assessment Guidelines requires consideration whether such development could adversely affect wildlife corridors, which are described as:

“An area as defined by a qualified biologist, which experiences recurrent fish or wildlife movement and which is important to fish or wildlife species seeking to move from one habitat area to another.”

The Assessment Guidelines provide the following threshold criterion, as determined by a qualified biologist, for impacting movement corridors:

“A significant impact to a migration corridor would result if a project would substantially interfere with the use of said area by fish or wildlife. This could occur through elimination of native vegetation, erection of physical barriers or intimidation of fish or wildlife via introduction of noise, light, development or increased human presence.”

The City of Ventura General Plan (City of Ventura, 2005) states that the City “…must pursue an “Infill First” strategy… [to] help avoid sacrificing farmland and sensitive areas in our hillsides and along our rivers.” The Ventura City General Plan also includes several policies and actions that are relevant to habitat in the watershed:

Policy 1B: Increase the area of open space protected from development impacts.

Action 1.8: Buffer barrancas and creeks that retain natural soil slopes from development according to State and Federal guidelines.

Action 1.9: Prohibit placement of material in watercourses other than native plants and required flood control structures, and remove debris periodically.

Action 1.10: Remove concrete channel structures as funding allows, and where doing so will fit the context of the surrounding area and not create unacceptable flood or erosion potential.

Action 1.11: Require that sensitive wetland and coastal areas be preserved as undeveloped open space wherever feasible and that future developments result in no net loss of wetlands or "natural" coastal areas.

Action 1.12: Update the provisions of the Hillside Management Program as necessary to ensure protection of open space lands.

Policy 1C: Improve protection for native plants and animals.

Action 1.17: Require development to mitigate its impacts on wildlife through the development review process.

Action 1.18: Require new development adjacent to rivers, creeks, and barrancas to use native or noninvasive plant species, preferably drought tolerant, for landscaping.

Action 1.19: Require projects near watercourses, shoreline areas, and other sensitive habitat areas to include surveys for State and/or federally listed sensitive species and to provide appropriate buffers and other mitigation necessary to protect habitat for listed species.

Action 1.22: Adopt development code provisions to protect mature trees, as defined by minimum height, canopy, and/or trunk diameter.

Action 1.24: Require new development to maintain all indigenous tree species or provide adequately.

The City of Ojai General Plan (Ojai, 1997) includes a policy to formulate a land use pattern that takes optimum advantage of natural and cultural resources in the Ojai Planning Area. In addition, the Conservation Element of the General Plan identifies the following policies to protect biological resources within the city and it's Area of Interest:

- …to allow no loss of existing resource value for rare, endangered and unique species habitat, except to provide for the maintenance of flood control facilities.
- …to allow no loss of existing resource value for regionally significant Oak Woodland/Savanna.
- …to allow no loss or the existing resource value or regionally significant riparian habitat.

- …to allow in Woodland/Brushland Ecotone areas no loss or existing resource value within "core" oak woodland and sycamore tree areas while minimizing/limiting loss or remaining existing resource value.
- …to minimize loss of resource value of locally significant stands of oak and sycamore trees.
- …to minimize the loss of resource values of locally significant stands of native brush land consistent with the best practiced methods for fire protection.

7.4.2 Site Planning

Section 7.1.1.1 above identifies Site Design Principles and Techniques that have the potential to preserve habitat on sites that are subject to development.

7.4.3 National Forest Lands

The Land Management Plan (Part 2) for the Los Padres National Forest (US Forest Service, 2005) identifies several relevant strategies for national forest lands within the watershed, including the Matilija Wilderness and portions of area identified in the plan as the Highway 33 Corridor. The plan includes several recommendations relevant to habitat, including:

- Focus on reducing risks from wildland fire to maintain water and scenic quality and improve steelhead and arroyo toad habitat.
- Work with Caltrans to designate and approve Road Spoil Disposal Sites along California State Highway 33.
- Work collaboratively with federal and state agencies and water management entities to restore steelhead trout to habitat upstream of Matilija Dam.

In addition, the following practices have been adapted from the Program Strategies and Tactics included in Appendix B of the Land Management Plan:

- Protect and manage wilderness to improve the capability to sustain a desired range of benefits and values, and so that changes in ecosystems are primarily a consequence of natural forces.
- Identify linkages between natural areas that are needed for maintenance of biodiversity and work to secure long-term habitat linkages.
- Prevent the introduction of new invasive and non-native species, conduct early treatment of new populations and contain and control established populations.
- Manage chaparral in selection locations to protect the life and property of human inhabitants, to improve wildlife forage, and to protect watersheds from the adverse impacts of large, destructive, high-intensity fires. In some watersheds, manage for even-aged patch sizes of 5,000 acres or less.
- Restore vegetation through reforestation or other appropriate methods after major fire events, severe drought, or other events or activities that degrade or cause the loss of plant communities.

7.4.4 Construction and Maintenance Activities in Riverine and Riparian Areas

Many agencies (i.e., Casitas, Golden State, Meiners Oaks County Water District, OVSD, the City of Ventura, and Ventura River County Water District) operate water supply and use facilities in, and near, the Ventura River and its tributaries that require maintenance, repair, and replacement due to normal operations and under emergency situations. Some of these activities could directly, or indirectly, affect sensitive species or their habitat in the Ventura River Watershed.

The measures listed in Table 7-1 represent recommended BMPs that shall be used to avoid or minimize adverse impacts on sensitive species and their habitat during temporary maintenance or repair work of water supply and use facilities. These measures are common conditions from Section 404 permits and Section 1602 Agreements recently issued to local agencies for work along the Ventura River and its tributaries.

Table 7-1 Best Management Practices for Construction and Maintenance Activities

Category	Specific Practice(s)
Protection for Wildlife and Aquatic Species	Minimize maintenance/construction activities during the recognized breeding and nesting season for sensitive species in areas subject to disturbance. If work must be done during this period that could affect such species, a qualified wildlife biologist shall survey the proposed work area and the riparian area within a distance of 500 to 1,000 feet upstream and downstream from the work area. Survey methods shall conform to the current agency guidelines for the sensitive species. Survey results, analyses, and recommendations, along with field notes shall be provided to the USFWS and CDFG prior to commencing work or within 2 weeks of completion of the field surveys, whichever is earlier. Surveys will be reported to the California Natural Diversity Data Base.
	To the extent feasible, construction activities within the stream channel shall be limited to the dry period of the year, typically from April 1 to November 1 or when the stream flows are minimal or absent. If instream work must be done during the period April 1 to November 1, a qualified biologist will survey the area to confirm the presence/absence of sensitive species prior to construction/maintenance activities. The sensitive species survey techniques shall be approved by the relevant agency. Survey results, analyses, and recommendations, along with field notes shall be provided to the appropriate agency prior to commencing work or within 2 weeks of completion of the field surveys, whichever is earlier. Surveys will be reported to the California Natural Diversity Database.
	Should any sensitive species be found during pre-project surveys and work must be done in identified areas during sensitive periods, develop and implement a plan for the protection of these species. This Plan shall be approved by the appropriate agency prior to commencing work. The results of any surveys and protective measures instituted, as part of the protection and monitoring plan, shall be provided to the appropriate agency within one week from implementation.
	Work areas shall be fenced to prevent access to sensitive areas within the riparian corridor or channel such as pools, seeps or wet spots that provide habitat for wildlife. Clearly defined and fenced work areas shall be established to reduce incidental take of species of special concern, through injury, damage or death due to straying of construction equipment and personnel.
	Workers shall be trained by a biologist to avoid and minimize activities that might affect wildlife. Worker education and well-defined operational procedures should be implemented, with the cooperation of the biologist, to avoid and minimize the take of species of special concern during creek maintenance activities.
	Prior to repair or maintenance activities, if fish or native aquatic vertebrates are present, a fish and native aquatic vertebrate relocation plan will be implemented by a US Fish and Wildlife Service (USFWS) approved biologist when cofferdams, water bypass structures, and silt barriers are installed to ensure that fish and native aquatic vertebrates are not stranded. If any of the species are present in the work area, a USFWS-approved biologist shall assist with the capture, handling, and monitoring of the sensitive species.

Table 7-1 Best Management Practices for Construction and Maintenance Activities

Category	Specific Practice(s)
Revegetation / Restoration Measures	Where feasible, revegetate the restored bank within the work area (including construction areas, access roads, etc.). Revegetation shall include planting native trees and shrubs local to the area.
	Planting, maintenance, monitoring and reporting activities shall be overseen by a specialist experienced with restoration of native plants.
	All plants shall be planted in randomly spaced, naturally clumped patterns.
	A plant palette and planting plan shall be prepared by a biologist familiar with restoration of native plants. The Plan shall include plantings of both overstory and understory vegetation and shall be consistent with the recommended list of native plants for the area as determined by the California Native Plant Society. The Plan shall also include a description of the proposed numbers, container sizes, and planting location, by species, the proposed monitoring activities (locations, techniques, scheduling, etc.), maintenance operations with particular emphasis on watering methods and schedules; the removal of invasive plant species, area treated, techniques to be used, and schedule and success criteria for controlling invasive plants; and any/all other references to revegetation and restoration activities specified by the permitting agencies.
	All planting should be done, after the first wetting rains between October 1 and February 1 to take advantage of the winter rainy season, dormancy of foliage, and rooting period to ensure optimum survival of plantings.
	A coarse mulch should be placed around plantings to minimize water loss and discourage weed growth. Mulch should be 3 to 4 inches deep and should be placed in a minimum area 1.5 times the diameter of the dripline of the plant or 2 feet in diameter, whichever is greater. The mulched area should be maintained throughout the course of restoration, unless otherwise authorized by the permitting agency. Mulch should not be placed directly against the mainstem of the plants.
	Plant material for revegetation shall be derived from cuttings, materials salvaged from disturbed areas, and/or seeds obtained from randomly selected native trees and shrubs occurring locally within the same drainage.
	Any replacement tree/shrub stock, which cannot be grown from cuttings or seeds, shall be obtained from a native plant nursery, and shall not be inoculated to prevent heart rot. The Operator shall provide a list of all materials which must be obtained from other than onsite sources.
	Restoration shall include the recontouring of the streambed to its original grade for areas of temporary impacts, including access roads.
Removal of Non-Native Vegetation	Remove any non-native vegetation (tree tobacco, castor bean, giant cane, etc.) from work areas and dispose of it in a manner and a location which prevents its reestablishment. Removal shall be done at least twice annually during the spring/summer season, as needed, through the turn of restoration.
	Giant cane, if present, shall be cut to a height of 6 inches or less, and the stumps painted with an herbicide approved for aquatic use within 5 minutes of cutting. Herbicides shall be applied at least three (3) times during the period from May 1 to October 1 to eradicate these plants. Where proposed methods for removing giant cane deviate from this procedure, present the alternate method, in writing, to the appropriate permitting agency for review and approval, prior to the onset of work.
	Whenever possible, invasive species shall be removed by hand or by hand-operated power tools rather than by chemical means. Where control of non-native vegetation is required within the bed, bank, or channel of the stream and the use of herbicides is necessary, there is a possibility that the herbicides could come into contact with the water, in which case only those herbicides approved for aquatic use (i.e., AquaMaster) shall be utilized. If surfactants are required, they shall be restricted to non-ionic chemicals (i.e., Agri-Dex), which are approved for aquatic use. Apply herbicides in accordance with state and federal law. No herbicides shall be used where threatened or endangered species occur. No herbicides shall be used when wind velocities are above 5 miles per hour.

Table 7-1 Best Management Practices for Construction and Maintenance Activities

Category	Specific Practice(s)
Pollution, Sedimentation, Diversion/Dewatering, and Litter	When necessary, applicants shall prepare and implement a program to control water pollution effectively during construction/maintenance activities (i.e., Storm Water Pollution Prevention Plan). To further minimize storm water pollution, specific BMPs targeted at preventing potentially hazardous materials from entering receiving waters shall be employed during work activities (i.e., dewatering operations, material delivery and storage practices, material use, spill prevention practices, solid waste management, vehicle and equipment cleaning and fueling, fuel storage, vehicle and equipment maintenance, etc.).
	No debris, soil, silt, sand, bark, slash, sawdust, rubbish, cement or concrete or washings thereof, oil or petroleum products or other organic or earthen material from any maintenance, construction, or associated activity of whatever nature shall be allowed to enter into or placed where it may be washed by rainfall or runoff into, waters of the State. When work is completed, any excess materials or debris shall be removed from the work area. No rubbish shall be deposited within 150 feet of the high water mark of any stream.
	Comply with all litter and pollution laws. All contractors, subcontractors and employees shall also obey these laws and it shall be the responsibility of the operator to ensure compliance.
	Any equipment or vehicles driven and/or operated within or adjacent to the channels or basins shall be checked and maintained daily, to prevent leaks of materials that if introduced to water could be deleterious to aquatic life.
	Stationary equipment such as motors, pumps, generators, and welders, located within or adjacent to the stream shall be positioned over drip pans.
	No equipment maintenance shall be done within or near any stream channel where petroleum products or other pollutants from the equipment may enter these areas under any flow.
	Field personnel shall be appropriately trained in hazardous material control, and clean up of accidental spills. The cleanup of spills shall begin immediately.
	Raw cement/concrete or washings thereof, asphalt, paint or other coating material, oil or other petroleum products, or any other substances which could be hazardous to aquatic life, resulting from activities, shall be prevented from contaminating the soil and/or entering the waters of the state. Any of these materials, placed within or where they may enter a stream, by the Operator or any party working under contract, or with the permission of the Operator, shall be removed immediately.
	Precautions to minimize turbidity/siltation shall be taken into account during implementation of the activities within the riverine and riparian zones. Incorporate erosion controls into the planning, construction, and follow up process for all maintenance activities. Erosion control and sediment-detention devices shall be installed prior to construction and all phases of routine maintenance projects to control sediment and minimize water quality impacts. Select applicable BMPs for which materials are available and plan to have the necessary materials on hand for implementation before starting work. This may require that the work site be isolated and that water be diverted around the work area by means of a barrier, temporary culvert, new channel, or other means approved by the permitting agencies. Precautions may also include placement of silt fencing, hay or straw bales, sandbags, and/or the construction of silt catchment basins, so that silt or other deleterious materials are not allowed to pass to downstream reaches.
	The performance of erosion control BMPs should be monitored daily during maintenance/construction activities. Added attention should be given to the monitoring of BMPs after storm events, and BMPs should be maintained, upgraded, or augmented with additional BMPs as needed.
	Flow diversions shall be done in a manner that will prevent pollution and/or siltation and provide flows to downstream reaches. Flows to downstream reaches shall be provided during all times that the natural flow would have supported aquatic life. Said flows shall be of sufficient quality and quantity, and of appropriate temperature to support fish and other aquatic life both above and below the diversion. Normal flows shall be restored to the affected stream immediately upon completion of the work at that location. A relocation plan shall be implemented to ensure that fish and native aquatic vertebrates are not stranded.

Table 7-1 Best Management Practices for Construction and Maintenance Activities

Category	Specific Practice(s)
	The Operator shall coordinate project site dewatering, if needed, with a fisheries biologist qualified to perform relocation activities. Also, a qualified fisheries biologist shall be present during implementation of diversion structures.
	Pump intakes placed in stream water shall be fitted with (1/8) inch or smaller mesh screens for January 1 through March 30, and (1/4) inch or smaller mesh screens thereafter to prevent the entrainment of fish or amphibians that failed to be removed. The intake should be checked periodically for impingement of fish and amphibians. Properly sized bypass pipes or gravity-fed pipe systems, if used, shall be installed to prevent increases in water temperature and decreases in dissolved oxygen.
	Wastewater shall be discharged from the work area to an upland location where it will not drain sediment-laden water back to the stream channel.
	When activities require the moving of equipment across a flowing stream, such activities shall be conducted without increasing stream turbidity. For repeated crossings, the operator shall install a temporary bridge, culvert, or rock-fill crossing pursuant to the design standards located in the California Department of Fish and Game's "Culvert Criteria for Fish Passage" (April 2003) and in conjunction with the NOAA Fisheries Southwest Region's "Guidelines for Salmonid Passage at Stream Crossings" (September 2001).
	If a stream's low flow channel, bed or banks have been temporarily altered, these shall be returned as nearly as possible to their original configuration and width, without creating future erosion problems.
Temporary Work Areas and Temporary Vegetation Removal	Limit the disturbance or removal of vegetation. The disturbed portions of any stream channel within the ordinary high water mark (OHWM) of the stream shall be restored to their original condition.
	Restoration shall include the revegetation of stripped or exposed work and/or mitigation areas with vegetation native to the area.
	The work areas for construction shall be flagged to identify their limits within the streambanks. Work areas shall not exceed 100 feet upstream or 100 feet downstream of the centerline of the project area. Vegetation shall not be removed or intentionally damaged beyond these limits. Construction areas, access ramps, and roads shall be flagged and restored as specified above
	In areas of temporary disturbance, where vegetation must be removed, native trees and shrubs, with diameter breast heights (dbhs) of 2 inches or less, shall be cut to ground level with hand operated power tools rather than by grading. No replanting will be required for vegetation of this size and type if it is cleared in this manner. There should be no cutting or removal of native trees 4 inches or greater (diameter at breast height – dbh), except willows, for which there should be no cutting or removal of trees 6 inches or greater dbh.
	If any oaks (*Quercus* spp.) and sycamores (*Platanus* spp.) must be removed they shall be replaced in kind. The replacement ratios (using rooted plants in liners or direct planting of acorns) for plants which are to be removed shall be as follows: plants less than 5 inches dbh shall be replaced at 3:1; plants from 5 to 12 inches shall be replaced at 5:1; trees from 12 to 24 inches shall be replaced at 10:1; trees from 24 to 36 inches shall be replaced at 15:1; all oaks greater than 36 inches shall be replanted at a ratio of 20:1. The replacement ratio for damaged trees shall be 2:1 for plants with dbh less than 12 inches. The replacement ratio for damaged trees shall be 5:1 for plants with dbh greater than 12 inches.

Table 7-1 Best Management Practices for Construction and Maintenance Activities

Category	Specific Practice(s)
Equipment and Access	Staging/storage areas for equipment and materials shall be located outside of the stream and away from storm drain inlets.
	Vehicles should be clean and free of any weed seeds prior to arriving at the work site to prevent the introduction or spread of noxious weeds. No fueling, repair, or vehicle washing shall be performed in the stream channel or in areas at the top of the channel bank that may flow back into the stream channel. No washing of vehicles should occur at the work site. No fueling or equipment servicing should be done within 50 feet of the edge of the riparian zone. For stationary equipment (i.e., pumps and generators) that must be fueled onsite, containment shall be provided in such a manner that any accidental spill of fuel shall not be able to enter the watercourse or contaminate sediments that may come in contact with the water.
	Where technically feasible, vehicles and heavy equipment shall not be driven or equipment operated in water covered portions of the stream channel, or where wetland vegetation, riparian vegetation, or aquatic organisms may be destroyed, except as necessary to complete the authorized work. When technically feasible, restrict construction activities to scoured areas or to areas dominated by non-native vegetation to avoid damaging native trees and shrubs.
	Where technically feasible, the use of heavy equipment shall be avoided in a channel bottom with rocky or cobbled substrate. Instead, manual labor should be used whenever practical. If manual labor in rocky substrate is not feasible, a rubber tire loader/backhoe is the preferred vehicle by the Services and the amount of time this equipment is stationed, working, or traveling within the creek bed shall be minimized
	Access to the work site shall be via existing roads and access ramps, unless otherwise specified or approved by the Services. If no ramps are available in the immediate area, a ramp should be constructed in the footprint of the project. Any temporary ramp shall be removed upon completion of the project. Where feasible, ramps should be graded within the elevated bank area, down to but not in the channel bottom.
	Vehicles may be driven on the streambed to traverse the distance to the work site from the access point, and in the immediate vicinity of the work area, and only as necessary to accomplish the authorized work.
	When temporary access is removed, remaining disturbed soil shall be stabilized and seeded with appropriate native seed mix immediately after work completion. If a stream's low flow channel, bed or banks have been altered during operations, channel topography and geometry shall be restored to pre-project conditions to the extent possible, without creating future erosion problems.
Fill and Spoil	Fill shall be limited to the minimal amount necessary to accomplish the activities. Fill construction materials, other than on-site alluvium, shall consist of clean silt-free gravel or river rock.
	Rock riprap may be used to repair eroded slopes that previously contained riprap, allowing for in-kind replacement or repair of existing facilities. Material for backfilling an eroded slope area may be obtained from onsite alluvium.
	Where feasible, to facilitate recovery of vegetation and provide additional protection from erosion on ungrouted riprap banks, the Operator shall place branches from willow trees into the open toe-trench and within the wick zone of the shaped sideslope, prior to placing the filter rock and unconcreted armor rock.
	Spoil storage sites shall not be located within a stream, where spoil can be washed back into a stream, or where it will cover aquatic or riparian vegetation. Upslope erosion control BMPs (i.e., blankets/geotextile fabrics, coir fabric/netting, mulching, planting, silt mat, etc.) shall be used to protect and stabilize stockpiles and exposed soils to prevent movement of materials. Avoid placing temporary spoil stockpiles at the top of unstable slopes or at the edges of slopes. Remove temporary stockpiles to permanent disposal locations before the rainy season or, if work is conducted during the rainy season, as soon as feasible and before the next rain storm.

7.4.5 Measures Recommended by the Draft Southern California Steelhead Recovery Plan

In July 2009 the National Marine Fisheries Service (NMFS) released the draft Recovery Plan for the endangered Southern Steelhead (NMFS 2009). Recommendations for the recovery of this Distinct Population Segment for the Ventura River watershed include a number of best management practices and actions that in the view of the NMFS would lead to the recovery of the species in Southern California. Inclusion of these recovery actions can help assure that projects defined within the watershed management plan are consistent with the requirements for the federal endangered species act. Recovery actions (from Table 8-6 in NMFS 2009) include:

- Conduct hydrological analysis(groundwater).
- Develop and implement a groundwater monitoring program.
- Develop and implement a water management plan.
- Develop and implement a restoration and management plan for the Ventura River Estuary.

Review development and management plans for all recreational areas (e.g., Emma Wood State Beach, City of Ventura Seaside Wilderness Park, E.P. Foster Memorial Park, Matilija Reservoir, Camp Comfort) to provide for the restoration and protection of the Ventura River Watershed, estuary, Coyote Creek, Matilija Creek, San Antonio Creek and riparian/floodplain area. Develop and implement an integrated wildland fire and hazardous fuels management plan, including monitoring, remediation and adaptive management, to reduce potentially catastrophic wildland fire effects to steelhead and their habitat and preserve natural ecosystem processes (including sediment deposition)

- Develop, adopt, and implement land-use planning policies and standards.
- Relocate agricultural development.
- Relocate livestock grazing and water sources.
- Develop and implement a plan to minimize disturbance of instream habitats and riparian vegetation.
- Develop and implement a flood control maintenance program.
- Develop and implement a plan to restore natural channel features where feasible.
- Develop and implement a plan to vegetate levees and minimize herbicide use near levees.
- Develop and implement a non-native species monitoring program.
- Develop and implement a plan to assess the impacts of non-native species and develop control measures.
- Develop and implement a public educational program on non-native species impacts.
- Review and modify applicable County and/or City Local Coastal Plans.
- Develop and implement a public educational program.
- Review U.S. Forest Service Los Padres National Forest Land Management Plan (Southern California National Forest Vision, Forest Strategy, and Design Criteria).

- Relocate roadways outside of riparian corridor and restore abandoned roadways.
- Retrofit storm drains to filter runoff from roadways and developed areas.
- Develop, adopt, and implement urban land-use planning policies and standards.
- Review California Regional Water Quality Control Board Central Coast Region Watershed Plans and modify applicable stormwater permits.
- Review, assess and modify if necessary all National Pollutant Discharge Elimination System (NPDES) wastewater discharge permits (e.g., OVSD Wastewater Treatment Facility).
- Develop and implement a watershed-wide sediment management plan.
- Develop and implement a plan to minimize runoff from agricultural activities.
- Develop, adopt, and implement recreational land-use planning policies.
- Physically modify or remove passage barriers in the Ventura River, Matilija and San Antonio Creek sub-watersheds to allow unimpeded volitional migration of steelhead to upstream spawning and rearing habitats.
- Physically remove Matilija Dam to allow unimpeded volitional migration of steelhead to upstream spawning and rearing habitats.
- Review, assess and modify, if necessary, residential wastewater septic treatment facilities.
- Review and modify aggregate mining operations.
- Develop and implement a plan to remove and maintain quarry and landslide debris from the channel.

Chapter 8

Future Actions to Improve Water Sustainability and Ecosystem Functions

8.1 Recommended Actions

Based on the information contained in the previous chapters, the following actions are recommended to improve the sustainability of water resources, improve ecosystem functions, and facilitate development of the watershed plan.

8.1.1 Watershed Management Plan

Based on lessons learned from review of other applicable plans, the recommendations (in Chapter 5) are summarized as follows:

- Identify the intended audience and provide appropriate content.
- Engage watershed stakeholders.
- Clearly define and state the plan's goals and objectives.
- Focus the scope of the plan.
- Focus on issues where stakeholders can make a meaningful difference.
- Work with regulatory programs.
- Prioritize projects that can meet the plan's objectives.
- Identify mechanisms and a process to gauge progress towards plan implementation.

8.1.2 Stakeholder Involvement

The creation of the Ventura River Watershed Council provided a forum for discussion of issues at the watershed scale. In addition, the implementation of the "Watershed U" expanded awareness of watershed issues and generated substantial interest in how individual actions could improve watershed conditions. To enhance and extend stakeholder involvement:

- Continue meetings of the Watershed Council and consider extending invitations to relevant organizations or entities that have not participated regularly.
- Improve and regularly update the Watershed Council's webpage, to provide a consistent source of meeting notices, agendas, and other relevant information and consider providing links to relevant information for other organizations and groups involved in watershed restoration.

- Build upon stakeholder interest by publicizing meetings and workshops that provide useful information for residents and land-owners, such as: water conservation, stormwater management, or watershed-friendly gardening.

8.1.3 Watershed Coordinator

Without a specific individual or entity responsible to assure an ongoing dialog, making progress towards resolution of issues in the watershed will be difficult. Although it has been suggested that the current Watershed Coordinator will work to secure future grants that would continue to fund the position indefinitely, this concept is not assured. It does not appear likely that alternative funding sources will be available for all of the coordinator's current responsibilities. Instead, it is more likely that funding might be available for more focused studies, which might limit the ability of the coordinator to work on a broad spectrum of issues. To assure long-term funding of the position:

- The Ventura River Watershed Council and the District should work together to identify a mechanism(s) to assure continued funding of a watershed coordinator.

8.1.4 Data Gaps

Various water resource data gaps have been identified, which limit the potential for assessment of long-term trends in groundwater level or development of a water budget. However, the scope, cost and priority of addressing these data gaps have not been identified, which limits their potential for implementation. To develop a conceptual plan to address water resources data gaps:

- The District should convene a technical advisory group to assess and prioritize data gaps that limit development of a comprehensive water budget, with input from the Ventura River Watershed Council.

8.1.5 Ventura River Groundwater Management Plan

The groundwater budget report developed by DSB&A outlined an approach for the development of a groundwater management plan for the Ventura River basins, and suggested that the Ventura River Watershed Council could serve as the sponsoring entity for that effort. However, it is not clear that the Watershed Council has the resources or technical expertise to develop and implement such a plan.

- The Ventura River Watershed Council should conduct a facilitated discussion about the opportunities and constraints for development of a groundwater management plan and forward their recommendations to the Watershed Protection District and all public and private water purveyors that utilize groundwater.

8.1.6 Water Budget

A watershed-wide water budget could be used to determine whether the water resources in the Ventura River watershed are sufficient to meet total water demand. To promote development of a watershed water budget:

- The technical advisory group convened by the Watershed Protection District should develop an outline of the scope of work for a water budget and identify options to fund development

of the water budget, including improved estimates of water demand, with input from the Ventura River Watershed Council.

8.1.7 Matilija Dam

Removal of the Matilija Dam has been the subject of study and discussion for many years, but progress has been slow, in part due to insufficient federal funding. Following completion of the Feasibility Study by US Army Corps of Engineers, issues arose concerning the Corps' preferred solution, which would move sediment via a slurry pipeline to several downstream sites. The Matilija Dam Project Fine Sediment Study Group (Study Group) was subsequently convened to reach consensus on how to move the project forward, which identified several options (such as re-routing water around the dam) that could require a non-federal fund source (e.g., for additional notching of the dam). To keep the proposal moving forward:

- The entities involved in the Study Group should convene a technical advisory group to develop a scope of work for technical studies that would determine the feasibility and cost of implementing the alternative options recommended in the Study Group's Final Report.

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Chapter 9

Flood Management Issues in the Watershed

A number of characteristics of the Ventura River watershed associated with flood management are described in Chapter 2 of this report, including precipitation (Section 2.1.2); topography (Section 2.3); fires (Section 2.5); surface water flows and flooding, including the roles of Matilija and Casitas reservoirs and the Robles Fish Passage Facility (Section 2.6.2); water management facilities, including debris and detention basins (Section 2.9.1); and flood protection levees (Section 2.9.3). This section provides an expanded discussion of flood management issues, including the following:

- Nature of flood hazards.
- History and consequences of flooding in the watershed.
- Areas at risk of flooding.
- Identified deficiencies in flood management structures.
- Proposed flood management improvements.
- Revenue sources to implement flood management projects and programs.
- Flood protection and floodplain management measures and policies that are relevant to the watershed.

9.1 The Nature of Flood Hazards

The Ventura River watershed is vulnerable to hazards associated with flooding. Prevailing storm patterns, along with steep topography (ranging from sea level to approximately 6,000 feet in the upper portions of the watershed) and the east-west orientation of the mountains, frequently create the potential for significant precipitation. This can result in flooding along stream channels and on alluvial fans, leading to inundation of flood-prone areas.

Since 1992, there have been five flood events that resulted in significant damage and a subsequent Presidential disaster declaration for Ventura County. In addition, damage that is not substantial enough to qualify for a disaster declaration, but may cost county residents, businesses, and taxpayers millions of dollars, occurs with a long-term probability of every 5 years. The risks posed by these hazards will increase as the county's population continues to grow (URS 2005).

Nationwide, floods result in more deaths than any other natural hazard. Physical damage from floods includes the following (URS 2005):

- Inundation of structures by water and sediment, causing damage to structural elements and contents.
- Erosion or scouring of stream banks, roadway embankments, foundations, footings for bridge piers, and other features.

- Impact damage to structures, roads, bridges, culverts, and other features from high-velocity flow and from debris carried by floodwaters and road closures. Debris may also accumulate on bridge piers and in culverts, increasing loads on these features or causing overtopping or backwater effects.
- Destruction of crops, erosion of topsoil, and deposition of debris and sediment on croplands.
- Release of sewage and hazardous or toxic materials as wastewater treatment plants are inundated, storage tanks are damaged, and pipelines are severed.
- Damage to cultural or historic artifacts, such as the aqueduct from the Mission period.
- Damage to Native American sites that are often found along streams and creeks.
- Damage to wildlife and fish habitat, destruction of nesting or breeding grounds, and injury to or death of wildlife.

Floods also cause economic losses through closure of businesses and government facilities, disrupt communications, disrupt the provision of utilities such as water and sewer, result in excessive expenditures for emergency response, and generally disrupt the normal function of a community (URS 2005).

Ventura County typically receives most of its rain between November and March. The average annual precipitation ranges from 15.1 inches at the coast to 28.8 inches in the mountains northwest of Ojai. Floods typically occur during the season of highest precipitation, particularly during heavy rainfalls when the ground is saturated, or in the first few years following a fire. Prevailing weather patterns during the winter and the topography and orientation of the mountain ranges in the northern half of the county combine to produce extremely high-intensity rainfall. Based on information available through WY 2005, the peak historic rainfall intensity recorded by a Ventura County rain gage occurred on February 12, 1992, when a rate of approximately 4.04 inches per hour was observed during a 15-minute period at the Wheeler Gorge gage approximately 3 miles northeast of Matilija Dam (URS 2005).

Such rainfall intensities can produce flooding, particularly in small watersheds with steep slopes, saturated soils, and sparse vegetation, where runoff collects quickly and creates the potential for local flash floods. *The National Weather Service defines a flash flood as one in which the peak flow travels the length of a watershed within a 6-hour period.* These floods arise when storms produce a high volume of rainfall in a short period of time. They often strike with little warning and are typically accompanied by high-velocity flows (URS 2005).

9.1.1 Flood History and Consequences

Damaging floods in Ventura County were reported as early as 1862 and on average, floods causing substantial damage have a long-term probability of occurring every 5 years. A 1945 report by the District reported that floods of sufficient magnitude to cause extensive damage occurred in 1862, 1867, 1884, 1911, 1914, 1938, 1941, 1943, and 1944 (Warren 1945, as cited in URS 2005). Major floods on the Ventura River and peak discharges are listed in Table 2.6-4.

The 1938 flood caused an estimated $1.3 million in damage to homes, businesses, agricultural land, transportation facilities, and utilities in the Ventura River area. In the City of Ventura, residents were evacuated from their homes as floodwaters flowed through the west end of the

city. Live Oak Acres also was heavily damaged, along with the Foster Park diversion works and oil field equipment north of the City of Ventura (FEMA 2010).

The 1943 flood threatened the west end of the City of Ventura. The flows did not, however, overtop the channel banks, and evacuation was not required. People were evacuated from their homes in Live Oak Acres, and rail and highway traffic were disrupted when landslides and washouts blocked transportation arteries (FEMA 2010).

Flood damage was estimated in excess of $16 million in the Ventura River watershed during the January and February 1969 floods. Major watercourses throughout the watershed were severely eroded or aggraded, depending on streambed slopes. Debris and boulders carried by flood flows from the mountains surrounding the Ojai Valley resulted in reduced channel capacities and bank overflow through orchards and residential areas (FEMA 2010).

The 1978 flood (the largest recorded on the Ventura River) caused extensive damage to roads, bridges, sewer systems, agricultural property, and flood control facilities in the upper Ventura River watershed. Traffic was disrupted by extensive road damage that occurred throughout the watershed. Some flood channels filled with debris and changed their course. Substantial damage to residential property occurred in Casitas Springs, Live Oak Acres, and Hawthorne Acres (FEMA 2010).

9.1.2 Areas at Risk of Flooding in the Ventura River Watershed

9.1.2.1 Adjacent to the Ventura River

Although the District and Corps have implemented various structural improvements along the Ventura River and several tributary streams, the potential for flood hazards still exists along the Ventura River and at other locations in the watershed. Reclamation's 2007 study, *Hydrology, Hydraulics and Sediment Studies of Alternatives for the Matilija Dam Ecosystem Restoration Project*, provided a summary of the areas at risk for hazards associated with flooding along the Ventura River, identified by reach and river mile (RM). These are briefly described below.

Reach 6b – RM 16.5-15.0

Reach 6b begins immediately downstream of Matilija Dam and extends downstream to the canyon mouth. This reach contains little development except the "Matilija Hot Springs" facility. While events do not inundate the swimming pool itself, flows above the 50-year event inundate the lower grounds (Reclamation 2007).

Reach 6a – RM 15-14.15

Reach 6a begins at the canyon mouth and extends downstream to Robles Diversion Dam. There are at least two houses situated along the south bank of the river on the floodplain surface–one upstream and one downstream of the Camino Cielo Bridge. There are nine structures that appear to be primarily vacation cabins, located upstream of the Camino Cielo Bridge on the north bank of the channel. They are located at a variety of elevations; at least five of these are less than 1 foot above the floodplain surface, and many are located within 50 feet of the channel bank. These structures have a considerable risk of inundation. All but the structures on the high terrace are within the 100-year floodplain (Reclamation 2007).

In the Meiners Oaks area, approximately 20 structures are located along Oso Road and North Rice Road between RM 14.4 and 14.15 within Reach 6a. All of the structures are constructed at grade, with no significant first floor elevation above the ground (Reclamation 2007). According to the latest Digital Flood Insurance Rate Map (1-20-2010 DFIRM), this area is in the AE Hazard Zone. (An AE Hazard Zone is an area subject to inundation by the 1-percent-annual-chance flood event determined by detailed methods. Base Flood Elevations are shown. Mandatory flood insurance purchase requirements and floodplain management standards apply).

The Robles Diversion Dam is located at the end of Reach 6a. The diversion crosses the Ventura River channel and is located within the 100-year floodplain (Reclamation 2007).

Reach 5 – RM 14.15 – 11.27

Reach 5 starts from downstream of Robles Diversion Dam and continues to the Baldwin Road Bridge. There is no functional levee in this reach. South of Meyer Road, a stable, residence, and appurtenant structures are located at grade with no significant first floor elevation above the 100-year floodplain (Reclamation 2007).

Reach 4 – RM 11.27 – 7.93

Reach 4 starts from downstream of Baldwin Road Bridge and continues to the confluence with San Antonio Creek. The Live Oak Acres Levee begins at RM 9.39 on the right bank upstream of the Santa Ana Boulevard Bridge and extends along the populated area of Live Oak Acres to approximately RM 10.23. The levee itself is joined to the fill of Burnham Road at the upstream end by the Riverside Dike, reducing the potential for the levee to be overtopped from the upstream end. Hydraulic modeling indicates this levee would contain a 100-year flood; however, the Santa Ana Boulevard Bridge creates a flow constriction that could result in backwater upstream of the bridge, thereby increasing the potential for the levee to be overtopped (Reclamation 2007).

Reach 3 – RM 7.93-5.95

At least 50 mobile homes in Casitas Springs are located close to the channel at RM 7.85, where there is no protective levee. The channel at this location is less than 10 feet deep, and extensive vegetation is present. The Casitas Springs Levee starts on the left bank at approximately RM 6.84 and extends upstream to approximately RM 7.77. Numerous structures are located on Ranch Road, Edison Drive, and Sycamore Drive at Casitas Springs, but the levee does not provide sufficient protection from a 100-year flood. At least three residences are located on the east bank of the river downstream of Casitas Vista Bridge (~ RM 6.8). Foster Park is located within the 100-year floodplain and is at risk of flooding (Reclamation 2007).

Reach 2 – RM 5.95-0.6

Along this reach of the river, numerous residences, businesses, a school, the Ojai Valley Wastewater Treatment Plant, and the City of Ventura Water Filtration Plant are located on the west side of the channel. These structures are all located in or near the 100-year floodplain. The Ventura Levee extends from the Pacific Ocean at RM 0.05 to RM 2.37. Hydraulic modeling indicates that flood flows up to a 500-year flood would be confined to the main channel on the west side by the Ventura Levee (Reclamation 2007).

9.1.2.2 San Antonio Creek Watershed

The NRCS conducted a study (NRCS 2010) of the San Antonio Creek watershed to evaluate flood hazards in rural areas that are not mapped by FEMA. The upper reaches of the San Antonio Creek watershed include canyons with steep terrain that can produce large volumes of debris and sediment, which is then discharged into the Ojai Valley, including alluvial fans located at the base of canyons. The NRCS found that frequent flooding resulted in erosion and deposition in the San Antonio Creek watershed, negatively affecting agriculture, residences, wildlands adjacent to riparian areas, infrastructure (including residences temporarily isolated by washed-out stream crossings), and critical habitat for steelhead.

Numerous orchards adjacent to the stream have non-engineered levees and in some areas, ditches, used to direct overland flood flows around and away from orchards and structures. However, even with these measures, damages from flooding often adversely affects citrus groves, roadways, and structures located on alluvial fans and floodplains. Floods in alluvial fans are highly unpredictable because they tend to break through existing channels and form new channels in loose fan sediments, delivering flood flows to unexpected locations. These conditions are exacerbated by channel obstructions in some areas (NRCS 2010).

On the floodplains and lower alluvial fans of the San Antonio Creek watershed, stream channels are well-defined, but tend to meander. Streambanks in these areas are formed from coarse cobble material, gravels, and sands received from upstream land areas, which are easily eroded. When debris and sediment are deposited in the stream channel during high flows, subsequent flows can be directed into the stream banks, causing erosion (NRCS 2010).

The channel of San Antonio Creek downstream of the City of Ojai is relatively confined, with limited floodplain development and sediment storage. Woody riparian vegetation along the lower portion of the creek is well established and helps promote a stable stream profile, although the storms of January 2005 caused widespread flooding and bank erosion along this reach (NRCS 2010).

9.1.2.3 Cañada de San Joaquin

Cañada de San Joaquin is a tributary to the Ventura River and flows in an east-west direction, draining a 1.5-square-mile drainage area north of the City of Ventura. Because the existing drainage facilities upstream of Highway 33 provide between a 4-year to 40-year level of flood protection, the adjacent areas experience flooding in larger storm events. The District has developed a pre-design project to address the deficiencies through the construction of new facilities that can accommodate projected flows from a 100-year event if the benefit/cost ratio warrants it (Kasraie Consulting 2012). This pre-design project will be completed by June 2012.

9.2 Identified Deficiencies in Flood Control Structures

Structural flood protection measures in Ventura County include dams, levees, debris and detention basins, groin fields, rock revetments, and the channelization of some watercourses. These measures are intended to provide partial or complete protection from the 100-year flood event, which is defined as having a 1 percent chance of annual recurrence (FEMA 2010). Flood protection structures on the Ventura River are described in Chapter 3 and include debris and

detention basins and dams (Section 2.91), and three levees (Section 2.9.3): Ventura Levee (VR-1), Casitas Springs Levee (VR-2), and Live Oak Acres Levee (VR-3).

9.2.1 Levee Certification

FEMA is undertaking a nationwide effort to have levee owners certify existing flood control levees. As part of this effort, the District is evaluating the VR-1 and VR-3 levees and preparing documents for the certification process based on FEMA's regulatory requirements as identified in Title 44 of the Code of Federal Regulations (CFR), Section 65.10 (44 CFR 65.10). FEMA did not request that the VR-2 levee be included in this process because a Letter of Map Revision (LOMR) based on a District project was underway at the time the Ventura River levees underwent the initial screening process. A FEMA LOMR modifies the effective Flood Insurance Rate Map for the community.

Certification criteria are as follows:

- Design criteria (freeboard, closures, embankment protection, embankment and foundation stability, settlement, and interior drainage).
- Operations plans and criteria (for closures and interior drainage).
- Maintenance plans and criteria.
- Actual certification requirements (i.e., as-builts, forms, documentation, and data).

As part of the Phase 1 process, Tetra Tech and AMEC (2009a and 2009b) were contracted by the District to evaluate the VR-1 and VR-3 levee systems and to recommend a levee categorization to facilitate the levee certification. Levee categorizations are as follows:

- Category 1 – Levees meet 44 CFR 65.10 requirements and all data or complete documentation is available.
- Category 2 – Levees may meet 44 CFR 65.10, but additional data or documentation is needed.
- Category 3 – Levees do not currently meet 44 CFR 65.10.
- Not a Levee – Based on physical conditions, an estimated low water surface elevation, no special flood hazard area has been delineated, and/or the structure was not built to provide flood protection.

A levee that is assigned a Category 1 or 2 rating will be further evaluated in the Phase 2 or 3 processes, respectively, in order to finalize its certification status. A levee that is assigned a Category 3 rating will require a Pre-Design Study in the Phase 4 process and implementation of the required improvements to achieve certification status.

9.2.1.1 Ventura Levee (VR-1)

The field investigation identified several critical issues that must be resolved prior to certification. These include deficient toedown protection (against erosion at the base of the levee), encroachments into the landward side embankment upstream of the ocean outlet and upstream of Main Street, and the presence of extensive vegetation within the channel.

Engineering analyses will also need to be performed to verify that this levee meets the National Flood Insurance Program (NFIP) Section 65.10 requirements (Tetra Tech and AMEC 2009a).

Approximately 1.4 miles of the Ventura River thalweg[2], from Station 64+00 to Station 138+50, is either below or very close to the existing levee toedown. There are no geological features, such as bedrock, or manmade features, such as rock groins, that would prevent the thalweg of the river from migrating toward the levee and undermining the toedown. Thus, the levee has the potential to fail from toedown undermining during major flood events (Tetra Tech and AMEC 2009a).

Based on the review and comparison of existing data and observations from the field investigation, it was recommended that the VR-1 levee system be classified as a Category 3 Levee (Tetra Tech and AMEC 2009a).

9.2.1.2 Live Oak Acres Levee (VR-3)

The field investigation identified several critical issues that must be resolved prior to certification. The most significant issues are the revetment failure, scouring/bank stability, and the presence of extensive vegetation. Engineering analyses will also need to be performed to verify that this levee meets the NFIP Section 65.10 requirements. Based on the review of existing data and observations from the field investigation, it was recommended that the VR-3 levee system be classified as a Category 3 Levee (Tetra Tech and AMEC 2009b).

Reclamation (2007) prepared a hydrology, hydraulics, and sedimentation study to support the design and/or improvement of two levees along the Ventura River in order to mitigate flood impacts from the proposed Matilija Dam Ecosystem Restoration Project. In this study, Reclamation noted that hydraulic modeling indicates the Live Oak Acres Levee would contain the 100-year flood, but the 500-year flood would overtop the levee at approximately RM 9.47 because of the backwater caused by the Santa Ana Boulevard Bridge. The Live Oak Acres Levee may also be subject to erosion as evidenced by damage caused by the January 2005 flood at approximately RM 9.4.

9.2.2 Santa Ana Boulevard Bridge

The Santa Ana Boulevard Bridge is on the downstream end of the Live Oak Acres Levee, and it is designed to convey the 100-year flood, but the calculated water surface elevation is only about 1-foot below the bridge soffit. Currently, deposition occurs on the upstream side of this bridge, and the County has a program to excavate the riverbed to maintain flow capacity. The bridge creates a constriction in the river, increasing velocities, producing scour around the bridge abutment, and creating a backwater condition upstream. Following the 1998 flood, a large berm was constructed on the east bank, downstream of the bridge, to prevent future erosion. While the rock protecting the berm is too small to eliminate erosion, the berm is over 50-feet-wide and will significantly delay erosion (Reclamation 2007).

[2] The thalweg is the line defining the lowest points along a river bed.

Another berm is located on the west bank of the river and extends for approximately 250 feet downstream of the bridge. This berm protects some buildings, but it is constructed of river bed material and can be easily eroded during high flow events (Reclamation 2007).

9.2.3 Live Oak Creek Diversion

Reclamation's 2007 study also provides relevant information on Live Oak Creek Diversion, which enters the Ventura River from the west side just upstream of Live Oak Acres at approximately RM 10.15. Live Oak Creek Diversion has an invert elevation of approximately 457.5 feet where it crosses under Burnham Road (All elevation references in this section are based on the 1988 North American Vertical Datum [NAVD]). It was designed to carry the 100-year flood; however, the design assumed an elevation of 456.5 feet at the confluence with the Ventura River. Since that time, the drain exit has aggraded to 458 feet, which has created a slight adverse slope in the drain from Burnham Road to the Ventura River, and aggradation is expected to continue. Because the 100-year flood surface water elevation for the Ventura River is estimated at approximately 465 feet at this location, water and sediment from the Ventura River can enter the drain, causing backwater effects and sediment deposition. Conveyance of the drain is likely to be compromised during large storm events.

9.2.4 East Side Vanes

Along the East Bank of the Ventura River, from RM 9.7 to 9.4, several properties are located at the top of a very steep, high terrace that appears to be composed primarily of old alluvial deposits. The base of this terrace may be subject to erosion during high flows, the top of the terrace may erode due to surface runoff. There is evidence of recent bank failure at RM 9.6. Most residences along this reach appear to be built 25 feet or more away from the edge of the terrace, but various fences, utility poles, and other accessory structures are within a few feet of the edge. The County installed protective vanes along this bank in the summer of 2005 to prevent further erosion at the base of the terrace. There are five vanes beginning approximately 1,200 feet upstream of Santa Ana Boulevard Bridge and extending approximately 1,300 feet further upstream. However, the presence of the vanes may increase the probability of erosion of the levee on the west bank of the river (Reclamation 2007).

9.3 Proposed Flood Management Projects

To support ongoing watershed protection efforts, the District developed the IWPP as the culmination of a series of long-range planning efforts. The objectives of the IWPP include the provision of a systematic process for the inclusion of projects into the District's Capital Improvement Program (CIP) and to improve the long-range District planning process (District 2011a).

The IWPP process achieves these objectives by gathering information about existing flooding, operations and maintenance, drainage facility deficiencies, access, and environmental concerns in the District's jurisdictional areas and developing a prioritized project list based on the gathered information. Projects are proposed to address identified issues, and are ranked relative to each other using a scoring matrix. The highest priority projects are the subject of further study. If the proposed alternative is found to be cost-effective and environmentally friendly, the project can be selected for inclusion in the CIP, and funded in priority order as resources become available.

The District's current CIP includes numerous projects to address flood management issues in the Ventura River watershed (Table 9-2), including several discussed above.

Table 9-2 Projects included in the Capital Improvements Program

No.	Project Name	Status	Description
1	Cañada de San Joaquin 30 Percent Pre-Design	In progress, to be completed by June 2012	Evaluate deficiencies, develop alternatives to correct flooding problems, and provide a 30 percent pre-design for selected alternative.
2	Cañada Larga Channel Improvements, State Highway 33	In the CIP, low priority pending funding	Excavate approximately 1,500 linear feet of channel and/or construct levee.
3	Dent Canyon Basin Retrofit	Completed September 2011	Modify outlet pipe and emergency spillway of the existing debris basin. Objective is to bring the basin outlet facilities up to District standards.
4	Dron Creek Detention/Debris Basin	In CIP, pending funding	Construct debris basin(s) in the canyon(s) north of Gridley Road. Additional feasibility study will be required to develop a detailed design concept and to determine the potential for causing erosion in the downstream channel.
5	East Ojai Alluvial Fan Flood Insurance Study (FIS) CTP	In CIP, slated for completion by June 2012	Prepare an FIS as part of a FEMA-granted CTP to delineate the floodplain more accurately.
6	Fox Canyon from Southern Pacific Rail Road to Grand Avenue Channel Improvements	In CIP, pending funding	Replace the existing concrete channel and increase flow capacity to mitigate local flooding.
7	East Ojai Avenue from Fox Street to Park Road (Lateral to Fox Canyon)	In CIP, pending funding	Upgrade the 1,156-ft long underground 36-inch corrugated metal pipe that is undersized to carry 255 cfs (100-year flood flow) from the area.
8	Fresno Canyon Flood Mitigation	In CIP, waiting for FEMA Hazard Mitigation Grant Program funding	Construct a bypass of reinforced concrete pipe from upstream of Highway 33 to the Ventura River. The purpose of this project is to provide 100-year flood protection from Fresno Canyon to the community of Casitas Springs.
9	Happy Valley Drain CTP FIS	In CIP, slated for completion by June 2012.	Prepare an FIS of the upper reach of Happy Valley Drain in the City of Ojai as part of a FEMA-granted CTP to delineate the floodplain more accurately.
10	Howard Avenue Drain/Oakview	In CIP, pending funding	Extend the 36-inch drain pipe from Howard Avenue upstream 1,060 feet to Brandt Avenue within the existing 12-foot-wide easement to collect stormwater.
11	Lower Ventura River, Cañada de San Joaquin CTP FIS	In CIP, slated for completion by December 2012	Perform an FIS of the lower reach of the Ventura River, including the Cañada de San Joaquin tributary, in the City of Ventura (an element of FEMA CTP agreement).
12	Matilija–Giant Reed Removal, State Highway 150	In progress, expected completion at end of 2012	Removal of *Arundo donax* and other invasive species from the mainstem of the Ventura River. This project is a mitigation component of the Matilija Dam Ecosystem Restoration Project.
13	Matilija Dam–California River Parkways Trailhead	Construction completed, project files will be closed by April, 2012	Construction of earthen equestrian trail, paved and concrete walkway, equestrian parking and staging area, parking bays, two American Disability Act compliant parking spaces, driveway approaches, fences, metal pipe.

Table 9-2 Projects included in the Capital Improvements Program

No.	Project Name	Status	Description
14	Matilija Dam–Camino Cielo Bridge Replacement	Work on hold pending funding	Replace the existing bridge at Camino Cielo. This project is a mitigation element of the Matilija Ecosystem Restoration Project. There are a number of other projects related to Matilija Dam Removal that are on hold pending agreements between the District, State of California, and USACE on technical issues.
15	Matilija Dam–Preliminary Engineering Design	Project schedule based on federal appropriations to the USACE. Local sponsor responsible for 25% of Corps $8 million budget. Subsequent environmental documentation and permitting likely, but unknown at this time.	Preconstruction, Engineering, and Design (PED) to Remove Matilija Dam. The objective is to provide fish passage of the endangered steelhead trout and enhanced habitat quality in the Matilija Creek and reduce flood control maintenance cost.
16	Matilija Dam–Santa Ana Boulevard Bridge Modification	Preliminary design in progress	Add a fourth span to the Santa Ana Boulevard Bridge. This Project is a mitigation element of the Matilija Dam Ecosystem Restoration Project.
17	Matilija Dam Ecosystem Restoration–Live Oak Acres Levee (VR-3)	In CIP, pending funding from USACE and other agencies	Modify and upgrade the existing Live Oak Acres Levee and Floodwall to mitigate impacts from the removal of Matilija Dam.
18	Matilija Dam Ecosystem Restoration–Meiners Oaks Levee	In CIP, pending funding from USACE and other agencies	Construct levee along the left bank of the Ventura River in the vicinity of Meiners Oaks to protect the residents.
19	Ojai Valley Trail Bridge at San Antonio Creek	Construction in progress, expected completion date May 2012	Construction of an equestrian and pedestrian bridge across the San Antonio Creek near the confluence with Ventura River to replace the current low flow crossing. Project enhances fish passage to San Antonio Creek and provides access for pedestrian and horseback riders across the creek during high flows.
20	Prince Barranca, Detention Basin/Channel Improvements	In CIP, pending funding	Revise the preliminary design to construct a detention/debris basin in the canyon to reduce design flood flows to the capacity of the existing flood conveyance facilities.
21	V-1: Ventura River Watershed Assessment and Management Plan	In progress, slated to be completed February 2012	This is a Proposition 50-funded project with a number of elements that include development of a watershed model of the Ventura River watershed using HSPF and development of water budget and groundwater monitoring plan for the lower Ventura River.
22	V-2: San Antonio Creek Spreading Grounds Rehabilitation Project	Construction start is planned for August 1, 2012; 4 month's duration (to be completed by December 1, 2012); all permit work is completed	Increase groundwater storage and recharge in the Ojai Valley Groundwater Basin by rehabilitating four existing, relict spreading ground ponds, and constructing a new intake structure, monitoring well, diversion piping/channels and four passive percolation ponds.
23	San Jon Barranca, System Improvements	In CIP, pending funding	Construct floodwalls upstream of Harbor Boulevard to prevent flooding of San Jon Road and Harbor Boulevard. Construct underground drain downstream of Poli Street. Repair existing pipe invert.
24	Senior Canyon Detention Basin	In CIP, pending funding	Complete a detailed feasibility study and construct a debris/detention basin at the existing basin site. The size of the basin is estimated to be more than 100 acre-feet.

Table 9-2 Projects included in the Capital Improvements Program

No.	Project Name	Status	Description
25	Skyline Drain Stabilizer	In CIP, pending funding, on hold for further evaluation	Evaluate, redesign and reconstruct a concreted rock outlet chute at the downstream end of the existing Skyline Drain Channel.
26	Thacher Creek Channel Improvement at Siete Robles	In CIP, pending funding	Construct channel improvements to provide 100-year level of protection and replace the existing deteriorating, inadequate facility.
27	Ventura River Levee (VR-1) Evaluation and Rehabilitation	In progress, working with consultant and USACE on the best approach for funding mechanism	Complete evaluation of all improvements required to enable certification of the existing Ventura River Levee (VR-1). The objective is to provide 100-year level of flood protection and certify the levee so that FEMA will accredit (recognize) the levee as a certified flood control facility.
28	Ventura River Levee at Casitas Springs (VR-2) Certification and Rehab Pre-Design	In CIP, pending funding	Evaluate the Casitas Spring Levee for certification and prepare a pre-design for rehabilitation of the levee to meet FEMA's 44 CFR 65.10 certification criteria.

9.4 Flood Management Revenue Sources

The District's revenue sources are described in the IWPP (District 2011a). They are derived from property taxes, benefit assessments, and land development fees paid by property owners within the county. The benefit assessment revenues are dedicated to fund operations and maintenance and NPDES permit-related activities. A portion of the property taxes collected within a zone is set aside to fund District administration, overhead, and service functions. The remaining revenues are available for flood management studies and the implementation of projects.

Although funds from other agencies, such as FEMA, and the State of California are sometimes available for District projects, the IWPP process only relies on estimates of property tax and land development fees within an IWPP zone over the long-range planning period. Thus, the funding available for flood management is directly related to the number (and value) of developed parcels and the number of new development projects.

As discussed in Chapter 2, most of the Ventura River watershed is undeveloped open space, with over 75 percent of the watershed classified as rangeland and forest. Development is focused in relatively flat areas, including floodplains, along the Ventura River and tributary streams and the floor of the Ojai Valley (Figures 2.2-1 and 2.2-2). The limited extent of existing development (and new development) results in limited revenue for flood management improvements in the Ventura River watershed. Because traditional structural improvements such as levees, are very costly, the District also works to identify and implement other flood management practices that can reduce hazards in flood-prone areas.

It is also important to note that some areas in the Ventura River watershed subject to flooding are located on alluvial fans. As discussed above under Section 9.1.1.2, San Antonio Creek Watershed, floods in alluvial fans are highly unpredictable, and the District cannot provide cost-effective structural improvements in such areas. In these areas, individual property owners need to be proactive to identify flood hazards and implement measures to reduce risk from those hazards, such as those described below.

9.5 Integrated Flood Management Practices

9.5.1 Overview

Traditionally, flood risk management has relied on physical improvements that divert or reduce floodwaters to avoid damage to lives and property located adjacent to rivers and streams. Recently, the emphasis has shifted to more integrated forms of flood management that include a mix of structural and non-structural methods that minimize development in flood prone areas (e.g., floodplains and alluvial fans). These methods seek to enhance the ability of undeveloped floodplains and other open spaces to absorb, store, and slowly release floodwaters during small and medium-sized events. In addition to flooding along rivers and streams, there is increased recognition that other areas may also be subject to flooding, including alluvial fans, which are found in some portions of the Ventura River watershed.

Integrated flood management is an approach to dealing with flood risk that recognizes the interconnection of flood management actions within broader water resources management and land-use planning; the need to consider existing land use; the value of coordinating across geographic and agency boundaries; the need to evaluate opportunities and potential impacts from a system perspective; the importance of environmental stewardship and sustainability; and the value of rural farms and communities (DWR 2011).

Floodplain management is a major element of this strategy and seeks to: 1) minimize impacts of flood flows; 2) maintain or restore natural floodplain processes; 3) remove obstacles within the floodplain; 4) keep structures or other obstacles out of the floodplain; 5) educate and plan for emergency preparedness; and 6) ensure that floodplain management does not adversely affect flood management operations (California Floodplain Management Task Force 2002).

Floodplain regulation is a key component of floodplain management and includes land use policies that guide the development of areas adjacent to streams, rivers, and coastal areas subject to periodic flooding or inundation. Floodplain regulation may include measures to restrict or prohibit development within floodplains, or provide protection to buildings from potential flood damage (such as flood-proofing). Where development is permitted, measures may require protection of buildings from potential flood damage. Measures to reduce potential impacts to other development, such as requiring that new development result in no adverse flood impacts to existing structures, also are under consideration. This may also include acquisition of land in identified floodplains or easements, which will allow the restoration of the natural, beneficial functions and values of the floodplain. Development of runoff detention requirements for medium and high runoff events keep water resources higher in the watershed for delayed release, maintain the existing drainage system, and reduce the need for capital projects to expand the drainage system capacity.

Development and redevelopment policies include land use practices that are designed to reduce flood risks, reduce the severity of potential floods, and expedite recovery after floods. This may include floodplain regulation (described above), stream protection ordinances, storm water management practices, open space preservation, and watershed management programs. The intent of these practices is to reduce risk to structures by requiring rigorous analysis of flood risk and/or limiting development in flood prone areas (including development of critical facilities such as hospitals, schools, police, fire protection, and wastewater treatment); preserving the

ability of open spaces to absorb precipitation and slowly release runoff; and reducing the extent of impervious surfaces (DWR 2009). Redevelopment policies may include measures that impose conditions on future construction by restricting the size and placement of structures, encouraging reduction of impervious areas, and encouraging the long-term restoration of streams and floodplains.

Housing and building codes include specific measures that reduce flood damage and preserve egress routes during high water events. The codes may include reference to flood proofing, which consists of measures that render buildings and their contents less vulnerable to floods through structural changes to existing buildings and specific design features for new buildings. These modifications or features can include impervious walls (around structures or properties) without any openings, and valves on sewer lines that automatically close from back pressure. Alternatively, the lowest floor could be completely open, consisting of open columns that create a covered patio or storage area that can allow flood waters to pass.

Floodplain function restoration recognizes that periodic flooding of undeveloped lands adjacent to rivers and streams is a natural function and may be a preferred alternative to restricting flood water to the existing low flow channel (DWR 2009). The erosion, transport, and deposition of sediment create a diverse mosaic of floodplain landforms that vary with time. These landforms support different types of vegetation and affect in-stream habitat quality for fish and other aquatic life. They also form side channels that can provide important fish and wildlife habitat. Many plant and animal species evolved life history strategies that allowed them to exploit the temporal and spatial variability associated with the region's Mediterranean climate and variable hydrologic and geomorphic processes (DWR 2011).

Where rivers and streams have been separated from their adjacent floodplains, floodplain function restoration is a technique to restore the natural ability of undeveloped floodplains to absorb, hold, and slowly release floodwaters. To permit seasonal inundation of undeveloped floodplains, some structural improvements may be needed to constrain flooding within a defined area, along with nonstructural measures to limit development and permitted uses within those areas subject to periodic inundation.

As noted above, the management of watershed lands can have a substantial impact on the nature and magnitude of flood events (DWR 2009), including the following:

- Stewardship of agricultural lands can enhance the ability of agricultural and ranch lands to absorb rainfall and runoff, limit soil erosion, reduce the magnitude of some flood events, and enhance recovery after flood events.
- Ecosystem restoration can enhance the ability of open spaces to absorb rainfall and runoff and enhance recovery after flood events.
- Forest management, including preservation of riparian vegetation along streams and maintenance of forest canopy, may reduce soil erosion, and moderate the severity and frequency of some flood events, and also promote recovery after flood events.
- Watershed management can promote the retention of open space and habitat, which may reduce the severity and frequency of flood events and promote recovery after flood events.

Land areas within and adjacent to rivers and creeks are not the only lands exposed to potential risk from flooding in the watershed. Alluvial fans, which are found around the borders of the Ojai Valley, are gently sloping, fan-shaped landforms that are created over long periods of time by the natural deposition of eroded sediment from an upland source.

When alluvial fan flooding occurs it can be very unpredictable, as it does not necessarily occur as the result of large amounts of rain. Often, it is triggered by intense rainfall over short periods of time (Alluvial Fan Task Force 2010). The natural flooding process that drives alluvial fan sedimentation tends to produce thick deposits of sand and gravel, particularly near the apex of the fan, with relatively minor proportions of fine-grained particles. Fine-grained sediment associated with flood flows may be transported to the valley floor.

Alluvial fan flooding differs from flooding along rivers and creeks because the flows in alluvial fan systems are often highly variable and the soils may be highly erosive, which can result in flows that are a mixture of water, rocks, boulders, trees and structural debris. As a result, flood hazards on alluvial fans cannot be managed by traditional flood management measures.

9.5.2 Relevant Flood Management Practices

The challenge in sparsely developed areas such as the Ventura River watershed is to develop effective flood-control/stormwater management practices in a cost-effective manner given the lack of tax base and limited infrastructure. Some of the BMPs included in Section 7.2.1, *County of Ventura Technical Guidance Manual for Stormwater Quality Measures,* can be effective in minimizing damage from flooding. Additionally, self-sufficiency is important in remote areas, and individual property owners and communities can take steps to protect private property from flood damage.

9.5.2.1 General Floodplain Management Strategies

The Association of State Floodplain Managers (ASFPM) has developed a list of recommended measures (ASFPM 2011), which are listed below, along with the rationales for their use:

- **Establish appropriate freeboard requirements in areas subject to flooding**. Freeboard is the single most effective means for reducing flood risk to a structure in the floodplain. Freeboard places the first floor of a structure above the calculated 1 percent flood elevation in order to allow for nature's uncertainty and future changes in the watershed that will increase flood levels. Freeboard is relatively inexpensive to incorporate into development, and typically pays for itself in reduced insurance premiums and prevented flood damage within the first 10 years of a structure's lifetime. Significant Community Rating System (CRS) credit is available for this activity, which leads to lower flood insurance premiums for all policy holders in the community.
- **Promote development design that will reduce flood damage and facilitate emergency vehicular access and/or pedestrian access and evacuation during flood events**. Ensuring that building sites are relatively accessible during floods decreases the likelihood of stranded residents, reduces the need for water rescues which places emergency personnel at risk, and increases public safety.
- **Compensate for the loss of floodplain storage caused by filling in the floodplain, which can result in raising flood elevations, especially with the impact of cumulative fills**.

Floodplains provide the critical and beneficial functions of flood storage, natural habitat, and water quality. The placement of fill impairs these functions and should be avoided. Where some placement of fill is unavoidable, requiring compensatory storage can mitigate some of the negative impacts of floodplain fill.

- **Protect critical facilities and development against damage, and minimize the potential loss of life from flooding**. Facilities that provide critical services, or services that are depended on during storms, should be protected to an even higher standard than other development. Failure to provide flood protection to these types of critical facilities creates severe and unacceptable public safety risk.
- **Track cumulative improvements or damages to structures in special flood hazard areas to ensure that flood protection measures are incorporated**. The vast majority of flood damages to structures amount to less than 50 percent of the value of the structure. Without cumulative substantial damage/improvement provisions, the cycle of flood-repair-flood is typically never broken by mitigating risk. The NFIP Increased Cost of Compliance provisions (which provide added funds to substantially damaged flood insurance claims for mitigating the structure) are most effective in communities with cumulative provisions.
- **Provide guidelines for the placement of fill in special flood hazard areas.** Nearly all floodplain filling activities create negative consequences for adjacent areas. Improperly designed and constructed fill can also jeopardize structures elevated on fill.
- **Delineate a larger area within the 1 percent-annual-chance floodplain for flood-flow conveyance and restrict future encroachments that could increase flood levels**. Communities with flood studies based on FEMA's standard floodway encroachment criteria typically see more frequent and more severe flood events because those standards allow the carrying capacity to be reduced by pinching in the floodway until flood levels raise 1 foot, thus causing the allowable development area to encroach into the natural floodway. Base flood elevations and flood insurance premiums do not account for these increases, leaving communities unprotected during the base flood event, and property owners uninsured or under-insured.
- **Ensure proper design and construction of building foundations to protect building structural integrity against the effects of buoyancy, uplift, debris impacts, and other flood forces**. ASCE-24 provides a standard of practice for flood-resistant design and construction in flood-prone areas.
- **Protect property against impacts of increased flood heights due to anticipated future development anywhere in the watershed, especially in rapidly developing areas**. In many cases, flood studies reflect current conditions at best and, more likely, past conditions since the studies often rely on old data. As watersheds are developed, future flood heights are likely to increase. The flood risk criteria used to site and design a project should rely on conditions the location is likely to experience during the project's lifetime, not past or current conditions.
- **Protect the community against flood damage from materials that may block flood flows or which become buoyant, flammable, explosive, or cause other environmental health issues in floods**. Storage of materials is often difficult to regulate since many areas do not require building permits for storage. Stored materials can become waterborne debris during

floods, endangering adjacent properties, and creating potential debris blockages where bridges or culverts exist.

- **Provide a limited use/development set aside area along a stream for flood damage prevention, resource protection, floodwater storage, water quality, pollutant/sediment removal, and natural stream function**. Most floodplain regulations protect lands adjacent to streams with property protection and flooding conditions in mind. Floodplains provide a wide range of natural and beneficial functions, and many of these resource protection functions can only be achieved with setbacks that preserve a riparian corridor adjacent to streams. Significant CRS credit is available for this activity, if it results in floodplain open space.
- **Prevent increased flood flows and limit increased runoff from a proposed development to pre-development conditions, and to maintain floodplains and stream channels by reducing erosion and sedimentation from construction activities in flood hazard areas.** One of the most effective ways to prevent flooding problems from getting worse over time is to limit the changes in watershed hydrology that increase flood flows. Probably the single most effective way to accomplish this is through storm water regulations that limit increases in runoff that result from new development. Significant CRS credit is available for this activity.
- **Ensure subdivisions, including infrastructure and lots, are created and designed to minimize risk of damage to property and potential loss of life from flooding, and minimize the disturbance of floodplain riparian zones.** Avoidance of floodplains is far preferable to setting standards and allowing building in the floodplain. The cost of a typical residential flood insurance policy is approaching $1,000 dollars, and this does not account for public expenses associated with building in the floodplain.
- **Restrict or prohibit uses of the floodplain which are dangerous to health, safety or property in times of flood, or which cause excessive increases in flood stages or velocities.** Avoidance of floodplains is far preferable to setting standards and allowing building in the floodplain. For many types of critical facilities, the tolerance for even minimal flood risk is extremely low, and complete avoidance of the floodplain should be the standard.
- **Provide a means for a community to regulate development in areas at risk to flooding that have not been mapped on FEMA's Flood Insurance Rate Maps**. At best, most flood insurance studies do not map floodplains in watersheds with drainage areas of less than 1 square mile, floodplain widths less than 200 feet, areas of minimal development, and areas with poor drainage not associated with flooding sources. In many undeveloped areas, some larger watersheds may not have been mapped. Estimates are that nationally, over one-third of flood damage occurs outside of mapped floodplains.
- **Protect new horizontal additions (increase in building footprint) from flood damage** by elevating the lowest floor and all heating, ventilation, and air conditioning equipment to the regulatory base flood elevation. Building an addition below flood level is essentially expanding a non-conforming use–a practice that has been prohibited in many contexts.

9.5.2.2 Ventura County Flood Plain Management Ordinance Strategies

Many of the above measures have been incorporated in the Ventura County Flood Plain Management Ordinance (Ordinance 3954) (URS 2005). The following outlines some of the requirements of the ordinance:

- **Establishment of development permit**: Requires developers to obtain a development permit before any construction or other development begins within a Special Flood Hazard Area.
- **Designation of the floodplain administrator**: Requires the floodplain administrator to implement and enforce the ordinance, review permits and other base flood data, notify other agencies of the alteration/relocation of a watercourse, document floodplain development, and interpret Flood Insurance Rate Maps.
- **Standards of construction**: Requires standards for anchoring new or substantially improved structures and manufactured homes, construction materials, flood proofing, and a freeboard requirement of 1 foot above base flood elevation.
- **Standards for utilities**: Requires utilities and facilities such as sewer, gas, electrical, and water systems to be located and constructed to minimize flood damage.
- **Standards for subdivisions**: Requires all subdivision proposals to identify the Special Flood Hazard Area, elevation of the base flood, and elevation of structures and pads.
- **Standards for manufactured homes**: Requires manufactured homes placed outside of a home park or subdivision to be on a permanent foundation such that the lowest floor is 1 foot above the base flood elevation.
- **Standards for recreational vehicles**: Requires that recreational vehicles located within the Special Flood Hazard Area be on the site for fewer than 180 consecutive days, and be fully licensed and ready for highway use.
- Floodways: Prohibits encroachments, including fill, new construction, substantial improvements, and other new development in the FEMA-designated floodway unless certification by a registered professional engineer is provided to demonstrate that encroachments will not result in any increase in base flood elevation during the occurrence of the base flood discharge.

9.5.2.3 Other Flood Control/Stormwater Management Strategies

In combination with the strategies outlined above, reducing flows to storm drains over impervious surfaces is an effective practice, because such flows can overwhelm tributaries, major collectors, and main rivers during storm events. The overall strategy of increasing porous surfaces in the existing land uses coupled with detention/debris basins to slow the flow of runoff to tributaries and mainstems is key to reducing flood events.

Another strategy that could reduce flows involves the District and groundwater management agencies working cooperatively to increase percolation into water recharge areas. Storm channels with natural bottoms are encouraged so that infiltration can take place. Creating overflow areas and ponds along the storm channel could also slow down flow and allow for infiltration. Slowing the flow can change the timing of the storm peak and allow the floodplain to operate more efficiently. Floodplain managers already hold a monthly meeting to discuss strategies for improving floodplain management.

9.5.2.4 San Antonio Creek Water Management Strategies

The Ojai Water Conservation District has offered a conceptual proposal to optimally balance flood control, aquifer basin recharge, and environmental values in the streambeds of San Antonio Creek and its tributaries in the Ojai Valley (NRCS 2010). In summary:

- Basin streambeds provide a means for brief winter rains to replenish a limited groundwater basin.
- Infrastructure development, such as roads, orchards, and homes are impinging on the natural tendency of streams in the Ojai Basin to deposit coarse sediment, meander, and spread out.
- These streambeds also provide habitat and passage corridors for wildlife and are vulnerable to infestation by invasive plant species, such as *Arundo donax*.

The Ojai Water Conservation District proposes the development of a comprehensive, area-wide plan to address the following three concerns in a simultaneous process:

- Optimize and enhance groundwater recharge.
- Protect life and property from floods and erosion.
- Maintain an attractive and sustainable environment along stream channels.

Development of this plan will require additional research and development, and the Ojai Water Conservation District proposes to solicit funds to pursue this plan. Implementation will require a cooperative approach between local entities and regulatory agencies. This approach would be facilitated by a common understanding regarding the importance of optimizing the three concerns (recharge, flood protection, and habitat maintenance) simultaneously.

9.6 Conclusions

As described in this chapter, many areas in the Ventura River watershed are vulnerable to hazards associated with flooding. Prevailing storm patterns and the topography and orientation of the mountains in the watershed frequently create the potential for significant precipitation, which can result in flooding along stream channels, associated floodplains, and on alluvial fans.

To address flood risks, various structural improvements, including dams, levees, and debris and detention basins, have been implemented on the Ventura River and tributary streams. Even with these improvements, flood management deficiencies have been identified at various locations, and the District has proposed projects to provide structural improvements (listed in Table 9-1). The implementation of these projects is, limited by the availability of funding, which is generated by property taxes and land development fees.

Although additional improvements are proposed for implementation along the Ventura River and tributary streams, flood hazards will still remain at other locations in the watershed, including alluvial fans in the Ojai Valley. Because structural improvements are generally designed to address estimated flood flows from a 100-year event, residual flood risks associated with larger storm events are still present in those locations that receive protection from the structural improvements.

To address residual risks along floodplains, the County has adopted a floodplain ordinance that limits development in these areas or imposes conditions upon such development. Building codes also provide regulatory protection, but they only apply to new development or renovations. Thus, property owners, cities, and other jurisdictions located in areas that are at risk for flooding must be aware of and take appropriate precautions to minimize such risks.

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Chapter 10

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Appendix A

Excerpts from Applicable Watershed Management Plans

Appendix A

Excerpts from Applicable Watershed Management Plans

Tujunga-Pacoima Watershed Plan

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- State of the Tujunga Table of Contents
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- Section 3.0: Goals and Objectives

Ballona Creek Watershed Management Plan

- Table of Contents
- Section 3: Goals and Objectives

Calleguas Creek Watershed Management Plan (Phase I)

- Table of Contents
- Excerpt from Introduction

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TUJUNGA/PACOIMA WATERSHED PLAN

April 2008

Prepared by:

The RIVER PROJECT

With assistance from:
PBS&J
Tetra Tech, Inc.
Larry Walker Associates
Everest International Consultants
Los Angeles & San Gabriel Rivers Watershed Council
National Park Service, Rivers Trails & Conservation Assistance Program

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The State of the Tujunga

An Assessment of the Tujunga/Pacoima Watershed

Prepared by The River Project
With funding from the CALFED Bay-Delta Watershed Program

October 2006

CALFED BAY-DELTA PROGRAM

The RIVER PROJECT

Tujunga Watershed Project

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1.6 What This Plan is For

> We can require ourselves to be accountable to our grandchildren and to their great-grandchildren. By making the right choices now, we can promise them bright streams and lasting forests and rewarding employment and welcoming communities.
>
> *—Charles Wilkinson*

This Plan is intended to facilitate positive change. As we undertake to redevelop our region and adapt to change, it can help us shift our planning framework to a more holistic perspective, one that uses the watershed as a basis for decision making.

Shifting existing patterns of development and employing an integrated management context can help us to: increase local water supplies; improve water quality; restore habitat; better manage open-space; make more parks; create new recreational opportunities; and design viable multi-modal transit.

Shifting from the current “silo system” of management to a more cooperative “systems approach” can help us to: partner more effectively; identify necessary funding sources; increase our quality of life; and develop a monitoring plan that will alert us to things that need our attention and tell us what strategies work.

In short, this Plan can show us how to rebuild and sustain a great place.

This plan is intended as a resource for anyone interested in working towards a sustainable future in this region. It aims to educate and inspire and to provide local advocates, urban planners, agencies, elected officials, policy-makers, individual property owners, residents, and youth a road map and a toolkit to do the following:

- Develop a more holistic understanding of the our local environment
- Facilitate widespread watershed awareness and education
- Empower the community to be directly engaged in the decision making process
- Catalyze actions to sustain support and implementation of the Plan over the long term
- Improve coordination and integration among agencies
- Enhance communication and collaboration between agencies and other stakeholders
- Bring together key agencies with other stakeholders to plan the financing and implementation of large-scale watershed retrofitting

This is intended to be a LIVING Plan that will adapt over time through continued participation from and collaboration between all stakeholders. It provides a sound foundation to support consensus decisions and actions now and in the future.

> There can be no purpose more inspiriting than to begin the age of restoration, reweaving the wondrous diversity of life that still surrounds us.
>
> *—E.O. Wilson*

Chapter 3 GOALS AND OBJECTIVES

> The goal of life is living in agreement with nature.
>
> —*Zeno, Greek philosopher*

The following goals and objectives were generated through a collaborative stakeholder process. Each goal includes subgoals and related objectives. Collectively, they reflect a single over-arching goal:

> To revitalize the Tujunga/Pacoima Watershed, balancing water supply, water quality, community open space needs, environmental protection and restoration, and public safety.

Optimize Local Water Resources to Reduce Dependence on Imported Water

- Improve groundwater infiltration:
  - > Develop groundwater management strategy for optimum use of local water resources.
  - > Improve quality and quantity of on-site water recharge to the SFV Groundwater Basin.
  - > Restore natural streams, washes, and floodplains in areas of high soils permeability.
- Reduce dependence on imported water:
  - > Facilitate on-site collection systems for stormwater and graywater.
  - > Expand water conservation programs.
  - > Extend the distribution and range of uses for reclaimed water.
- Integrate groundwater infiltration with other public and/or beneficial uses:
  - > Provide for compatible public activities and uses in infiltration areas.
  - > Restore natural streams, washes, and floodplains and associated habitats.

Improve Surface Water & Groundwater Quality

- Reduce pollutant loads:
  - > Expand source reduction programs.
  - > Implement Best Management Practices.
  - > Implement institutional controls such as water quality zones, urban forestry, product substitution/ source control, and public outreach and education.
- Maximize “nature’s services” before utilizing manufactured solutions:
  - > Reinstate sediment transport to support assimilative capacity.
  - > Increase permeable surfaces throughout the watershed area.
- Implement a citizen-based water quality monitoring program.

Restore Hydrologic Function to the Watershed while Maintaining Public Safety

- Reestablish functional streams:
  - > Restore/acquire functional floodplains.
  - > Restore natural, bioengineered streambanks.
  - > Daylight/reestablish tributary streams where feasible.
  - > Develop sediment management strategy.
  - > Establish meanders as needed to facilitate dynamic equilibrium of sediment transport.
- Design restoration projects to maintain flood protection:
  - > Capture and infiltrate stormwater where it falls to reduce runoff volume in streams.
  - > Acquire gravel pits for stormwater detention.
  - > Remove or elevate structures in floodways.
  - > Implement a flood hazard warning system.

Enhance Quality, Quantity and Connectivity of Native Terrestrial and Riparian Habitats

- Restore, protect, and augment terrestrial and aquatic species habitat:
  - > Create habitat corridors along Tujunga and Pacoima washes.
  - > Restore riparian habitat along historic tributaries where feasible.
  - > Identify, enhance, and restore natural habitat and wildlife corridor between Verdugo and San Gabriel mountains.
  - > Acquire land or conservation easements in ecologically sensitive areas, including along streams.
- Integrate fire and vector management strategies into native vegetation zones.
- Reduce extent of invasive, non-native species.
- Expand use of native plants in landscaping through mandate on publicly-owned lands and through incentives on private lands.

Improve and Increase a Network of Public Open Space

- Augment overall open space network to meet the national standard for park space per capita ratio:
  - > Protect existing open spaces.
  - > Implement a targeted, prioritized program to utilize surplus properties and acquire land from willing sellers.
- Improve connectivity and access to Tujunga and Pacoima washes and the Angeles National Forest using tools such as easements and greenway linkages.
- Develop a design standard for open space that integrates natural resources management with various recreational needs.
- Provide for maintenance and security of parks, open space, and trails.

Create Green Transit Linkages and Recreational Access

- Improve multi-modal transit:
  - > Create a watershed–wide network of pedestrian, equestrian and bicycle routes utilizing BMPs in design.
  - > Connect multi-modal transportation routes to communities, public facilities, transit focal points, greenways, and other open spaces.
  - > Design multi-modal routes for user safety.
- Enhance and expand recreational opportunities to meet needs of local communities:
  - > Determine appropriate recreational uses with local community guidance.
  - > Group activities according to use compatibility.
  - > Provide a diversity of recreational opportunities and experiences within each community.

Promote Watershed Awareness & Increase Stewardship through Public Outreach and Education

- Conduct education and outreach programs to expand appreciation of the natural character of Tujunga & Pacoima Washes and the importance of watershed restoration:
  - > Identify and understand target audiences to develop and deliver most effective outreach and educational programs.
  - > Focus on local eco-system, groundwater/water supply issues, flood safety, sustainable living, and environmental justice.
  - > Develop and deliver an educational curriculum for grades K-12.
  - > Partner with community colleges to gather data, monitor conditions, and implement plan development and also encourage continued participation of local universities.
  - > Use the internet as an informative outreach tool.
- Engage community interest through participation in restoration activities:
  - > Include youth and community groups in watershed restoration activities.
  - > Involve the business community.
  - > Provide opportunities and resources for individuals to participate on their property.
- Protect and interpret natural, cultural, and historic resources.

Implement Watershed-based Planning and Projects

- Implement ordinances and incentives to protect watersheds and streams:
  - > Require “no net gain” of stormwater runoff on developed sites, based on natural conditions.
  - > Create a River Overlay Zone to acquire floodplains opportunistically or through long term programs.
  - > Incentivize multiple-objective developments and BMP integration in private-sector projects.
  - > Develop alternative approaches to land use designations in order to integrate, preserve, and protect natural systems within urban environments.

- Require integrated open space in mixed use, live/work developments:
  - > Recycle underused sites along Tujunga & Pacoima Washes.
  - > Leverage Quimby and other park funds to acquire parkland in developed areas.
  - > Increase park acreage required by General Plan.
- Preserve agricultural zones.

Improve Collaboration among all Agencies, Organizations & Communities in the Watershed

- Institute a comprehensive program to facilitate communication and collaboration:
  - > Involve elected officials and their staff, governmental, regulatory and infrastructure agencies, NGOs, CBOs, professional and business organizations and individuals in a cooperative watershed stewardship program.
  - > Assign a liaison with decision-level capability from each agency to communicate with each other and the stakeholders.
  - > Develop a system that fosters early notification and cooperation amongst all stakeholders prior to all project planning.
- Encourage mutual understanding of the goals, objectives, and roles of each individual agency and organization involved.
- Partner with existing local programs and projects where appropriate.
- Develop a collaborative strategy to finance implementation of the Plan.

BALLONA CREEK

WATERSHED MANAGEMENT PLAN

SEPTEMBER 2004



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CHAPTER THREE

goals and objectives

A. STAKEHOLDER ISSUES OF INTEREST

In January 2002, following a series of "start-up" meetings that began in August 2001, the Ballona Creek Watershed Task Force developed a Draft Procedures and Protocols document (included as Appendix A to this Watershed Plan), which articulated objectives and guiding principles for development of this Watershed Management Plan and described stakeholder roles, guidelines for attendance and participation in stakeholder meetings, decision making, sharing of information and subsequent amendments to the document. The Procedures and Protocols document also include a list of Issues of Interest, which were intended to capture specific project suggestions, hopes and aspirations, doubts and concerns about the planning process that lie ahead. These issues were prioritized by task force members in March 2003 and are listed on the following page.



View from Baldwin Hills

B. WATERSHED PROBLEMS

The Issues of Interest, the minutes of the BCWTF, and other sources permitted identification of several watershed problems, which were generalized under the basic themes of water, land, and planning:

WATER

- Water quality in Ballona Creek, the estuary, Marina del Rey and nearby beaches is degraded
- Ballona Creek (and tributaries) and the estuary do not function as natural hydrologic systems
- Dependence on imported water is high and use of reclaimed water is low



- Aquatic, estuarine and riparian habit is poor and limited in area

LAND

- Terrestrial Habitat is poor and limited in area
- Access to Open Space is limited for many communities
- A comprehensive system of bike trails and hiking paths does not exist
- Public appreciation of the value of native plants and preservation of cultural resources is low

PLANNING

- Planning by individual jurisdictions often does not adequately consider downstream or watershed-wide implications
- Many public projects are planned to achieve single, rather than multiple, benefits
- Planning does not always integrate sound scientific concepts and principles
- Public appreciation of the Ballona Creek Watershed is limited
- Ballona Creek is not recognized as a potential focus of sustainable economic development

1. BCWTF Issues of Interest

BCWTF stakeholders subsequently developed a more specific "Issues of Interest" list over the course of four meetings, early in 2002. After sessions of brainstorming, eliminating duplicates, and sorting, problems and project ideas were categorized under larger group headings. Stakeholders participated in a "sticky dot" exercise to identify which general categories were most important to them. The following list, with groupings identified by bold print headings, represents key stakeholder priorities, with categories of the greatest interest or concern listed first, and descending according to a waning frequency of responses.

WATER QUALITY & QUANTITY (SOURCE WATER)

- Beneficial reuse
- Constructed wetlands
- Flood protection
- Groundwater basin
- Groundwater recharge
- North outfall treatment facility
- Permeability
- Reclaimed water
- Seasonal anf annual trends
- Spreading grounds
- Surface waters
- Water retention
- Stormwater / urban runoff
- Beneficial uses for channel or receiving waters
- Contact recreation
- Groundwater protection
- Inventory of the dischargers/discharges
- Noncontact recreation
- Point/nonpoint source pollution
- Sediment quality
- Sources of contamination
- Oil seeps
- Air pollution
- Illegal dumping
- Interim permitting

- List of impaired water bodies [303(d) list]
- National Pollutant Discharge Elimination System (NPDES) permit
- TMDLs
- Regulatory agencies

ECOSYSTEMS

- Connections
- Fisheries
- Greenways
- Habitat
- Invasive plant species
- Natural resources
- Rare, threatened, and endangered species
- Recovery and restoration of native species
- Seawater barrier
- Wetlands restoration
- Wildlife access (fencing and roads)
- Wildlife crossings
- Wildlife communities and biodiversity
- Conservation, preservation, and restoration
- Land subsidence
- Soil

PUBLIC BENEFITS

- Alternative transportation
- Bike/walking path and network (including recreation and commuter uses)
- Every existing city park
- Historic and cultural resources
- Naturescaping/landscaping
- Public access
- Public art
- Urban forestry

SUBSYSTEMS

- Baldwin Hills Park
- Ballona Lagoon Marine Preserve
- Ballona Northeast (Area C—State lands)
- Ballona Wetlands
- Del Rey Lagoon city park
- Grand Lagoon / Canal
- The Harbor
- Marina del Rey
- Oxford Flood Control Basin
- Venice Canals
- Ballona Creek
- Estuaries of Ballona and Centinela Creeks
- Wetlands hydrology improvement
- Centinela Creek
- Sepulveda Channel
- 15+/- tributaries in the Santa Monica Mountains

PUBLIC OUTREACH

- Educational opportunities
- Environmental justice
- Public awareness
- Public safety
- Public participation
- Involving public schools



LAND USE

- Land acquisition strategies
- Land development
- Open space creation
- Playa Vista properties
- Projected growth

MAINTENANCE

ECONOMICS

- Revitalization along the creek
- Tourism and fishing

MAPPING

- Visibility of Watershed boundaries
- Watershed boundary
- Existing springs/creeks
- Historic streams
- Stream daylighting

PUBLIC HEALTH

MONITORING

JURISDICTIONS

VECTOR CONTROL

C. GOALS AND OBJECTIVES

In the Procedures and Protocols document, the BCWTF adopted the following goal:

> To develop and facilitate implementation of a Comprehensive Watershed Management Plan for the Ballona Creek Watershed that sets forth pollution control and habitat restoration actions to **achieve ecological health.**



Ladera Park

To further articulate this overarching goal, on May 20, 2003, the Task Force also adopted the following additional goals:

1. WATER

A. Improve Quality of Surface Water and Groundwater

B. Maintain Flood Protection

C. Restore Natural Hydrologic Function to Ballona Creek and Tributaries Where Feasible

D. Optimize Water Resources to Reduce Dependence on Imported Water

E. Improve Aquatic, Estuarine, and Riparian Habitat Quality and Quantity

2. LAND

A. Improve Terrestrial Habitat Quality, Quantity and Connectivity

B. Improve Access to Open Space and Recreation for All Communities

C. Improve Pedestrian and Bicycle Access and Safety

D. Practice Stewardship of the Landscape

3. PLANNING

A. Coordinate Watershed Planning Across Jurisdictions and Boundaries

B. Implement Multi-Objective Planning and Projects

C. Use Science as a Basis for Planning

D. Involve the Public through Outreach and Education

E. Utilize the Plan in an Ongoing Management Process

F. Realize the Potential of Watershed Restoration for Sustainable Economic Development

To establish criteria that can be used to measure progress, the following objectives have been articulated by the BCWTF:



Ballona Creek Watershed Management Plan Objectives

Goals	*Objectives*
WATER	
Improve Quality of Surface Water and Groundwater	Implement projects, BMPs and other methods to reduce pollutant loads and improve water quality, consistent with TMDL implementation
	Minimize dry weather urban runoff discharge into waterways and the Bay
	Achieve fishable, swimmable water quality standards in Ballona Creek
	Improve water quality in Santa Monica Bay
Maintain Flood Protection	Implement incentives to encourage new and existing developments to detain stormwater onsite to reduce runoff
	Implement a plan to utilize nonstructural flood protection projects to the maximum extent feasible
	Reduce the volume and velocity of stormwater runoff
Restore Natural Hydrologic Function to Ballona Creek and Tributaries Where Feasible	Expand water conservation programs
	Extend the distribution and range of uses of reclaimed water
	Maximize onsite collection of stormwater for irrigation and percolation
	Establish a network of stormwater detention sites
	Expand groundwater recharge facilities
Optimize Water Resources to Reduce Dependence on Imported Water	Restore tidal flushing to lagoons and wetlands where consistent with flood protection objectives
	Restore natural hydrologic conditions in stream channels where feasible
Improve Aquatic, Estuarine, and Riparian Habitat Quality and Quantity	Improve aquatic, estuarine and salt marsh habitat in the Ballona Creek estuary system, including the Ballona Wetlands, Ballona Lagoon, Playa del Rey Lagoon, and associated water bodies, by restoring tidal flushing, removal of invasive species, and restoration of native habitat
	Restore riparian habitat along a section of a tributary stream
	Establish self-sustaining populations of key indicator species in the Ballona Wetlands and the associated estuary system
	Establish self-sustaining populations of key indicator riparian species along tributaries
	Restore riparian habitat along Ballona Creek where feasible
	Daylight tributary streams and restore riparian habitat wherever feasible

Ballona Creek Watershed Management Plan Objectives

Goals	*Objectives*
LAND	
Improve Terrestrial Habitat Quality, Quantity and Connectivity	Restore habitat wherever feasible on publicly owned land in the Baldwin Hills, the Santa Monica Mountains and the Hollywood Hills, including removal of invasive species and restoration of native upland habitats, where consistent with use
	Expand protection of high-quality habitat and ecologically-significant areas
	Establish self-sustaining populations of key indicator riparian species tributary streams
	Develop and implement habitat monitoring programs
	Maintain, restore and enhance wildlife corridors as continuous linkages from the Santa Monica Mountains to Baldwin Hills, Ballona Wetlands and Santa Monica Bay
Improve Access to Open Space and Recreation for All Communities	Increase public open space by targeted, prioritized programs of land acquisition
	Coordinate open space planning, land acquisition and management among jurisdictions
	Accommodate a range of active and passive recreational uses
	Improve access to open space based on population density, distance and travel time for underserved communities
	Connect open spaces to transit access points
	Connect waterway projects to adjacent communities
Improve Pedestrian and Bicycle Access and Safety	Provide and maintain bicycle, pedestrian and equestrian trail systems along waterways and within the watershed to link public open space
	Provide for public safety and security along pedestrian and bicycle routes
Practice Stewardship of the Landscape	Adopt requirements for the use of native, regionally-adapted and drought-tolerant plants in all public sector projects, where consistent with use
	Provide incentives for use of native, regionally-adapted and drought-tolerant plants in private sector projects
	Encourage identification, preservation and restoration of historic sites and cultural landscapes



Ballona Creek Watershed Management Plan Objectives

Goals	*Objectives*
PLANNING	
Coordinate Watershed Planning Across Jurisdictions and Boundaries	Integrate watershed planning with water supply, natural resource, land use, and transportation plans
Implement Multi-Objective Planning and Projects	Employ comprehensive cost-benefit analysis to evaluate multiple-objective projects Leverage planned single-purpose infrastructure projects by incorporating multiple objectives and partnerships Provide incentives to promote sustainable, multiple-objective private sector projects Incorporate sustainability objectives and practices in all projects
Use Science as a Basis for Planning	Base plans and projects on scientifically-derived principles, practices and priorities Utilize applied scientific research to guide public policy
Involve the Public through Outreach and Education	Conduct public educational and outreach programs to promote watershed restoration. Establish a process for project participation by stakeholder representatives and the public. Incorporate appropriate interpretive signage and educational elements and facilities in watershed restoration projects.
Utilize the Plan in an Ongoing Management Process	Periodically assess progress towards meeting Watershed Plan objectives and revise as appropriate Develop benchmarks to assess watershed status by a regular monitoring process
Realize the Potential of Watershed Restoration for Sustainable Economic Development	Recycle underused sites along Ballona Creek as frontage for new, sustainable mixed-use development. Encourage compatible residential, commercial, and service uses adjacent to rehabilitated creek.

CALLEGUAS CREEK

Watershed Management Plan

A Cooperative Strategy for Resource Management & Protection

PHASE I REPORT



November 10, 2004

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CHAPTER 1



1.1 Introduction and Overview

Started in 1996, the Calleguas Creek Watershed Management Plan (WMP or plan) is a comprehensive, stakeholder driven effort to develop a resources management and protection program and strategy for the 341-square mile Calleguas Creek Watershed in southeastern Ventura County. Watershed stakeholders initiated the WMP in response to a clear need to work cooperatively and responsibly to develop a comprehensive plan that would guarantee the long-term health of natural resources in the watershed. Led by a broadly representative Steering Committee, the WMP has completed its first phase, the development of action recommendations and technical tools to address coordinated environmental and resource management by public agencies and private sector participants. Phase II, which is currently underway, focuses on how responsible parties in the watershed will act collectively to address significant water quality improvements and meet the mandatory standards of the federal Clean Water Act and California Porter-Cologne Act.

This document is a compilation and description of the work and process which has led to the completion of Phase I.

The Calleguas Creek WMP is designed to:

- Take a comprehensive approach involving all major stakeholder groups;
- Develop a common vision for the future;
- Create a permanent forum and structure for cooperative decision-making;
- Develop an in-depth understanding of current conditions and identify resource management needs;
- Facilitate comprehensive natural resource management, protection and enhancement;
- Coordinate public facility siting and development;
- Provide constructive guidelines for private sector actions;
- Meet required water quality standards through effective solutions; and
- Maintain a high quality of life while accommodating forecast growth.

In developing the WMP, the Steering Committee has also acknowledged that:

- A program of coordinated actions specifically designed for the Calleguas Creek Watershed will best meet its needs;
- A locally developed plan is most effective for watershed protection;
- A cooperative planning structure must involve locally-elected policy makers and a new entity should not be required for implementation; and
- A comprehensive and cooperative approach provides the best opportunity to invest public resources and effectively achieve objectives.

This Phase I Final Report helps meet these objectives by documenting the development of two major components, Action Recommendations and WMP Tools, which are integrated into the WMP.

Action Recommendations:
These watershed-wide recommendations have been developed by the functional WMP Subcommittees using common data and information, with a focus on complimentary implementation. Phase I Action Recommendations include six key areas:

- Water Resources and Water Quality;
- Habitat and Recreation;
- Flood Protection and Sediment Management;
- Agriculture;
- Land Use; and
- Public Outreach and Education.

Chapter 2 describes the Action Recommendations in detail, addressing their intent, purpose and development.

Watershed Management Planning Tools:
Since 1996, the WMP, in coordination with related projects, has assembled a large body of baseline data, maps, strategic plans, resource documents, and evaluation models. These comprehensive planning tools go well beyond what has existed in the past and are intended to help evaluate management options and inform public policy and private sector decision-making, particularly to:

- Encourage watershed-wide resource management planning;
- Enable watershed-wide public facility planning;

Appendix B

Comments on the Draft Report and Responses

From: Shirley Birosik [SBIROSIK@waterboards.ca.gov]

Sent: Wednesday, December 07, 2011 10:42 AM

To: Mark Horne

Cc: Zia.Hosseinipour@ventura.org

Subject: comments on the draft Ventura River Watershed Protection Plan Report

I have just a few comments.

On Page 2-44 there is a discussion of City of Ventura's Sanitary Survey Update from 2005. There is a more recent update from 2010 available. The sanitary surveys conducted by the Casitas Municipal Water District (covering lands draining to Lake Casitas) should be mentioned also. The most recent one was adopted in 2011.

Page 2-45: The current 303d list is from 2010 (although originally intended to be released in 2008). Some impairments are missing from Table 2.7-2 (those for Matilija Creek, Matilija Reservoir, and Lake Casitas). See http://www.waterboards.ca.gov/water_issues/programs/tmdl/integrated2010.shtml.

On Page 5-3, second paragraph under Lessons Learned, as I mentioned at a recent Ventura River Watershed Council meeting, the Ballona Creek Watershed Task Force is meeting once again after taking time off to refocus.

Shirley A. Birosik
Watershed Coordinator
CA Regional Water Quality Control Board, Los Angeles Region
320 W. 4th St., Suite 200
Los Angeles, CA 90013
213-576-6679
sbirosik@waterboards.ca.gov

Responses to comments from Shirley A. Birosik, dated December 7, 2011

The discussion of the Sanitary Surveys (in Section 2.7) has been updated to incorporate the new information from the Ventura and Casitas 2011 surveys.

The water quality impairments included in Table 2.7.2 has been updated with the more recent list (adopted in 2011).

The text in Section 5.3.1.3 has been revised to acknowledge that the Ballona Creek Task Force has recently begun to meet again.

Comments received during the presentation of the Draft Report to the Ventura River Watershed Council, December 13, 2011, and responses to those comments (which were not attributed to specific individuals).

Topic/ Comment	Response
Water Demand	
Using a one year snapshot (2010) is not the same as an "average" year for water demand, given the variation in water year types, as well as when precipitation occurs and the type of rain events. In particular, water use for agriculture varies greatly.	Water demand estimates in Urban Water Management Plans are typically provided in five year increments for three water year types: average, dry year, and multiple (or critically) dry years. The data incorporated into the Draft Report was average year demand for 2010, to the extent that information was available. Data for dry or multiple dry years was not available from other available sources, and thus estimation of water demand for those water year types was not feasible.
Do the numbers for water demand in Ventura: 1) include water provided to petroleum operations or 2) double count water supplied by Casitas.	The estimate of M&I water demand in the City of Ventura in Table 4-1 of the Draft Report did not include water provided to petroleum operations. Tables 4-1 and 4-3 in the Final Report have been revised accordingly. As Table 4-1 is an estimate of water demand, it does not account for water supplied by Casitas to the City of Ventura.
Groundwater extraction values for the Upper Ojai Basin (of 700 AFY) are available from DWR Bulletin 118.	The estimate of agricultural demand have been revised (in Tables 4-2 and 4-3) to include this additional information.
The combined estimate for agriculture and urban water demand are very similar to what Casitas calculated in 1990. The numbers look about right.	Comment noted.
Water Budget	
There may not be a lot of data on groundwater, however you can "back in" to the water budget numbers based on storage in reservoirs. Some maps and other reports could be included in the report.	An map of Ventura River Watershed Groundwater Basin and Surface Water Reservoirs was provided at the meeting (and is attached to the comment letter from Bill O'Brien in this Appendix). This map provides information that is similar to Figure 2.6-6 in the Draft Report.

Topic/ Comment	Response
The amount of water that evaporates from Lake Casitas should be included in the report. That information is available in Casitas' Urban Water Management Plan and the annual Casitas Hydrology reports.	The discussion of the Water Budget in Section 4.3 was revised to include an estimate of annual loss from evaporation and rainfall from Lake Casitas (of 2,630 AF).
Data Gaps	
The HSPF model needs ground-truthing and additional data to allow for the reduction in the size of the cells.	Comment noted. The discussion of data gaps for the HSPF suggests specific locations where additional data would be useful.
Fox Canyon GMA has produced estimates of water use for 22 crops and water year type, and this could be used to estimate agricultural water demand in the Ventura River watershed.	The discussion of data gaps in Section 6.3 will be revised to acknowledge the potential to use the agricultural water use data developed by the Fox Canyon GMA.
Report Scope and Purpose	
The report needs to clearly state the purpose and note that the scope is very limited; the last sentence in the introduction has the "why" statement – this should be moved to the beginning of the introduction and expanded.	The introduction to the Report will be revised.
The report should be more general, it is not a deliverable specifically for the VCWPD, as it is going to the State Board.	The introduction to the Report will be revised to acknowledge it fulfills a requirement of a grant from the State Water Resources Control Board.
Add a caveat in the introduction noting that the report is not a comprehensive assessment of the watershed and focuses on water supply. This is especially important since the report is going to the State Board, and they won't understand the limitations of the VCWPD Scope of Work.	The introduction to the Report was revised to insert this acknowledgement.
Water supply section needs to include an overview – and should note that the Ventura River watershed does not receive any imported water.	The text of the introduction to Chapter 4 (Water Demand and Water Budget) was revised.
The summary of V-1 projects is written in terms that are too technical; it needs an introduction that explains the section in lay person terms.	The initial text on each of the V-1 projects was to provide a short overview of each project.

Topic/ Comment	Response
Corrections or Clarifications	
The maximum credible earthquake for Red Mountain is incorrect. Based on recent research, that value should be 7.5.	The text in Section 2.4.1 was revised to modify the maximum credible earthquake from 6.8 to 7.0, per the Bureau of Reclamation's 2010 EIR/EIR on the Lake Casitas Management Plan. No other sources could be identified that confirmed the suggested value of 7.5.
The County built Matilija Dam, not the Corps.	The text in Section 2.9.3.1 of the report was revised.
The portion of the Matilija Dam removal project that the Corps can't do is related to the notching, the rest of the proposed work is within the Corps' scope.	The recommendation concerning moving forward with the Matilija Dam Ecosystem Restoration project (in Section 8.1.7) was revised.
Suggested Additions to Report	
Land use section needs to be beefed up and a habitat section added.	As noted in the Introduction (Chapter 1), the report relied on available information from reports produced for the V-1 projects and the Appendices to the in-progress Ventura River Multi-Species Habitat Conservation Plan. Those source documents did not include an extensive section on Land Use. As noted in the discussion of Data Gaps (in Section 6.3, limited information on habitat in the watershed was available from the referenced sources. We concur that additional information on Land Use and Habitat would be useful for the development of a watershed management plan.
Include an overall map with roads and creeks identified, as the existing maps don't identify those features	Several of the maps do provide identifying information. However, the report relied on existing graphics from available reports, which were not in a format that could be modified.
Each major section needs an introduction that highlights the themes/big picture for the section	The introduction to the Report (in Section 1) was revised to provide an overview of the report.
The report should identify themes/synopsis or a 3-5 page executive summary. The IRWMP has general information on the watershed that could be added.	The introduction to the Report (in Section 1) was to incorporate more summary information on the content of the document. Since Chapter 2 provides a summary of watershed characteristics, adding similar information to Chapter 1 was deemed too redundant.

Topic/ Comment	Response
There is not much discussion of what is going on in USFS lands and how that affects the watershed – e.g. septic tanks in the upper watershed.	As noted in the discussion of data gaps, information from the Los Padres National Forest Management Plan was utilized in the report, but that Plan provides very little information related to the Ventura River Watershed, and the information is focused on the management of the forest lands.
Disposition of Comments	
Suggest creating a matrix of comments received and response to comments to include with the document.	Oral comments from the meeting are summarized and responded to herein. Written comments are responded to individually in this Appendix.
Provide all comments to the State Board so they see what comments were made.	This section summarizes oral comments received at the meeting. Copies of all written comments are included in this Appendix.

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www.venturawater.net

January 11, 2012

Zia Hosseinpour
Ventura County Watershed Protection District
800 South Victoria Ave.
Ventura, CA 93009-1600

Mark Horne
Cardno ENTRIX
201 N. Calle Cesar Chavez, Suite 203
Santa Barbara, CA 93103

RE: Ventura River Watershed Protection Plan Report – Draft Report

The City of Ventura has completed a review of the draft report of the Ventura River Watershed Protection Plan (dated December 2011). Our comments are noted below:

General Comments:

In general we feel the report is disjointed and incorporates information from various reports into a cut and paste document. This has contributed to conflicting data being included in the report. In addition, there is information that is incorporated into the report that is outdated and better not included. Therefore, we recommend the report be revised to incorporate current information provided in the City of Ventura's March 2011 Water Master Plan, 2010 Urban Water Management Plan and 2010 Ventura River, San Antonio Creek Watershed Sanitary Survey Update and perhaps other current agency annual reports that provide water production data (i.e. Ojai Groundwater Management Agency).

In addition the report looks at the City's water usage within the watershed to calculate a water balance for the watershed, which does not take into consideration that the Ventura River is just one of several sources utilized by Ventura Water customers. Ventura has been successful in utilizing multiple sources of water supply to create a reliable water system that relies on conjunctive use. Therefore, the report miss represents the City's water rights by restricting usage of our Ventura River water to only those present customers within the watershed. Therefore, the report needs to identify that the City's appropriate water rights are used conjunctively to provide service to all our customers.

Chapter 8 of the draft report, "Future Actions to Improve Water Sustainability and Ecosystem Functions" provides a list of recommended actions, which includes the development of a Ventura River Groundwater Management Plan. As noted in the list of recommended actions there are various water resource data gaps, which limit the potential for assessment of long-term trends in groundwater level and the development of a water budget. Therefore, we support the recommendation to develop a technical advisory group to assess and prioritize data gaps that need to be evaluated prior to moving forward with the development of a Groundwater Management Plan for the Ventura River Watershed.

Report Comments:

We are attaching Hopkins Groundwater Consultants Letter to the City dated January 10, 2012, that addresses our concerns (Attachment A).

Text Edits:

In addition, we have attached a few pages with revisions to the text for incorporation into the report (Attachment B).

We request that our comment letter be included in an appendix to the final report.

If you should have further questions please contact me at (805) 677-4503.

Sincerely,

Shana Epstein
General Manager, Ventura Water

cc: Ariel Calonne, City Attorney
Susan Rungren, Principal Engineer
Curtis Hopkins, Hopkins Groundwater Consultants

Attachments: A - Letter dated January 10, 2012, from Hopkins Groundwater Consultants to City

B - Mark-up copies of pages from *Draft Ventura River Watershed Protection Plan Report*

Attachment A –

Letter dated January 10, 2012, from Hopkins Groundwater Consultants to City

HOPKINS
GROUNDWATER
CONSULTANTS, INC.
THE WATER RESOURCE SPECIALISTS

January 10, 2012
Project No. 01-009-10

City of San Buenaventura
Ventura Water
Post Office Box 99
Ventura, California 93002-0099

Attention: Ms. Shana Epstein
General Manager Ventura Water

Subject: Review Comments on Ventura River Watershed Protection Plan Draft Report, Dated December 2011.

Dear Ms. Epstein:

As requested, Hopkins Groundwater Consultants, Inc. (Hopkins) has conducted a cursory review of the Ventura River Watershed Protection Plan Draft Report. Based on our review findings, we have developed the comments in this letter about the report contents and recommend that the City of San Buenaventura (City) consider requesting that the Ventura County Watershed Protection District (District) consider potential modifications or clarifications.

We recognize that the report is intended to be a generalized summary of the Ventura River watershed conditions that were obtained from existing, readily available documents. However, in light of the significant data gaps identified in this report and previous reports referenced (see report section 6), we question whether this compilation provides sufficient relevant information to develop a comprehensive and integrated watershed management plan.

It is our understanding that the report is intended to satisfy the fourth and final bullet of tasks that Project V-1 was proposed to include (i.e., the Ventura River Watershed Protection *and Supply* Plan [see page 1-1]). The supply aspect of the originally proposed plan was removed in title and the water demand was subsequently summarized in a confusing manner (see report section 4.2). The water demand does not appear to represent the City's historical demand of the water supply obtained from within the watershed. The discussion instead focused on grossly estimating the per capita water use within the watershed (which ignores industrial uses), not the total historical diversions from within the watershed as documented by the City and reported to the State.

The recommendations for the watershed management plan summarized in report section 5.4 should likely include a bullet that discusses; Identifying and quantifying established and permitted legal surface water diversion and groundwater pumping rights within the watershed.

P.O. Box 3596, Ventura, California 93006 Phone: (805) 653-5306 e-mail: chop4@earthlink.net

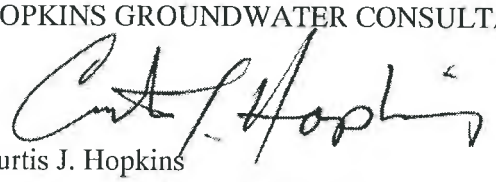
We believe the report should subsequently identify the City's efforts documented in the Foster Park Wellfield Design Study (Hopkins, 2007) and include the City's proposed diversion strategy in the report section located on page 7-4 titled *Implement Integrated Water Resource Management Practices*. If regulatory agencies were to approve, the City intends to completely abandon direct diversion of surface water flows and locate additional well facilities in the Foster Park area. The new facilities would allow a better conjunctive use of this supply during the rainy season when flows are high and subsequently a controlled diversion of water as flow diminishes in the river. This strategy is intended bolster the historically sustainable yield of the lowest reach of the Upper Ventura River Groundwater Basin in a manner that is environmentally responsible.

The report appropriately indicated the intentions and approach to developing a groundwater management plan; however, typical groundwater management plans are developed and implemented by a groundwater management agency comprised of historical groundwater users with legal authority provided by the State. It is unclear what legal entity will collect data, conduct study, and be accountable for the implementation of the plan when developed.

We trust the summary of the draft report review findings is sufficient for the City's administrative needs. If you have questions or need any additional information, please give us a call.

Sincerely,

HOPKINS GROUNDWATER CONSULTANTS, INC.



Curtis J. Hopkins
Principal Hydrogeologist
Certified Engineering Geologist EG 1800
Certified Hydrogeologist HG 114

Attachment:

References

Cardno Entrix (2011), *Ventura River Watershed Protection Plan Draft Report,* prepared for the Ventura County Watershed Protection District, Dated December.

Hopkins Groundwater Consultants, Inc. (Hopkins, 2007), *Preliminary Hydrogeological Study, Foster Park Wellfield Design Study, Ventura, California,* prepared for the City of San Buenaventura, Dated December.

Attachment B –

Mark-up copies of pages from *Draft Ventura River Watershed Protection Plan Report*

Cardno ENTRIX

Shaping the Future

DRAFT



Ventura River Watershed Protection Plan Report

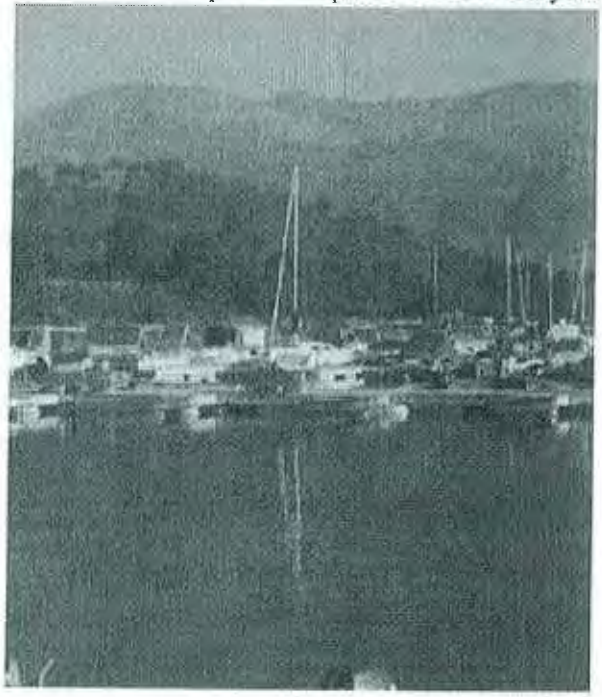
December, 2011

Prepared for

Ventura County Watershed Protection District

Several multiple-use trails serve bicyclists, equestrians, and pedestrians in the watershed. The Ojai Valley Trail follows the abandoned Southern Pacific Railroad right-of-way and is located along the west side of State Route 33 from Ojai to northern Foster Park. In the City of Ventura, the Omer Raines Trail parallels the Ventura River and terminates at Main Street. A Class I trail, following the Southern Pacific Railroad easement connects the Ojai Valley Trail with the Omer Raines Trail. The City of Ventura owns and ~~manages~~ maintains the Ventura River Trail, a multi-purpose trail that extends from Foster Park to the beach.

Lake Casitas is open to the public for non-body contact recreational activities. All recreational activities are operated by Casitas Municipal Water District (Casitas) or by concessionaries.



The Recreation Area encompasses approximately 4,097 acres and consists primarily of open space. The recreational facilities are located on approximately 400 acres scattered about the perimeter of the lake. Existing recreational facilities include camping, picnicking, motor boating, sailing, canoeing, and fishing. Lake Casitas hosted the 1984 Olympic Rowing and Canoeing Events and is currently the home of the Lake Casitas Rowing Association which provides recreational and competitive rowing training to youth and adults in the community. The lake is also used by bird watchers to view the many migratory birds that use Lake Casitas as they pass through the Pacific flyway. Facilities include stores, campgrounds, RV campgrounds, showers, restrooms, picnic areas, boat ramps, water playground, a radio-controlled airplane landing strip, and boat and trailer storage.

Lake Casitas is famous for its record fish catches. Fishing takes place from docks, boats, and shore. Lake Casitas contains a warmwater fishery that includes bass (primarily large mouth), catfish, sunfish, and crappie. These fish are non-native and were introduced when the lake was formed, but now are self-sustaining populations. Both the California Department of Fish and Game (CDFG) and Casitas also stock the lake annually with catchable size rainbow trout. Lake Casitas has also been stocked on an irregular basis with crappie and other panfish.

The Ventura County Parks Department maintains three regional parks (Camp Comfort, Soule Park, and Foster Park) located adjacent to waterways of the Ventura River. Camp Comfort Regional Park is situated adjacent to San Antonio Creek. Soule Park recreation area consists of a golf course and a public park. The confluence of San Antonio and Thacher creeks occurs within Soule Park, and the Ventura River runs through Foster Park. Activities at all parks include picnicking and playground areas and services such as public restrooms. Park users also wade in San Antonio Creek at Camp Comfort and in the Ventura River at Foster Park. Soule Park includes baseball and equestrian facilities as well as a public golf course. Water for golf course

2.3.1.1 Mountainous Uplands

The mountainous uplands are the primary water and sediment production areas, with few or no alluvial deposits and steep streambed gradients. The major sub-basins with significant uplands include Matilija, North Fork Matilija, Coyote, Santa Ana, and San Antonio creeks (Tables 2.3-1 and 2.3-2). This is also the zone in which two major water supply and flood control facilities are located (Matilija Dam and Casitas Dam).

Table 2.3-1 Major Ventura River Watershed Sub-Basins and Water Facilities

Sub-Basin	Unit Area (sq. mi.)	Percent of Area at Foster Park (%)	Storage and Diversion Facilities	Present Capacity
Uplands: Headwaters/Tributaries				
Matilija Creek	55	29.3	Matilija Dam	500[a] acre-feet (AF)
North Fork Matilija Creek	16	8.5		
San Antonio Creek (includes Ojai Valley)	51	27.1		
Coyote and Santa Ana Creeks	41	21.8	Casitas Dam	254,000 AF
Alluvial Valleys: Mainstem				
Upper Ventura River	74[b]	39.4	Robles Dam	900 AF/day
Ventura River near Ventura at Foster Park	188	100.0	Foster Park*** ?	Surface: 21.4AF/day Sub-surface: 11.1 AF/day
Ventura River below Foster Park	100			
Total	228			

a. Estimated by Reclamation (2000)
b. Includes area of all upstream sub-basins
c. Average daily capacity, exclusive of Nyo well field. Maximum production is effectively limited by the 13 mgd (20 cfs) capacity of the water treatment plant.

c footnote does not make sense

Source: ENTRIX and Woodward Clyde Consultants 1997 and Reclamation 2000

Clean up footnotes

Table 2.3-2 Drainage Area of Sub-Watersheds in the Ventura River Watershed

Local Area Watershed Name	Drainage Area (mi^2)	Maximum Length of Watershed (ft)	Minimum Elevation of Watershed (ft)	Maximum Elevation of Watershed (ft)	Mean Annual Precipitation (inches)
Matilija at Matilija Dam	54.6	83,363	1,009.29	5456.77	23.5
North Fork Ventura River-Matilija	16.2	40,554	1009.29	5006.72	22.1
Ventura River D/S of Willis Canyon	7.4	22,090	696.87	4,278.56	20.2
Ventura River at Live Oak Creek	11.6	45,685	290.61	2,310.04	17.8
San Antonio Creek	51.0	79,331	290.41	5,410.69	18.3
Santa Ana Creek at Lake Casitas	9.5	38,211	528.60	4,645.89	18.7
Coyote Creek above Lake Casitas	13.4	36,127	560.88	4,769.48	21.1
Drainage area that includes Lake Casitas	15.3	31,470	514.96	2,342.64	18.2
Ventura River Subarea to Foster Park	9.3	25,313	195.36	1,302.82	17.3
Cañada Larga Subarea to Foster Park	19.3	50,752	195.78	2,788.00	17.9

Table 2.3-2 Drainage Area of Sub-Watersheds in the Ventura River Watershed

Local Area Watershed Name	Drainage Area (mi^2)	Maximum Length of Watershed (ft)	Minimum Elevation of Watershed (ft)	Maximum Elevation of Watershed (ft)	Mean Annual Precipitation (inches)
Lower Ventura River	15.5	35,470	0.00	2,117.63	16.9
Entire Ventura River Watershed	228	—	0.0	5,456.77	19.9

Source: U.S. Army Corps of Engineers (USACE) 2004

Approximately 80 percent of the watershed is composed of uplands of hill slopes and ridges with surface geology of Tertiary sedimentary rocks (3 million to 70 million years old). The bedrock units of the Tertiary sedimentary rocks (i.e., well-cemented sandstones, siltstones, conglomerates, and shales) have been severely deformed by folding and faulting, and have low permeability relative to the unconsolidated alluvial deposits in the main valleys (Reclamation 2003).

2.3.1.2 *Alluvial Valleys*

The alluvial valleys are primarily a zone of storage and transfer of water and sediment and include the mainstem river, floodplain, and valley bottom downstream of the confluence of Matilija and North Fork Matilija creeks and the Ojai Valley (or the San Antonio Creek sub-basin). The upper portion of the Ventura River mainstem valley (upstream of Foster Park) is the reach of the river with groundwater production and surface diversions.

The alluvial valleys are underlain by relatively shallow deposits, ranging in age from 10,000 to 1 million years old. The Ventura River has slowly migrated to the west during the late Quaternary Period, leaving a series of terraces marking former channel and floodplain locations (Putnam 1942 and Rockwell et al. 1984, as cited in Keller and Capelli 1992).

The alluvial deposits continue to be affected by active regional tectonic forces that tilt and bend sediments and create vertical and horizontal offsets (faults), affecting subsurface water flow and water levels. The alluvial valley fills constitute the major groundwater aquifers, and the major groundwater basins of the Ventura River watershed are located in these valleys and include the Ojai Valley basin, the Upper Ventura River basin (above Foster Park), and the Lower Ventura River basin (Fugro West 1996). In addition, minor groundwater basins occur in the Upper Ojai Valley (along Lion Creek) and along lower San Antonio Creek (Turner 1971, as cited in EDAW et al. 1981).

2.3.1.3 *Lagoon/Delta*

The Ventura River lagoon encompasses approximately 3.7 acres between the shoreline and a few hundred yards upstream of the U.S. Highway 101 Bridge. The lagoon is separated from the Pacific Ocean by a sand/cobble bar during the dry season and opens and closes in response to storms and flow changes throughout the year. When full, the lagoon covers approximately 1.5 surface hectares and ranges in depth from 0.6 to 2.4 meters. The river lagoon includes the shifting channels and depositional environments at the mouth of the river, occurring in an arc-shaped delta that extends approximately 1 mile upstream from the ocean and is 2 miles wide at the coast. An estuary at the second mouth exists to the west of the main lagoon (CRWQCB-LA 2002).

Some areas of the watershed have not burned for many years, such as the area around Lake Casitas and parts of the San Antonio Creek basin. These locations may be susceptible to intense damage from future fires due to accumulated fuel loads (Chubb 1997). By reducing or destroying vegetative cover and altering soil characteristics, fires may result in conditions that can significantly increase runoff and erosion when winter rains begin to fall. These conditions may result in a debris flow (also referred to as mud flow) – a slurry of water, sediment, and rock that converges in a stream channel (URS 2005).

2.6 Hydrology

2.6.1 Historical Context

Although few records exist prior to the 20th century, a review of historical maps and documents suggests that the historical hydrology of the Ventura River was a result of the form of the river channel and the associated geology. In the reach of the river within Matilija Canyon, flows were perennial. As the river entered the Ojai Valley and the channel broadened, surface flows became intermittent. At the confluence with San Antonio Creek, and from Foster Park to the mouth of the river, flows were perennial (SFEI, 2011).

2.6.2 Surface Water

Flow conditions in the mainstem of the Ventura River and tributary watersheds are naturally variable depending upon precipitation (rainfall and snowmelt). About 80 percent of the time, there is no significant surface flow in the Ventura River above the confluence with San Antonio Creek. However, there is generally year-round flow in the lower reaches of San Antonio Creek. During the wet season, the surface flows are "flashy," with sudden rises in discharge immediately following the onset of precipitation, and relatively rapid declines in streamflow after precipitation decreases (USACE 2004).

Under summer low-flow conditions, surface streamflow at various locations in the watershed is governed by a number of factors, including precipitation input, spring discharge, groundwater levels, the effects of water diversions, water storage and water supply releases, treated wastewater discharge, and groundwater extraction. Some reaches of the mainstem Ventura River tend to go dry on a yearly basis. This typically includes the Ventura River reach between Robles Fish Passage Facility and the upstream end of the Casitas Springs/Foster Park reach between the confluence of San Antonio Creek and Foster Park. The Casitas Springs/Foster Park reach and Ventura River downstream from the OVSD Wastewater Treatment Plant to the lagoon typically retains flows year round. This section of the Ventura River has perennial flows, even during drought years, due to a natural bedrock barrier that forces subsurface flow to the surface. The river channel occurs as a wide floodplain and during high flows is "characterized by a typical pool riffle continuum found in low gradient streams." Vegetation such as watercress and water veronica is consistent with the spring-fed nature of this reach (Moore 1980).

← we have seen the river dry, during drought years.

San Antonio Creek typically goes dry upstream from Soule Park across the Ojai Valley, but is typically perennial downstream to the confluence with the Ventura River. North Fork Matilija Creek retains perennial surface flows except during long periods of severe drought (ENTRIX 2003). Along the mainstem, surface flows dry up in locations between the Robles Fish Passage Facility and the confluence of San Antonio Creek. However, small summer flows are maintained upstream of the Robles Fish Passage Facility; in the Casitas Springs/Foster Park reach, between Foster Park and the confluence of San Antonio Creek; and downstream of the OVSD Wastewater

Treatment Plant (ENTRIX and Woodward Clyde Consultants 1997). The following background information summarizes the general hydrology of the Ventura River watershed.

From the Matilija Creek headwaters to Camino Cielo, the Ventura River is perennial, supported in part from releases from Matilija Dam. The flow is intermittent from Camino Cielo to the confluence with San Antonio Creek with the reach below the Robles Fish Passage Facility typically going subsurface during the summer months (ENTRIX 2001). Historically, there has been little or no surface flow in the river in the summer from Hollingsworth Ranch (8 miles above the lagoon) to the former Soper's Ranch (14 miles inland). There is a geologic discontinuity at Casitas Springs that causes groundwater to rise and feed a perennial stretch of the surface flow below San Antonio Creek (CRWQCB-LA 2002). Surface flows in this reach come from San Antonio Creek, Live Oaks Acres Creek, and small springs and rising groundwater. Between the confluence with San Antonio Creek and Foster Park, flow is perennial, with some disruption at Foster Park by the groundwater extraction. The river has a perennial flow to the lagoon due to rising groundwater and water treatment plant discharges.

2.6.2.1 Surface Flow Conditions

The factors controlling surface streamflow differ considerably during the high-flow season or wet years from those that occur during low-flow seasons or dry years. The following summary of historical conditions presents separate discussions of high and low flows to help clarify the relationship between streamflow conditions and various water resource developments and operations. Several stream gages are located in the Ventura River watershed, and some have a record extending as far back as 1927 (Table 2.6-1). Originally, the U.S. Geological Survey (USGS) operated them all, but starting in the 1980s, the District and Casitas have operated several gages. The operation of some gages has been discontinued for various reasons. The gage above Matilija Dam (11114500) was destroyed in the 1969 flood. The records for gages above Casitas Lake (11117600 and 11117800) are not considered reliable for high flows after 1988 because Casitas took over their operation at that time and was not concerned with recording high flows in this area. The gage locations are shown in Figure 2.6-1 along with their periods of record.

Table 2.6-1 Stream Gages in the Ventura River Watershed

Description	USGS Gage Number	Drainage Area (mi²)	Period of Record	Data Source
Matilija Creek U/S Reservoir near Matilija Hot Springs	11114500	50.7	1948-1969 (destroyed)	USGS
Matilija Creek at Matilija Hot Springs	11115500	54.7	1927-present	USGS and Casitas
North Fork Matilija Creek at Matilija Hot Springs	11116000	15.6	1928-present	USGS and District
Ventura River near Ojai	11116500	70.7	1911-1984 (not maintained)	USGS
Ventura River near Meiners Oaks	11116550	76.4	1959-present	USGS and Casitas
San Antonio Creek near Ojai	11117000	33.7	1927-1932	USGS
San Antonio Creek at Casitas Springs	11117500	51.2	1949-present	USGS and District
Coyote Creek near Oak View	11117800	9.11	1958-present (not reliable)	USGS and Casitas
Coyote Creek near Ventura	11118000	41.2	1927-1982	USGS and Casitas

Table 2.6-1 Stream Gages in the Ventura River Watershed

Description	USGS Gage Number	Drainage Area (mi²)	Period of Record	Data Source
Ventura River Diversion near Ventura	11118400	–	1969-present	USGS
Ventura River near Ventura	11118500/ 11118501	188	1929-present, 1932-present, respectively	USGS
Ventura River at Santa Ana Blvd.	Flood warning gage	–	2002-present	District
Thacher Creek at Boardman	Flood warning gage	–	2002-present	District
Matilija Creek upstream of Reservoir	11114495	47.8	2002-present	USGS

Source: District 2007; USGS 2007; Casitas, no date

Description changes for Tables 2.3-1, 2.3-2, 2.6-1 & 2.6-2. Need to be consistent on data & description.

2.6.2.2 River and Tributary Runoff Production

The production of runoff in various tributaries is generally related to sub-basin area, peak elevations, and variations in vegetation and soil conditions, as well as local storm patterns. Runoff volumes, hydrograph timing, and sediment yield over the period of record has been greatly affected by interaction of fires and floods (refer to Section 2.5, Fire Regime).

Long-Term Averages

The long-term average runoff production for the gauged tributaries and the Ventura River is presented in Table 2.6-2. Matilija and San Antonio creek sub-basins have the largest average annual runoff volumes, with Matilija Creek being the single most important sub-basin for total volume. North Fork Matilija Creek and Matilija Creek are the major water production areas, with long-term average runoff of approximately 500 AF per square mile of watershed area. San Antonio Creek has the lowest runoff production per unit area, but has a larger watershed than either Coyote or Santa Ana creeks. Therefore, the average annual runoff produced from the San Antonio Creek basin is approximately equal in volume to that from both the Coyote and Santa Ana sub-basins upstream of Lake Casitas.

Water Year Types

Annual unimpaired runoff for the Ventura River watershed between 1930 and 2005 varies greatly, with several extremely high years of runoff much higher than the mean value (Table 2.6-3; Figure 2.6-2). The totals range from a low of 1,602 AF in water year (WY) 1961 to a maximum of 277,300 AF in WY 1995. The median annual unimpaired runoff, 18,116 AF, is much lower than the mean due to the statistical effect of a few extremely large runoff years.

The wide range of streamflows from year to year is not unusual for a semi-arid setting, but has important implications as a natural limitation to both the native fisheries resources and water supply management. Over typical planning timeframes (20 to 50 years), such variability creates limitations to water supply management and native fisheries resources. However, when viewed from longer time spans, the conditions are less of a limiting factor than an evolutionary pressure affecting the traits of native fishes. The entire historical record has been analyzed and categorized into WY types. Standard hydrologic methods were used to rank the years and analyze the percent of years with certain ranges of values creating five classes: wet, above normal, normal, below normal and dry. The WY type was determined using the unimpaired runoff for the Ventura River, near Ventura gage (combined record, USGS #8501) (Table 2.6-3).

These water years need to be defined as to what the range for each class means.

Table 2.6-3 Water Year Types for the Ventura River Basin Based on Unimpaired Runoff

Water Year	Ventura River Runoff**		Water Year	Ventura River Runoff**	
	Annual Volume (AF)	Water Year Type*		Annual Volume (AF)	Water Year Type*
1939	24,773	Normal	1976	7,731	Below Normal
1940	16,807	Normal	1977	6,558	Dry
1941	262,031	Wet	1978	242,412	Wet
1942	27,751	Above Normal	1979	37,661	Above Normal
1943	142,573	Wet	1980	137,703	Wet
1944	81,338	Wet	1981	14,888	Normal
1945	37,087	Above Normal	1982	10,121	Below Normal
1946	30,919	Above Normal	1983	221,222	Wet
1947	19,268	Normal	1984	34,373	Above Normal
Matilija Dam began storing water in water year 1948			1985	8,820	Below Normal
1948	4,473	Dry	1986	52,680	Above Normal
1949	4,308	Dry	1987	10,523	Below Normal
1950	7,863	Below Normal	1988	12,087	Below Normal
1951	3,574	Dry	1989	7,011	Dry
1952	130,918	Wet	1990	3,672	Dry
1953	14,112	Normal	1991	23,967	Normal
1954	14,102	Below Normal	1992	61,637	Above Normal
1955	4,909	Dry	1993	101,855	Wet
1956	14,972	Normal	1994	3,683	Dry
1957	5,804	Dry	1995	277300	Wet
1958	165,177	Wet	1996	13009	Below Normal
Casitas Dam, Robles Diversion began functioning in water year 1959			1997	19513	Normal
1959	10,847	Below Normal	1998	264364	Wet
1960	4,238	Dry	1999	12141	Below Normal
1961	1,602	Dry	2000	18068	Normal
1962	64,884	Above Normal	2001	73788	Wet
1963	7,087	Dry	2002	7299	Below Normal
1964	3,960	Dry	2003	15466	Normal
1965	6,155	Dry	2004	9901	Below Normal
1966	42,424	Above Normal	2005	235817	Wet

*Water Year Type is defined as the surface-water supply for the 12 month period October 1 through September 30. The water year is designated by the calendar year in which it ends and which includes 9 of the 12 months. Thus, the year ending September 30, 1990, is called "water year 1990."

Please define water year types.

need , to make easier to read

Low Flows

Under summer low flow or drought conditions, surface streamflow at various locations in the watershed are governed by a complex interaction of precipitation input; discharge from springs; groundwater levels; the effects of water diversions, water storage, water supply releases, and treated wastewater discharge and groundwater extraction.

It is not unusual for streams in Southern California that are rainfed, and lack groundwater support, to dry up in summer months, in both average and below average precipitation years. In the Ventura River watershed, however, several of the smaller tributaries, and even the mainstem, have short perennial reaches that are fed by springs and/or the perched groundwater over shallow bedrock. Perennial flows are present in San Antonio Creek, and in the Casitas Springs/Foster Park reach, defined as the portion upstream of, and including, Foster Park and including lower San Antonio Creek from SR 33 to its confluence with the Ventura River. The presence of year-round flow in this reach of the river is due to high groundwater levels in the shallow alluvium over bedrock, which is artificially raised at Foster Park by the City's subsurface dam (URS Corporation 2003).

Small summer streamflows maintained by springs were documented by both Reclamation (1954) and EDAW et al. (1981) in the upper reaches of the larger sub-basins. EDAW reported typical summer base flows of 1 to 2 cfs in North Fork Matilija Creek, 1 to 3 cfs in Matilija Creek, and less than 0.5 cfs in San Antonio Creek and Coyote Creek below Casitas Dam. Since the 1960s, effluent discharge from the OVSD Wastewater Treatment Plant provides summer flows of approximately 1.9 cfs (2002 data) from the OVSD Wastewater Treatment Plant downstream to the lagoon.

2.6.3 Groundwater

Groundwater has been an important water source for irrigation and municipal supplies in the Ventura River watershed for many decades. In general, groundwater in the Ventura River system occurs under unconfined conditions. However, in some localized areas (where fine-grained overbank deposits form a relatively low permeability cap over old channel deposits with higher permeability), semi-confined conditions may exist, especially during periods of high water levels (Fugro 2002). The primary source of recharge to the alluvial aquifer system is direct infiltration of surface flows. Two other sources of recharge include direct infiltration of precipitation, and downvalley underflow through alluvial sediments.

The Ventura River system is composed of five major groundwater basins: the Upper Ojai basin; the Ojai basin; the Upper Ventura River basin; the Lower Ventura River basin; and the San Antonio Creek basin (ENTRIX 2001c). Of primary importance to this report are the Upper Ventura River, Ojai, and San Antonio Creek basins because local agencies operate and maintain water supply facilities in these areas (Figure 2.6-6). A description of the major groundwater basins is provided below.

2.6.3.1 Groundwater Basins

Upper Ventura River Basin

The Upper Ventura River Basin has a partial downslope along the Arroyo Parida fault to the north (ENTRIX 2001b). The upper basin extends from the confluence of Matilija Creek and North Fork Matilija Creek (RM 16.2) to the City's subsurface dam at Foster Park (RM 5.9),

which delineates the boundary between the Upper and Lower Ventura River groundwater basins. The basin is believed to have a capacity of approximately 14,000 AF when full (USACE 2004). The boundary between the Ojai Basin and the Upper Ventura River Basin is situated between Camp Comfort to the south and Arbolada to the north. The depth to bedrock decreases in the vicinity of this boundary resulting in a decrease in thickness of the aquifer materials.

The Upper Ventura River is underlain by alluvial deposits with a maximum thickness of approximately 200 feet and an average thickness of 60 to 100 feet. A natural subsurface obstruction blocks subsurface flow below the Ventura River just above San Antonio Creek causing groundwater to rise as springs. Therefore, the groundwater beneath the Ventura River is divided into an upper cell and a lower cell (Reclamation 2003).

The thickness of aquifer materials is generally shallow, but varies along the river due to the geologic structure of the basin (variations in the depth to bedrock and faulting). Along the Upper Ventura River, the water-bearing units increase in thickness downstream of the confluence of Matilija and North Fork Matilija creeks, attaining a maximum thickness of approximately 200 feet on the north (down dropped) side of the Arroyo Parida-Santa Ana fault (Figures 2.6-7 and 2.6-8). Downstream of the Santa Ana fault, in the Mira Monte area, the alluvium thickness is controlled by the folded bedrock surfaces and is approximately 65 feet thick. In the Foster Park area, north of the subsurface dam and in the vicinity of the City's Nye Wells, the aquifer materials are 45 to 60 feet thick, providing a saturated thickness ranging from 35 to 45 feet (Fugro West 2002). The total storage capacity of about 14,000 AF typically empties during a 1 to 3-year critical dry period. The dominant source of recharge is direct infiltration or precipitation and percolation from local streambeds (ENTRIX and Woodward Clyde Consultants 1997).

→ See Paragraph 1, under general comments of our comment letter.

Ojai Groundwater Basin

The Ojai Groundwater Basin (Ojai Basin) is located within the Ventura River watershed, within the western portion of Ventura County, California. The Basin is bordered by the Topa Topa Mountains and Santa Ynez Mountain Range on the north and east, Black Mountains on the south, and the Upper Ventura River Groundwater Basin to the west. Ground surface elevations across the alluvial surface of the Basin range from over 1,300 feet above mean sea level (amsl) at the northeastern portion of the Basin, to approximately 700 feet amsl. The drainage area for the basin comprises 36 square miles and rises to elevations over 4,500 feet amsl. The alluvial groundwater Basin is 10.7 square miles (Kear 2005, as cited in Daniel B. Stephens & Associates [DBS&A 2010b]). A large fraction of land within the basin is dedicated to orchards, with the remaining area composed of residential, pasture, commercial and vacant land uses. Municipal and agricultural water requirements of the basin have historically been supplied by both surface water and groundwater sources.

The Ojai Basin is composed of alluvium deposits within a structural depression, and the lateral boundaries of the basin are defined by the contact between the alluvial deposits and the underlying sedimentary rocks (SGD 1992, as cited in DBS&A 2010b). The alluvial aquifer consists of undifferentiated and poorly consolidated deposits of clay, sand, gravel, and boulders. Confining clay units exist within the alluvium, and Kear (2005, as cited in DBS&A 2010b) reported that the units are thickest in the southern portion of the basin.

see paragraph 1 of General Comments in attached City Comment Letter.

Additionally, the City of Ventura collects water quality samples at 11 sites located throughout the watershed. Since 2002, the City has monitored water quality along the Ventura River and San Antonio Creek at these sites for *Cyptosporidium*, *Giardia*, bacteria, nutrients, bromide, total organic carbons, chloride, and conductivity.

The Ventura River and San Antonio Creek Watershed Sanitary Survey 2005 Update (Kennedy/Jenks 2006) reviewed water quality sampling in the Ventura River and San Antonio Creek watersheds. The survey mapped and discussed overlap in sampling sites and constituents among the City of Ventura's, OVSD's, and Ventura County Stormwater Monitoring programs, the Ventura River Stream Team water quality monitoring program, and planned agricultural lands monitoring (associated with the Regional Board's Agricultural Waiver program) due to begin in fall 2006. The report recommended consolidation of the monitoring programs with data stored in a central NPDES database maintained by the District (Kennedy/Jenks 2006).

The Sanitary Survey Update cites the 2005 County Storm Water Monitoring Report in a summary of water quality conditions from 2001 to 2004 with the statement:

"These results [of the water quality monitoring] indicated that water quality in the watershed remained relatively stable during this four year period."

The Sanitary Survey Update notes that *Giardia* and *Cyptosporidium* were below detection limits in the City of Ventura's water sampling program during the 2000 to 2005 period and that general mineral, physical, radionuclide and inorganic chemicals stayed within historical ranges (Kennedy/Jenks 2006). The Sanitary Survey Update also notes actions since 2000 that have reduced the risk of contamination including:

- New OVSD siphons that reduce the risk of spilling untreated wastewater.
- Horse manure public awareness program.
- Successful operation of the permanent Household Hazardous Waste Collection Facility.
- Improvements to the City's Avenue Water Treatment Plant.

2.7.1 Summary of Water Quality Conditions in the Subwatersheds

Above Foster Park, surface water quality in the Ventura River is controlled in large part by the tributary water quality. In the upper tributaries, boron is contributed by hot springs in the Santa Ynez Mountains. Boron can be as high as 6.5 ppm in Matilija Creek above the reservoir during low flow conditions. The high boron is diluted in the reservoir so that water downstream is of higher quality. Turbidity in the watershed can rise as high as 600 turbidity units following storms (Casitas and City of Ventura, 1984).

Uncontrolled stockpiling and storage of horse manure has been observed at some locations within the watershed which could lead to nutrient loading and coliform problems (URS 2002). Organic chemical analysis of raw water by the City of Ventura in 1997 and 1999 did not find organic chemicals at detectable levels (URS 2002). The excessive growth of vascular plants, particularly the non-native water primrose, is prevalent in the lower Ventura River. Below the discharge point from the Ojai Valley Wastewater Treatment Plant, DO generally remains above 7.0 mg/l, but seasonally in the late summer and early fall DO levels fall. With the first major

winter or spring storms and corresponding increased flows in the Ventura River, the DO levels tend to return to desirable levels. Actually, DO levels in the river have improved dramatically to about 11 mg/l. Nitrate levels continue to be considerable in San Antonio Creek, which drains much of the Ojai area. According to the Ventura Stream Team, slightly elevated levels of nitrate are also seen in the lower river.

2.7.2 Impaired Water Bodies in the Ventura River Watershed

The Clean Water Act requires each state to assess the status of water quality in the state (Section 305(b)) and provide a list of impaired water bodies (Section 303(d)) to the U.S. Environmental Protection Agency (USEPA) every 2 years. Impaired water bodies are those that have been determined to not achieve designated beneficial uses. A finding of impairment is made through use of decision rules specified in the State Board Listing Policy, which considers data on chemical-specific water quality standards; bacterial water quality standards; health advisories; bioaccumulation of chemicals in aquatic life tissues; nuisances such as trash, odor, and foam; nutrients; water and sediment toxicity; adverse biological response; and degradation of aquatic life populations and communities. For water quality limited segments included on the 303(d) list, the state is required to develop a Total Maximum Daily Load (TMDL) or take other action to address the impairment. The 2008 update to the Section 303(d) list (CRWQCB-LA 2009, Appendix F) identifies a number of waterbody segments in the Ventura River watershed as water quality limited and requiring a TMDL. These listings are shown in Table 2.7-2. A TMDL for trash has already been developed for the Ventura River Estuary (Tetra Tech 2009b).

Table 2.7-2 2008 Section 303(d) List of Water Quality Limited Sections in the Ventura River Watershed Requiring Development of a TMDL

Impairements

Waterbody Name	CALWATER Watershed	Estimated Size Affected	Pollutant(s)
Cañada Larga (Ventura River watershed)	40210010	8.01 miles	Fecal coliform Low DO TDS
San Antonio Creek (tributary to Ventura River Reach 4)	40220023	9.79 miles	Indicator bacteria Nitrogen TDS
Ventura River Estuary	40210011	0.2 miles	Algae Eutrophic Total coliform
Ventura River Reach 1 and 2 (Estuary to Weldon Canyon)	40210011	4.49 miles	Algae
Ventura River Reach 3 (Weldon Canyon to Confl. w/ Coyote Cr.)	40210011	2.82 miles	Indicator bacteria Pumping Water diversion
Ventura River Reach 4 (Coyote Cr. to Camino Cielo Rd.)	40220021	19.22 miles	Pumping Water diversion

Source: Tetra Tech 2009b

instream flow

instream flow

2.9.2 Diversion Structures

Four major on-stream diversion structures and conveyances have been identified in the Ventura River watershed (Figure 2.9-3). Three canals are represented spatially in the GIS; the fourth (Foster Park) is shown only as a point. Water stored in Casitas Reservoir is in large part derived from the Ventura River via the Robles Diversion Dam and the Casitas-Robles Canal (Tetra Tech 2008a).

See Paragraph 1, General comments of attached comment letter

The Foster Park Diversion supplies water to the City of Ventura. The diversion is apparently via a pipe embedded in the alluvium, and so may include both surface and shallow subsurface flow – but these flow types are difficult to separate in this stretch of the river, which has high storage capacity in the alluvium. Daily gauged flows for the Foster Park Diversion have been obtained for 1932 to 2006. It is not known if later flows are available, or if the diversion has ceased. Little is known at present about the other two mapped diversions – Live Oak and Rancho Matilija. No gauging data or other information has been provided or located to date (Tetra Tech 2008a).

2.9.3 Water Supply and Use

Surface water and groundwater diversions have been developed for use along the Ventura River for over 200 years. As of 1981, approximately 45 known entities withdrew water from the Ventura River system (EDAW et al. 1981). These entities include irrigators, domestic users, industrial users, and water purveyors or suppliers.

2.9.3.1 Matilija Dam

Matilija Dam was constructed in 1946 to 1947 by the US Army Corps of Engineers, Los Angeles District to provide water storage for agricultural needs and for limited flood control. The structure is a concrete arch dam with an average height of 190 feet and a crest length of 616 feet, located approximately 0.6 miles upstream of the confluence of Matilija Creek and North Fork Matilija Creek. The original storage capacity of the dam and reservoir was 7,020 AF, but structural modifications to address concrete deterioration and siltation since 1947 have reduced the water storage capacity to less than 500 AF at present. Matilija's current operations are primarily for optimizing diversions at the Robles Diversion Dam, using a release valve with a maximum capacity of 250 cfs (Reclamation 2000).

In July 2004, the District and the USACE – Los Angeles District completed the public draft of The Matilija Dam Ecosystem Restoration Feasibility Study, a study of the feasibility of removing Matilija Dam and restoring the ecosystem above and below the dam location. The report presents the findings of the alternatives analysis and the selection of a recommended preferred alternative. The study focuses on ecosystem restoration in the Ventura River watershed to benefit native fish and wildlife (including the federally listed endangered southern steelhead trout) of the Ventura River and Matilija Creek in the vicinity of Matilija Dam, and improvement to the natural hydrologic and sediment transport regime to support coastal beach sand replenishment from the Ventura River. In September 2004, the Final Environmental Impact Report/Environmental Impact Statement for this project was completed (USACE 2004).

In 2005, the Project Management Plan was developed specifically for the Matilija Dam Ecosystem Restoration Project, Preconstruction Engineering and Design Phase for the purpose of setting forth the management strategy to be employed by both the USACE – Los Angeles District and the District (Sponsor/Partner/Non-Federal Interest). Currently, grant applications and congressional funding is being sought to fund project components outlined in the feasibility study.

2.9.3.2 Casitas Dam

Casitas Dam was constructed in 1959 and is located approximately 2.5 miles upstream of the Ventura River on Coyote and Santa Ana creeks (near RM 6.2). Lake Casitas has a maximum storage capacity of 254,000 AF and is supplied by inflow from the Robles Diversion via the Robles-Casitas canal in addition to watershed runoff from the Coyote and Santa Ana basins.

2.9.3.3 Robles Fish Passage Facility

The Robles Diversion Dam was first built in 1958 and is located approximately 1.5 miles downstream of the confluence of Matilija Creek and North Fork Matilija Creek (RM 14). Since 1960, the diversion has been used to transfer water to Lake Casitas via a canal. The surface water diversions primarily occur in January, February, and March, and the mean monthly diversions during these months range from 2,183 to 3,489 AF (Reclamation 2003). The annual total diversion volume varies with available runoff and storage capacity remaining in Casitas Reservoir, averaging 13,095 acre-feet per year (AFY), with a median diversion volume of 6,335 AFY (Reclamation 2003). In dry years, there are often almost no diversions.

Since 2003, the Diversion Dam has been referred to as the Robles Fish Passage Facility due to the construction of a fish ladder at the facility. Prior to construction, The National Oceanic and Atmospheric Administration Marine Fisheries Service (NOAA Fisheries) issued a Biological Opinion on southern steelhead for the construction, operations and maintenance of the Robles facility (NOAA Fisheries 2003).

See paragraph 1, General Comments - See City's 2011 Water Master Plan.

2.9.3.4 Foster Park Surface Diversion and Subsurface Dam

The City of Ventura's water supply facilities at Foster Park consist of a surface and subsurface water collection system. These facilities operate in conjunction with an underground dam (a weir that is 973 feet long and maximum of 65 feet deep and stops short by 300 feet from extending the full breadth of both streams) that was constructed between 1906 and 1908 at the confluence of Coyote Creek and the Ventura River. The underground dam and confining bedrock surfaces increase groundwater levels in the vicinity of Foster Park to produce enhanced surface flows. These flows are captured by a surface diversion and a subsurface collector system consisting of two perforated concrete pipes situated on the upstream side of the dam. Since 2001, the City of Ventura has not used the surface water diversion, although it maintains the structures for possible use in the future (Kennedy/Jenks 2006). The subsurface diversion has produced water consistently and reliably despite heavy storm water flows.

2.9.3.5 Groundwater Wells

Several public and private groundwater supply wells are located within the Upper Ventura River basin in the vicinity of the mainstem of the river. The largest groundwater extraction entities are

Meiners Oaks County Water District (CWD), Casitas Springs Mutual Water Company, the Ventura River CWD, and the City of Ventura. Meiners Oaks CWD operates two wells located approximately 1 mile downstream of Matilija Dam and two wells in the vicinity of Meiners Oaks, one of which is adjacent to Rice Road. Meiners Oaks CWD produces approximately 1,150 AF of water per year from these wells. The Ventura River CWD operates three wells located between Meiners Oaks and the SR 150 crossing. The Ventura River CWD produces approximately 1,320 AF of water per year from these wells. Casitas Springs Mutual Water Company operates at least one water supply well north of the City's property at Foster Park. The location and annual production from that well is unknown (URS Corporation 2003). The City of Ventura operates four wells located in the Foster Park area. The City of Ventura produces approximately 4,000 AFY from these wells. (ENTRIX and Woodward Clyde Consultants 1997; Ventura County Water Purveyors' database 2000; updated by City of Ventura 2006). Production from the City's Foster Park facilities varies greatly from year to year due to effects of weather, local hydrology, the storage capacity of the Ventura River alluvium, and upstream diversions (URS Corporation 2003). The City's wells and pipelines are subject to damage by erosion from heavy storm flows.

More than 300 wells have been installed along the Ventura River and its tributaries, extracting groundwater from the Ventura River Alluvial Basin, outside of the Ojai Basin. Records of groundwater wells were examined at the Ventura County Public Works Agency, Water and Environmental (W&E) Division. A summary of the wells recorded and mapped is provided in Table 2.9-2. Data are unavailable for most wells. However, based on the limited data, it appears that most of the wells are shallow (less than 200 feet), drilled for domestic use, and potentially intact. The available data do not indicate how many wells are still in operation. A large number of the wells appear to have been installed during the 1986 to 1991 drought period. Because the vast majority of the wells are private, there is no monitoring of extractions and, therefore, no estimate of annual private pumping from the alluvial basin.

Table 2.9-2 Summary of Wells Adjacent to the Ventura River Mainstem and Tributaries

Area	No. of Wells				Type of Well			
	Active	Inactive or Abandoned	Unknown	Total	Domestic or Municipal	Irrigation	Unknown	Total
A. Estuary area, including Seaside and Emma Wood Parks	?	?	7	7	?	?	?	7
B. Lower river, between Main Street bridge and Foster Park	2	1	7	10	5	?	5	10
C. Foster Park area	?	1	22	23	3	?	20	23
D. Coyote Creek below the dam	?	?	6	6	1	?	5	6
E. Casitas Springs area	?	?	9	9	1	1	7	9
F. San Antonio Creek, below Soule Park	?	1	49	50	4	1	45	50
G. Santa Ana Creek watershed above Lake Casitas	?	?	18	18	10	?	8	18
H. Oak View, Live Oak Acres, and western Mira Monte	?	1	139	140	10	2	128	140

* See paragraph 1 of General Comments from attached comment letter - See City Water Master Plan March 2011

Canyon. Water users in the Ventura River watershed have no access to imported water and are therefore dependent upon maintaining an adequate supply of usable quality local water resources. For this reason, protection of local groundwater is vital, and an adequate understanding of groundwater storage volume and water quality trends is necessary. This report presents a groundwater budget for the sub-basins and an approach to a groundwater management plan (GWMP), as the first steps in planning for long-term protection.

The general approach for the groundwater budget is to estimate, based on available data and hydrogeologic analyses, the magnitude of all groundwater inputs and outputs within each of the sub-basins. Inputs include infiltration from precipitation, infiltration from irrigation, surface water recharge to groundwater, recharge from domestic septic systems, inflow from bedrock to the alluvial aquifer, and groundwater inflow from upgradient sub-basins. Groundwater outputs include municipal groundwater extractions, domestic groundwater extractions, agricultural groundwater extractions, industrial groundwater extractions, groundwater discharge to surface water, groundwater outflow, and groundwater consumption by riparian vegetation.

The resulting budget provides an estimate of the net gain or loss of the volume of groundwater in storage within the sub-basins per year. For the Upper Sub-Basin, a net gain of 1,466 AFY (Table 3.4-1) is estimated for the budgeted time period (WY 1997 through 2007). The primary inputs to groundwater in this sub-basin are infiltration and surface water recharge from Lake Casitas and the Ventura River, while the primary outputs are municipal and agricultural extractions. The estimated net gain in groundwater storage is relatively small and is consistent with long-term hydrographs of wells within the Upper Sub-Basin that indicate stable groundwater levels with 5 to 10-year rise and decline cycles. See Paragraph 1- General Comments to attached comment letter.

Table 3.4-1 Groundwater Balance Upper Ventura Sub-basin

Category	Parameter	Upper West (AFY)	Upper East (AFY)	Upper (Combined)[a] (AFY)
Groundwater Inputs	Infiltration from precipitation	893	4,181	5,073
	Infiltration from irrigation	222	2,891	3,113
	Net surface water to groundwater	2,003	2,290	4,293
	Septic system recharge	18	120	139
	Bedrock to alluvial [b]			113
Groundwater Outputs	Extractions (domestic)	1	16	17
	Extractions (municipal)	0	7,385	7,385
	Extractions (agricultural)	0	1,898	1,898
	Groundwater outflow to Lower Sub-basin [b]			535
	Consumption by riparian vegetation [b]			1,430
			Final Balance [c]	+1,466

Notes:
a: Numbers may not add exactly because of rounding
b: Values not calculated independently for East and West Sub-basins
c: Sum of groundwater inputs minus sum of groundwater outputs
Source: Daniel B. Stephens & Associates 2010

For the Lower Sub-Basin, a net loss of 2,423 AFY (Table 3.4-2) is estimated for the budgeted time period. The primary inputs are infiltration and inflow from the Upper Sub-Basin, while the primary outputs groundwater discharge to surface water and discharge to the Pacific Ocean. There are currently no water levels monitored by Ventura County within the Lower Sub-Basin for comparison to the budget. See Paragraph I- General comments to attached comment Letter.

Table 3.4-2 Groundwater Balance Lower Ventura Sub-basin

Category	Parameter	AFY[a]
Groundwater Inputs	Infiltration from precipitation	616
	Infiltration from irrigation	655
	Net surface water to groundwater	5
	Septic system recharge	319
	Bedrock to alluvial [b]	535
Groundwater Outputs	Extractions (domestic)	1,254
	Extractions (municipal)	1
	Extractions (agricultural)	522
	Groundwater outflow to Lower Sub-basin [b]	2,412
	Consumption by riparian vegetation [b]	365
	Final Balance [b]	-2,423

Notes:
a: Numbers may not add exactly because of rounding
b: Sum of groundwater inputs minus sum of groundwater outputs
Source: Daniel B. Stephens & Associates 2010

The intention of a GWMP is to provide a framework to manage groundwater to ensure a long-term, sustainable, reliable, good-quality water supply suitable to the political, legal, institutional, hydrogeologic, and economic conditions and constraints that exist in a groundwater basin. This report presents an approach to development of a GWMP for the sub-basins, including specifications for public participation, interagency involvement, coordination with the Ventura River Watershed Council, literature review and technical analysis, establishment of management objectives, and development of a monitoring program. The following outline provides an approach to development of a GWMP.

Component 1. Develop a map showing the area of the Basin, with the area that will be subject to the GWMP, as well as the boundaries of other local agencies that overlie any portion of the Basin. As a delineated groundwater basin with two delineated groundwater sub-basins, maps of the basins have been developed by both state and county agencies.

Component 2. Provide a written statement to the public describing the manner in which interested parties may participate in development of the GWMP. The statement should be provided to the public via local newspapers and/or other media, with distribution throughout the Basin. Documentation of public notification will be included in the GWMP.

See Paragraph 1, General Comments of this attached comment letter.

Chapter 4

Water Demand and Water Budget

4.1 Introduction

This section provides a summary and analysis of water supply and demand determinations for the overall Ventura River watershed. Data collected from various previous investigations has been compiled and presented in a form to illustrate both the level of understanding of water supply and demand and the types of data that will need to be addressed to improve the accuracy of a water budget for the watershed.

Wholesale and retailed water service within the watershed is provided by:

- Casitas (Municipal Water District) provides service within a 150-square mile area that includes the Ojai Valley and much of the lower Ventura River watershed. Casitas operates and maintains the Casitas Dam, Robles Diversion, and Robles-Casitas Canal (collectively referred to as the Ventura River Project) under contract with the U.S. Bureau of Reclamation to supply surface water from the Ventura River and Coyote Creek. Additionally, Casitas operates a single groundwater well in Mira Monte. Casitas provides water to retail customers, as well as several other public and private retail water operations.
- Golden State Water Company (Golden State) provides service to an area that is approximately the limits of the City of Ojai. Golden State relies on groundwater extractions from the Ojai Basin and supplements the groundwater supply with additional water from Casitas' service connections.
- Hermitage Mutual Water Company provides service to a limited area in the foothills north of the Ojai Valley. It relies on wells in the Ojai Basin and a supplemental connection to Casitas.
- Meiners Oaks Water District provides service in Meiners Oaks. It relies primarily on two wells in the Ventura River and has relied on Casitas only during infrequent system emergencies.
- Senior Canyon Mutual Water Company provides service in the east end of the Ojai Valley. It relies on three wells in the Ojai Basin and surface water diversions, with Casitas as a secondary source of water to buffer peak demands and as a drought contingency supply.
- Siete Robles Mutual Water Company services a single housing development located southeast of the City of Ojai. It relies on a well in the Ojai Basin and one service connection to Casitas that is used occasionally.
- Sisar Mutual Water Company provides service in the northeast area of the Upper Ojai Valley. It relies on groundwater wells and on a connection to Casitas as an emergency water source.
- Tico Mutual Water Company provides service in Mira Monte. It relies on one well in the Mira Monte area and one 2-inch service connection to Casitas as a backup supply.

See Paragraph 5 of General Comments from attached Comment Letter.

Chapter 6

Data Gaps

Data gaps have been identified for both the HSPF model and the groundwater budget; these data gaps and recommendations to fill them are described below.

6.1 HSPF Model

6.1.1 Study Limitations

The Calibration and Validation Baseline Report (Tetra Tech 2009a) identified the following areas where the HSPF model might be further improved:

- There is uncertainty regarding the model's ability to accurately predict high flow peaks at the North Fork Matilija and Happy Valley Drain stream gages. Some improvement could likely be attained by refining the channel hydraulic representation through development of HEC-RAS models for these subwatersheds, which would require assembly of additional information on channel dimensions and structures. Note that as part of the Federal Emergency Management Agency (FEMA) Cooperating Technical Partners (CTP) Program for Happy Valley Drain, a HEC-RAS model was developed and is available for further refinement of HSPF in this area (District 2011b).
- Simulation of event peaks in Happy Valley Drain also was identified as being particularly problematic. The hydrology in this area is complex, including a diversion and a concrete channel. The report noted that detailed survey and small scale modeling of this area might reveal ways in which the model representation could be improved. This also was done as part of the FEMA CTP for Happy Valley Drain.
- Model fit to the Santa Ana and Coyote Creek gages is uncertain due to the lack of information on gage accuracy and bias. New rating tables have apparently not been developed for these gages in a number of years, and adjustments are likely needed to reflect changes in channel dimensions. Measurements to develop a current-day rating curve would assist in interpretation of records from earlier in this decade.
- As noted above, the quality of gage records for Coyote Creek and Santa Ana Creek is uncertain. These gages are useful for providing a broad basis to evaluate model performance. Tetra Tech suggests that field measurements be made on a regular schedule (at least annually) to provide a basis for calibrating and adjusting the Coyote Creek and Santa Ana Creek rating tables.
- No current gauging exists in the southernmost portion of the watershed, downstream of Foster Park. As a result, this portion of the model cannot be directly calibrated. Tetra Tech suggests that a mainstem gage should be installed at an appropriate location near the outlet of the Ventura River. In addition, the Canada Larga peak flow gage should be operated to provide continuous flow records.
- The present-day precipitation monitoring network appears to provide generally good coverage of the watershed. However, quality assurance can likely be improved for the high

1. Consider Density, as higher density development consumes less land and produces less impervious cover per capita than low density development.

2. Identify and Preserve Contiguous Open Space and look for opportunities to link open space preservation with regional open space preservation efforts.

3. Make use of Previously Developed Sites, as this reduces the need for greenfield development, and makes use of existing infrastructure.

4. Locate Development within Close Proximity to Mass Transit to reduce the number of automobile trips, and lessen the water quality impacts associated with transportation.

Design criteria at the Site scale include:

5. Maintain and Restore Natural Flowpaths for Runoff to reduce the amount of clearing and grading and maintain the pre-development hydrology's time of concentration.

6. Maximize Use of Existing Impervious Cover to reduce runoff at a watershed scale.

7. Design Public Spaces and Common Areas to Minimize Stormwater Runoff.

8. Compact Project Design to reduce the amount of impervious cover per capita and increase walkability, and decrease water quality impacts associated with transportation.

9. Encourage Use of Multiple Modes of Transportation.

Implement Integrated Water Resource Management Practices

Integrated Water Resource Management (IWRM) is a process which promotes the coordinated development and management of water, land, and related resources. Many of the concepts of IWRM are documented in the County's IRWMP, a product of an intensive stakeholder process, and address multiple water resource management goals. These practices include:

1. Conserve and Augment Water Supplies: Identify and evaluate the opportunities to recharge groundwater and increase water use efficiency. This can be accomplished through infiltration of stormwater runoff and selection of drought-tolerant landscaping. Additional wells at Foster Park to capture high river flows.
2. Protect People, Property and the Environment from Adverse Flooding Impacts: Identify opportunities to utilize BMPs that provide both water quality and water quantity benefits. Provide and maintain setbacks from streams and rivers.

3. Protect and Restore Habitat and Ecosystems in Watersheds: Implement the practices identified in Protect and Restore Natural Areas to integrate habitat and stormwater goals. Landscaping selection for stormwater management practices may also further encourage and attract wildlife.

4. Provide Water-related Recreational, Public Access and Educational Opportunities: Integrate recreation and stormwater management by creating multi-functional BMPs and designing

Table 7-1 Best Management Practices for Construction and Maintenance Activities

Category	Specific Practice(s)
	Where technically feasible, vehicles and heavy equipment shall not be driven or equipment operated in water covered portions of the stream channel, or where wetland vegetation, riparian vegetation, or aquatic organisms may be destroyed, except as necessary to complete the authorized work. When technically feasible, restrict construction activities to scoured areas or to areas dominated by non-native vegetation to avoid damaging native trees and shrubs.
	Where technically feasible, the use of heavy equipment shall be avoided in a channel bottom with rocky or cobbled substrate. Instead, manual labor should be used whenever practical. If manual labor in rocky substrate is not feasible, a rubber tire loader/backhoe is the preferred vehicle by the Services and the amount of time this equipment is stationed, working, or traveling within the creek bed shall be minimized
	Access to the work site shall be via existing roads and access ramps, unless otherwise specified or approved by the Services. If no ramps are available in the immediate area, a ramp should be constructed in the footprint of the project. Any temporary ramp shall be removed upon completion of the project. Where feasible, ramps should be graded within the elevated bank area, down to but not in the channel bottom.
	Vehicles may be driven on the streambed to traverse the distance to the work site from the access point, and in the immediate vicinity of the work area, and only as necessary to accomplish the authorized work.
	When temporary access is removed, remaining disturbed soil shall be stabilized and seeded with appropriate native seed mix immediately after work completion. If a stream's low flow channel, bed or banks have been altered during operations, channel topography and geometry shall be restored to pre-project conditions to the extent possible, without creating future erosion problems.
Fill and Spoil	Fill shall be limited to the minimal amount necessary to accomplish the activities. Fill construction materials, other than on-site alluvium, shall consist of clean silt-free gravel or river rock.
	Rock riprap may be used to repair eroded slopes that previously contained riprap, allowing for in-kind replacement or repair of existing facilities. Material for backfilling an eroded slope area may be obtained from onsite alluvium.
	Where feasible, to facilitate recovery of vegetation and provide additional protection from erosion on ungrouted riprap banks, the Operator shall place branches from willow trees into the open toe-trench and within the wick zone of the shaped sideslope, prior to placing the filter rock and unconcreted armor rock.
	Spoil storage sites shall not be located within a stream, where spoil can be washed back into a stream, or where it will cover aquatic or riparian vegetation. Upslope erosion control BMPs (i.e., blankets/geotextile fabrics, coir fabric/netting, mulching, planting, silt mat, etc.) shall be used to protect and stabilize stockpiles and exposed soils to prevent movement of materials. Avoid placing temporary spoil stockpiles at the top of unstable slopes or at the edges of slopes. Remove temporary stockpiles to permanent disposal locations before the rainy season or, if work is conducted during the rainy season, as soon as feasible and before the next rain storm.

7.4.5 Measures Recommended by the Draft Southern California Steelhead Recovery Plan

In July 2009 the National Marine Fisheries Service (NMFS) released the draft Recovery Plan for the endangered Southern Steelhead (NMFS 2009). Recommendations for the recovery of this Distinct Population Segment for the Ventura River watershed include a number of best management practices and actions that in the view of the NMFS would lead to the recovery of the species in Southern California. Inclusion of these recovery actions can help assure that projects defined within the watershed management plan are consistent with the requirements for the federal endangered species act. Recovery actions (from Table 8-6 in NMFS 2009) include:

- Conduct hydrological analysis(groundwater)

See Paragraph 3 of General Comments of attached Comment Letter.

Chapter 8

Future Actions to Improve Water Sustainability and Ecosystem Functions

8.1 Recommended Actions

The following recommended actions are provided to improve the sustainability of water resources and improve ecosystem functions.

8.1.1 Watershed Management Plan

Based on lessons learned from review of other applicable plans, the recommendations (in Chapter 5) are summarized as follows:

- Identify the intended audience and provide appropriate content
- Engage watershed stakeholders
- Clearly define and state the plan's goals and objectives
- Focus the scope of the plan
- Focus on issues where stakeholders can make a meaningful difference
- Work with regulatory programs
- Prioritize projects that can meet the plan's objectives
- Identify mechanisms and a process to gauge progress towards plan implementation

8.1.2 Stakeholder Involvement

The creation of the Ventura River Watershed Council provided a forum for discussion of issues at the watershed scale. In addition, the implementation of the "Watershed U" expanded awareness of watershed issues and generated substantial interest in how individual actions could improve watershed conditions. To enhance and extend stakeholder involvement:

- Continue meetings of the Watershed Council and consider extending invitations to relevant organizations or entities that have not participated regularly;
- Improve and regularly update the Watershed Council's webpage, to provide a consistent source of meeting notices, agendas, and other relevant information and consider providing links to relevant information for other organizations and groups involved in watershed restoration.
- Build upon stakeholder interest by publicizing meetings and workshops that provide useful information for residents and land-owners, such as: water conservation, stormwater management, or watershed-friendly gardening.

Responses to comments from Shana Epstein, dated January 11, 2012

As noted in the introduction, a major focus of the report is to summarize available information provided from existing reports, and as such does include substantial material from other reports. The City's 2010 Urban Water Management Plan was used as a source document for the Draft Report and the final report has been updated to incorporate information from the 2011 Sanitary Survey. The referenced 2011 Water Master Plan could not be located online and thus is not utilized as a source document.

The report provided an estimate of water demand within the watershed. As the service boundaries of Ventura Water extend outside of the watershed, the inclusion of the demand for the entire service area would have over-estimated water demand. To account for water demand within the watershed boundary, the report pro-rated water demand based on 2010 census data for the residential population that resides within the watershed. Cardno ENTRIX acknowledges that the pro-rated demand calculation is only an estimate, and should not be inferred as an attempt to misrepresent water rights, characterize water sources, or the appropriate utilization of those services within the service boundary of Ventura Water.

In response to the marked-up pages from the Draft Report, the Ventura Water Master Plan (RBF 2011) was reviewed, and several revisions were made to the text and tables in this Final Report.

Responses to comment letter (attached to letter from Shana Kaplan) from Hopkins Groundwater Consultants, dated January 10, 2012

As noted in the introduction, a major focus of the report is to summarize available information provided from existing reports, not to provide a foundation for a comprehensive watershed management plan.

The estimate of water demand did not address water supply, and thus does not include any data with respect to current or historical diversions from the Ventura River. The pro-rated estimate was derived from the water demand information provided in Table 2-5[2] of the 2010 Urban Water Management Plan for the City of Ventura, which included the following demand categories: Single-Family, Multi-Family, Commercial, Industrial, Government/Institutional, and Landscape. Thus, industrial water use (and several other categories) were included the estimate. Note that per an oral comment received on December 13, 2011, the estimate in of water demand in this report has been revised to add water demand associated with Petroleum Recovery Operations.

The recommendations provided in Section 5.4 (Recommendations for Ventura River Watershed Management Plan) were based on a review of the applicable watershed management plans that were summarized in Chapter 5, and are intended to address the scope, content, and approach to development of a plan, and were not intended to serve as limitations on information that could be helpful in the preparation of a plan.

[2] Instead of Table 2-1 as cited in the Draft Report.

The suggestion to implement Integrated Water Resource Management (on Page 7-4 of the Draft Report) was derived from the Ventura County Technical Guidance Manual for Stormwater Quality Measures, and thus does not address the implementation of a specific project or water management technique. It is assumed that the referenced Foster Park Wellfield Design Study proposes improvements which are consistent with the practices summarized on the referenced page, including: Conserve and Augment Water Supplies; Protect People, Property and the Environment from Adverse Flooding Impacts; and Protect and Restore Habitat and Ecosystems in Watersheds.

Cardno ENTRIX concurs that if a groundwater management plan is developed, it should be administered by a public agency.

VENTURA RIVER
COUNTY WATER DISTRICT

409 Old Baldwin Road
Ojai, CA 93023
Phone (805)646-3403
Fax (805) 646-3860
www.vrcwd.com

DIRECTORS

Ed Lee – President
Marvin Hansen – Vice President
Eddie Ramseyer – Treasurer
Tom Jamison
Jack Curtis

GENERAL MANAGER

Bert Rapp, P.E.

OFFICE MANAGER

Janet Schaefer

ATTORNEY

Lindsay Nielson, ESQ

January 12, 2012

Norma Camacho, Director
Ventura County Watershed Protection District
800 S. Victoria Ave.
Ventura, CA 93009-1600

SUBJECT: COMMENTS ON THE DRAFT VENTURA RIVER WATERSHED PROTECTION REPORT

Dear Norma;

The Ventura River County Water District respectfully submits comments to the draft Ventura River Watershed Protection Plan Report dated December 2011. The draft report was prepared by Cardno ENTRIX under the direction of the VCWPD.

Chapter 4 Water Demand and Water Budget

The water usage figures in this chapter are based upon the 2010 water year. While this may be close to an average year it is really irrelevant to water demand and water budgeting in the watershed because of the unique character of the Ventura River Watershed. The aquifers are small, hold only one to three years supply of water and re-fill rapidly in one good rain year.

It would be much more realistic to utilize the 20 year design drought Safe Yield analyses prepared by Casitas MWD because it is based upon actual ground water basin yields and user demands during droughts with variable rain years during the 20 years.

If needed the current Safe Yield analyses could be updated for recent changes in diversion restrictions and new pumping demands that may have occurred since the last update.

Chapter 8 Future Actions....

Section 8.1.4 Data Gaps recommends:

- The District should convene a technical advisory group to assess and prioritize data gaps that limit development of a comprehensive water budget, with input from the Ventura River Watershed Council.

Our District would recommend that the greatest data gap need is not for a "comprehensive water budget" but to move forward with the Data Gaps identified in the 2001 Surface Water-Ground Water Interaction Report referenced on page 2-42 of this report. The LARWQCB is scheduled to impose a Pumping TMDL for the Ventura River by 2019. The most critical data gap needed for implementing a Pumping TMDL is to fully understand the interactions between surface water, ground water and pumping. To that end we recommend changing the Section 8.1.4 bullet to read:

- The District (VCWPD) should convene a technical advisory group to assess and prioritize data gaps that limit the understanding of the groundwater – surface water – ground water pumping interactions, with input from the Ventura River Watershed Council.

Section 8.1.5 Ventura River Groundwater Management Plan

According to this report the Ventura River groundwater basins only hold a one to three year supply of water and refill with one wet year. This is in contrast to the ground water basins on the Oxnard Plain that hold a multi-year supply of water, do not recharge easily and are in overdraft. The report acknowledges that: "ground water extraction use during droughts has not exceeded recharge capability." (Section 2.6.3.2)

In order to survive a 20-year drought the water in the ground water basins must be utilized first before water is taken from Lake Casitas. Without the water in the groundwater basins there is not enough water in the valley to survive a 20-year drought.

Therefore we do not see a need to develop a Groundwater Management Plan for the Ventura River Watershed.

Section 8.1.6 Water Budget

The report recommends creating a watershed-wide water budget "to determine whether the water resources in the Ventura River watershed are sufficient to meet total water demand." However Casitas MWD already has a 20 year safe yield analysis that encompasses the lake, all ground water basins in the valley and water demand including anticipated future conservation efforts. This safe yield analysis utilizes historic and projected yields and demands. Creating a new "Water Budget" would be redundant.

If more water supply and demand precision is needed it would be better to update the Casitas 20-year Safe Yield analyses rather than create a new Water Budget. Therefore we recommend changing the recommendation bullet under **Section 8.1.6** to read:

- The Casitas MWD should update the 20-year safe yield analysis for Lake Casitas to incorporate current supply and demand projections with input from the Ventura River Watershed Council.

Chapter 3 Section 3.4 Groundwater Management Plan

Our District does not see the need at this time for a Groundwater Budget or a Groundwater Management Plan in this watershed. That being said we would like to comment on the recommendations for Component 11 & 12 on pages 3-22 & 3-23. These components recommend that the Watersheds Coalition of Ventura County and the Ventura River Watershed Council have administrative functions that should, in our opinion, be performed by a responsible Public Agency. The Coalitions serve as an excellent format for gathering stakeholders and being an advisory committee but they are not an "Agency."

The responsible Agency, if a Groundwater Management Plan is formed, should be the Watershed Protection District or Casitas MWD.

Additional comments are included on the marked up pages of the report attached to this letter.

Very Truly Yours

VENTURA RIVER COUNTY WATER DISTRICT

Bert J. Rapp, P.E.

General Manager

cc: Mark Horn, Senior Consultant/Water Resources, Cardno ENTRIX
Zia Hosseinipour, VCWPD
Casitas Municipal Water District
Ventura Water
Meiners Oaks County Water District

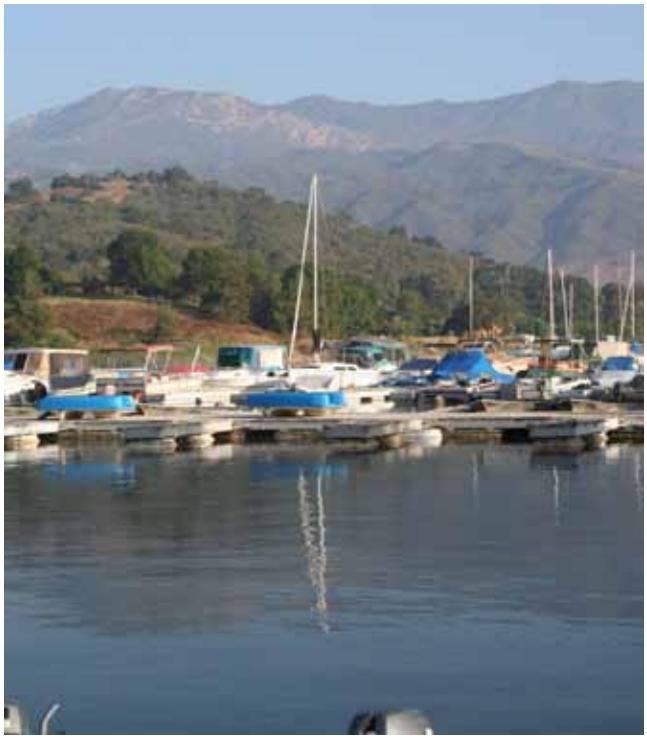
General Comment from VRCWD:

A location map is needed that shows the names of creeks and major roads along with major landmarks like the large faults etc.

Several multiple-use trails serve bicyclists, equestrians, and pedestrians in the watershed. The Ojai Valley Trail follows the abandoned Southern Pacific Railroad right-of-way and is located along the west side of State Route 33 from Ojai to northern Foster Park. In the City of Ventura, the Omer Raines Trail parallels the Ventura River and terminates at Main Street. A Class I trail, following the Southern Pacific Railroad easement connects the Ojai Valley Trail with the Omer Raines Trail. The City of Ventura owns and manages the Ventura River Trail, a multi-purpose trail that extends from Foster Park to the beach.

Is the Omer Raines Trail the Ventura River Trial? The text is not clear.

Lake Casitas is open to the public for non-body contact recreational activities. All recreational activities are operated by Casitas Municipal Water District (Casitas) or by concessionaries.



The Recreation Area encompasses approximately 4,097 acres and consists primarily of open space. The recreational facilities are located on approximately 400 acres scattered about the perimeter of the lake. Existing recreational facilities include camping, picnicking, motor boating, sailing, canoeing, and fishing. Lake Casitas hosted the 1984 Olympic Rowing and Canoeing Events and is currently the home of the Lake Casitas Rowing Association which provides recreational and competitive rowing training to youth and adults in the community. The lake is also used by bird watchers to view the many migratory birds that use Lake Casitas as they pass through the Pacific flyway. Facilities include stores, campgrounds, RV campgrounds, showers, restrooms, picnic areas, boat ramps, water playground, a radio-controlled airplane landing strip, and boat and trailer storage.

Lake Casitas is famous for its record fish catches. Fishing takes place from docks, boats, and shore. Lake Casitas contains a warmwater fishery that includes bass (primarily large mouth), catfish, sunfish, and crappie. These fish are non-native and were introduced when the lake was formed, but now are self-sustaining populations. Both the ~~California Department of Fish and Game (CDFG)~~ and Casitas also stock the lake annually with catchable size rainbow trout. Lake Casitas has also been stocked on an irregular basis with crappie and other panfish.

The Ventura County Parks Department maintains three regional parks (Camp Comfort, Soule Park, and Foster Park) located adjacent to waterways of the Ventura River. Camp Comfort Regional Park is situated adjacent to San Antonio Creek. Soule Park recreation area consists of a golf course and a public park. The confluence of San Antonio and Thacher creeks occurs within Soule Park, and the Ventura River runs through Foster Park. Activities at all parks include picnicking and playground areas and services such as public restrooms. Park users also wade in San Antonio Creek at Camp Comfort and in the Ventura River at Foster Park. Soule Park includes baseball and equestrian facilities as well as a public golf course. Water for golf course

Low Flows

Under summer low flow or drought conditions, surface streamflow at various locations in the watershed are governed by a complex interaction of precipitation input; discharge from springs; groundwater levels; the effects of water diversions, water storage, water supply releases, and treated wastewater discharge and groundwater extraction.

It is not unusual for streams in Southern California that are rainfed, and lack groundwater support, to dry up in summer months, in both average and below average precipitation years. In the Ventura River watershed, however, several of the smaller tributaries, and even the mainstem, have short perennial reaches that are fed by springs and/or the perched groundwater over shallow bedrock. Perennial flows are present in San Antonio Creek, and in the Casitas Springs/Foster Park reach, defined as the portion upstream of, and including, Foster Park and including lower San Antonio Creek from SR 33 to its confluence with the Ventura River. The presence of year-round flow in this reach of the river is due to high groundwater levels in the shallow alluvium over bedrock, which is artificially raised at Foster Park by the City's subsurface dam (URS Corporation 2003).

Small summer streamflows maintained by springs were documented by both Reclamation (1954) and EDAW et al. (1981) in the upper reaches of the larger sub-basins. EDAW reported typical summer base flows of 1 to 2 cfs in North Fork Matilija Creek, 1 to 3 cfs in Matilija Creek, and less than 0.5 cfs in San Antonio Creek and Coyote Creek below Casitas Dam. Since the 1960s, effluent discharge from the OVSD Wastewater Treatment Plant provides summer flows of approximately 1.9 cfs (2002 data) from the OVSD Wastewater Treatment Plant downstream to the lagoon.

2.6.3 Groundwater

Groundwater has been an important water source for irrigation and municipal supplies in the Ventura River watershed for many decades. In general, groundwater in the Ventura River system occurs under unconfined conditions. However, in some localized areas (where fine-grained overbank deposits form a relatively low permeability cap over old channel deposits with higher permeability), semi-confined conditions may exist, especially during periods of high water levels (Fugro 2002). The primary source of recharge to the alluvial aquifer system is direct infiltration of surface flows. Two other sources of recharge include direct infiltration of precipitation, and downvalley underflow through alluvial sediments.

The Ventura River system is composed of five major groundwater basins: the Upper Ojai basin; the Ojai basin; the Upper Ventura River basin; the Lower Ventura River basin; and the San Antonio Creek basin (ENTRIX 2001c). Of primary importance to this report are the Upper Ventura River, Ojai, and San Antonio Creek basins because local agencies operate and maintain water supply facilities in these areas (Figure 2.6-6). A description of the major groundwater basins is provided below.

Table 3.4-1 Shows Precipitation: 40%, Irrigation: 24% and Surface Water to Groundwater: 34%. So the primary source of recharge would be precipitation not surface flows. Which is correct?

2.6.3.1 Groundwater Basins

Upper Ventura River Basin

The Upper Ventura River Basin has a partial downslope along the Arroyo Parida fault to the north (ENTRIX 2001b). The upper basin extends from the confluence of Matilija Creek and North Fork Matilija Creek (RM 16.2) to the City's subsurface dam at Foster Park (RM 5.9),

which delineates the boundary between the Upper and Lower Ventura River groundwater basins. The basin is believed to have a capacity of approximately 14,000 AF when full (USACE 2004). The boundary between the Ojai Basin and the Upper Ventura River Basin is situated between Camp Comfort to the south and Arbolada to the north. The depth to bedrock decreases in the vicinity of this boundary resulting in a decrease in thickness of the aquifer materials.

The Upper Ventura River is underlain by alluvial deposits with a maximum thickness of approximately 200 feet and an average thickness of 60 to 100 feet. A natural subsurface obstruction blocks subsurface flow below the Ventura River just above San Antonio Creek causing groundwater to rise as springs. Therefore, the groundwater beneath the Ventura River is divided into an upper cell and a lower cell (Reclamation 2003).

This Figure is missing

The thickness of aquifer materials is generally shallow, but varies along the river due to the geologic structure of the basin (variations in the depth to bedrock and faulting). Along the Upper Ventura River, the water-bearing units increase in thickness downstream of the confluence of Matilija and North Fork Matilija creeks, attaining a maximum thickness of approximately 200 feet on the north (down dropped) side of the Arroyo Parida-Santa Ana fault (Figures 2.6-7 and 2.6-8). Downstream of the Santa Ana fault, in the Mira Monte area, the alluvium thickness is controlled by the folded bedrock surfaces and is approximately 65 feet thick. In the Foster Park area, north of the subsurface dam and in the vicinity of the City's Nye Wells, the aquifer materials are 45 to 60 feet thick, providing a saturated thickness ranging from 35 to 45 feet (Fugro West 2002). The total storage capacity of about 14,000 AF typically empties during a 1 to 3-year critical dry period. The dominant source of recharge is direct infiltration or precipitation and percolation from local streambeds (ENTRIX and Woodward Clyde Consultants 1997).

Ojai Groundwater Basin

The Ojai Groundwater Basin (Ojai Basin) is located within the Ventura River watershed, within the western portion of Ventura County, California. The Basin is bordered by the Topa Topa Mountains and Santa Ynez Mountain Range on the north and east, Black Mountains on the south, and the Upper Ventura River Groundwater Basin to the west. Ground surface elevations across the alluvial surface of the Basin range from over 1,300 feet above mean sea level (amsl) at the northeastern portion of the Basin, to approximately 700 feet amsl. The drainage area for the basin comprises 36 square miles and rises to elevations over 4,500 feet amsl. The alluvial groundwater Basin is 10.7 square miles (Kear 2005, as cited in Daniel B. Stephens & Associates [DBS&A 2010b]). A large fraction of land within the basin is dedicated to orchards, with the remaining area composed of residential, pasture, commercial and vacant land uses. Municipal and agricultural water requirements of the basin have historically been supplied by both surface water and groundwater sources.

The Ojai Basin is composed of alluvium deposits within a structural depression, and the lateral boundaries of the basin are defined by the contact between the alluvial deposits and the underlying sedimentary rocks (SGD 1992, as cited in DBS&A 2010b). The alluvial aquifer consists of undifferentiated and poorly consolidated deposits of clay, sand, gravel, and boulders. Confining clay units exist within the alluvium, and Kear (2005, as cited in DBS&A 2010b) reported that the units are thickest in the southern portion of the basin.

Component 3. Establish a plan to involve other agencies whose boundaries overlie the Basin in development of the GWMP. This may include involvement via agency representative participation in the Ventura River Watershed Council (see Component 4).

Component 4. Establish a process for the Ventura River Watershed Council to serve as the designated advisory committee of stakeholders (interested parties) within the plan area that will help guide the development and implementation of the GWMP and provide a forum for resolution of controversial issues.

Component 5. Describe, in detail, the area to be managed under the GWMP, including (1) the physical structure and characteristics of the aquifer system underlying the plan area in the context of the overall basin; (2) a summary of the availability of historical data; (3) issues of concern; and (4) a general discussion of historical and projected water demands and supplies.

Component 6. Establish management objectives (MOs) for the groundwater basin that is subject to the plan. MOs are intended to contribute toward a more reliable supply for long-term beneficial uses of groundwater in the plan area. For example, MOs for a typical groundwater basin may include the installation of infiltration basins or reduction in groundwater extraction.

Component 7. For each MO in Component 6, describe how meeting the MO will contribute to a more reliable supply for long-term beneficial uses of groundwater in the plan area, and describe existing or planned management actions to achieve MOs.

Component 8. Adopt monitoring protocols for the monitoring and management of groundwater levels, groundwater quality, potential inelastic land surface subsidence, and changes in surface flow and surface water quality that directly affect groundwater levels of quality.

Component 9. Describe the monitoring program, including the following:

- A map indicating the general locations of any applicable monitoring sites for groundwater levels, groundwater quality, subsidence stations, or stream gages.
- A summary of monitoring sites indicating the type (groundwater level, groundwater quality, subsidence, stream gage) and frequency of monitoring. For groundwater level and groundwater quality wells, indicate the depth interval(s) or aquifer zone monitored and the type of well (public, irrigation, domestic, industrial, or monitoring).
- A QAPP for monitoring in the basin.
- Standard operating procedures for monitoring in the basin.

Component 10. Describe any current or planned actions by the local managing entity to coordinate with other land use, zoning, or water management planning agencies or activities.

Component 11. Provide for periodic report(s) summarizing groundwater basin conditions and groundwater management activities. The report(s) prepared annually or at other frequencies as determined by the Watersheds Coalition of Ventura County, should include the following:

- Summary of monitoring results, including a discussion of historical trend
- Summary of management actions during the period covered by the repor

The responsibility for Component 11 needs to be fulfilled by a responsible Agency not a Coalition.

- § Discussion, supported by monitoring results, of whether management actions are achieving progress in meeting MOs.
- § Summary of proposed management actions for the future.
- § Summary of any plan component changes, including addition or modification of MOs during the period covered by the report.
- § Summary of actions taken to coordinate with other water management and land use agencies and other government agencies.

Component 12. Provide for the periodic reevaluation and updating of the plan by the Ventura River Watershed Council. Needs to be a responsible Agency not a Coalition.

3.5 Upper San Antonio Creek Watershed Giant Reed Removal Project

Giant reed (*Arundo donax*) is an invasive plant that consumes large quantities of water; displaces native vegetation and wildlife; disperses readily during floods; and exacerbates flooding, erosion, and fire intensity. The goal of the Upper San Antonio Creek Watershed Giant Reed Removal Project was to substantially reduce the abundance and distribution of giant reed from the Upper San Antonio Creek Watershed, including Upper San Antonio, McNell, Thacher, and Reeves creeks. The distribution of giant reed within these creeks is patchy; overall, its percent cover relative to other vegetation is fairly low (less than about 20 percent). However, there are a few locations where its percent cover is as much as 76 percent. Figure 3.5-1 provides a giant reed distribution map of the project area. The project also involved the opportunistic removal of castor bean in areas where it occurs in close proximity to the giant reed. The intended outcome of the Project is the re-colonization of native vegetation and the restoration of native habitats. A total of 212 acres were targeted for giant reed removal (District 2010c)

The “cut and daub” method was used to remove the giant reed and treatments only occurred when surface water was not present. The method involved manually cutting off the canes of the giant reed and painting the freshly cut surface with a glyphosate-based herbicide that is approved and labeled for use near and in open water, such as Aquamaster®. Treatment began in June 2010 and ended in December 2011.

Glyphosate is a broad-spectrum, non-selective, post-emergent herbicide that readily and completely biodegrades in soil and has little potential for leaching into groundwater. The primary MCL for glyphosate in drinking water sources or water bodies with a MUN (municipal and domestic supply) beneficial use designation has been set by the USEPA at 700 parts per billion (ppb). This is the equivalent of 700 parts of glyphosate to 999,999,300 parts of water and is the level of protection that the USEPA believes would not cause potential short-term or long-term health effects. Therefore, as a protective measure, the threshold for glyphosate for this project was also set at 700 ppb.

Aminomethylphosphonic acid (AMPA) is a breakdown product of glyphosate as the result of microbial metabolism. The laboratory method used to analyze for AMPA also measured glyphosate and glufosinate. Glufosinate is similar to glyphosate in its chemical structure and use. There are no regulatory limits for AMPA or glufosinate.

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- Ventura (City) provides service to the entire city and some adjacent unincorporated areas. Its water portfolio includes shallow wells in the Ventura River near Foster Park, rights to reclaim water from the OVSD Wastewater Treatment Plant, several connections to a Casitas pipeline, and groundwater sources from the east end of Ventura.
- Ventura River County Water District provides service to Casitas Springs, Rio Via, Monte Via and Oak View, and relies on two wells in the Ventura River and supplemental water from Casitas.

four

4.2 Water Demand

4.2.1 Muncipal and Industrial (M&I) Demand

The overall M&I water usage (demand) for an average water year can be calculated from deliveries reported by Casitas along with the groundwater extractions for municipal and domestic uses in the Upper and Lower Ventura sub-basins, the Ojai Basin, and the Upper Ojai Basin, as provided in Table 4-1 below. These cumulative water deliveries are representative of the basin as a whole because Casitas provides water service to a large portion of the watershed, and the remaining areas receiving M&I supplies are supported by Golden State (City of Ojai) and the City of Ventura, and the various smaller water providers (which primarily rely on groundwater with supplemental supplies from Casitas).

Table 4-1 Estimated 2010 Municipal and Industrial Water Demand

Source/Location	Amount (AF)	Note
Casitas	9,674	Sum of 2010 urban water demand and sales to other retail agencies, not including City of Ventura[1]
Golden State	1,741	2010 (groundwater) demand, not including sales from Casitas[2]
Ventura (City)	2,507	Pro-rated share of 2010 Ventura City demand within watershed[3]
Upper and Lower Ventura Sub-Basins	8,657	Estimated annual domestic & municipal extractions, 1997-2007[4]
Upper Ojai Basin	11	Extractions in 2008 by Sisar Mutual Water Company[5]
Total	22,591	Total of all extractions within watershed for M&I use

Sources:

1: Casitas, 2011, Tables 6 and 9, not including 300 AF of groundwater from Mira Monte well

2: Kennedy/Jenks, 2011b, Table 4-1, not including supplemental water delivered by Casitas.

3: Pro-rated estimate based on population residing within the Ventura River watershed. Total 2010 water demand in service area for the City of Ventura (including residential, commercial, industrial, institutional/government, and landscape uses) is 15,671 AF (Kennedy/Jenks, 2011a, Table 2-1). Population within the Ventura River watershed is estimated at 18,121 (for Ventura County census tracts 21.02, 22, 23 & 24, per census tract data from California Department of Finance, 2011), which is 16% of total service area population (of 113,478, per Kennedy/Jenks, 2011a, Table 2-1)

4: DBS&A, 2010a, Tables 13 and 14

5: Casitas, 2011, Table 8

It should be noted that the available data does not allow development of an estimate for a consistent timeframe (as the estimate in Table 4-1 is primarily for 2010, except for groundwater extractions). Thus some variations in the estimate are likely due to annual variations in climatic conditions. In addition, the Ojai Basin Groundwater Management Agency (OBGMA) assumes that all water extractions outside the Golden State service area are for irrigation use (as discussed below).

Responses to comments from Bert J. Rapp, January 12, 2012

Chapter 4, Water Demand and Water Budget: The estimate of Water Demand is generally based on 2010 data, to the extent that such data was available, and covers the entire watershed, including those portions of the watershed that are outside the service boundaries of the Casitas Municipal Water District. A more comprehensive estimate of water demand and supply could help improve the management of water resources, particularly if that assessment considered a variety of water year conditions, such as an average, dry, and critically-dry water years, consistent with recent Urban Water Management Plans. The suggested update of Safe Yield analysis for Lake Casitas would be a useful component, but additional data would be needed to reflect demand and supply for the entire watershed, including those areas for which water demand and supply information is only marginally available (such as Upper Ojai).

Section 8.1.4: Data Gaps: Cardno ENTRIX concurs that the understanding of the interaction between surface and groundwater within lower stretches of the Ventura River above Foster Park is not well understood. In their recommendations to improve groundwater estimates in the lower Ventura River groundwater basin, Daniel B. Stephens & Associates (DBS&A 2010a), proposed the installation of monitoring gauges to better track surface and groundwater in this area. This issue is one of the hindrances to the development of a water budget or a groundwater model, which could both be relevant to future planning related to compliance with a future TMDL related to pumping.

Section 8.1.5: Ventura River Groundwater Management Plan: Cardno ENTRIX acknowledges that differences of opinion exist with respect to the need to develop a groundwater management plan.

Section 8.1.6: Water Budget: The Water Supply and Use Status Report (Casitas 2004), which provides an estimate of the Safe Yield for Lake Casitas, is focused on surface water diversions to the lake, and thus does not address flows that enter the lower portions of the Ventura River, such as San Antonio Creek, nor addresses the utilization of groundwater on a comprehensive basis in the watershed. A comprehensive water budget would address all sources of water supply, including both surface and groundwater in a comprehensive fashion.

Chapter 3, Section 3.4 Groundwater Management Plan: Cardno ENTRIX concurs that if a groundwater management plan is developed, it should be administered by a public agency.

In response to the marked-up pages, the body of the report was revised to correct or clarify the text.

Unsigned comment letter from Ojai Basin Groundwater Management Agency, January 12, 2012

The Ojai Basin Groundwater Management Agency (OBGMA) appreciates the opportunity to comment on the Draft Ventura River Watershed Protection Plan Report of December 2011 (Draft Report, Report, also Plan) prepared by Cardno ENTRIX (CE) for the Ventura County Watershed Protection District (WPD).

The OBGMA manages the Ojai Groundwater Basin, the largest alluvial groundwater basin within the Ventura River Watershed. Numerous bedrock water wells are also within the OBGMA boundaries, similar to other bedrock aquifers elsewhere in the Ventura River Watershed. Comments contained herein are the result of a collaborative effort of board members, staff, and stakeholders within the OBGMA jurisdiction.

Based on presentations to the Ventura River Watershed Council by the WPD and CE, we understood that the Draft Report intended to summarize the four other elements in the top-priority project suite of the Proposition 50 Implementation Grant for the Ventura River Watershed (Project V-1). There is considerable information quoted from existing reports that should be validated and be in context with conclusions made, and the report should be clear on which information is original to the CE effort. Project V-1 is not the only Proposition 50-funded project within the Ventura River Watershed; the V-2 project (SACSGRP) and others contribute to the understanding of the system and should at least be discussed in the Plan.

The Ventura River Watershed is very dynamic and unique. The Plan should lay an outline for understanding and managing the Ventura River Watershed rather than attempt to fit a plan into the mold of another drainage basin. Inclusion of other plans in the Report seems unnecessary.

One of the most significant recommendations within the plan is to develop a water budget for the whole watershed. This recommendation echoes those of other efforts, and based on the experience of the OBGMA this is a difficult task that is compounded by the number of alluvial groundwater basins within the Watershed (note the differences between State delineations and County delineations), the overlap of surface water divides over alluvial groundwater basins (such as Upper Ojai) and the complex bedrock geology and hydrogeology. Bedrock systems are also linked to other watersheds. A complex, comprehensive model will likely be necessary to most accurately develop the water budget for the entire watershed. The Report should build the framework for funding and implementing such a recommendation, and should be a significant focus of the Ventura River Watershed Protection Plan.

In the Draft Report, water conservation activities are discussed as not being accomplished at the present time. Casitas MWD is leading the way in Conservation activities in the Watershed. The Plan should discuss those activities as well as any of the purveyors' conservations programs, such as Golden State Water Company's free distribution of water-saving fixtures to customers in Ojai.

The Draft Report contains many details and we encourage a thorough quality assurance/quality control review of the report both internally and with respect to cited references.

Responses to comments from OBGMA

The introduction to the report has been modified to clarify which sections summarize existing information and which contain new information.

A description of the San Antonio Spreading Grounds Rehabilitation Project was added to Section 2.9.1.

Cardno ENTRIX concurs that the Ventura Watershed has many characteristics that are unique in Southern California, most notably the complete reliance on local water supplies. The review of other watershed plans was not intended to determine the scope of the proposed Watershed Management Plan. Instead it was intended to identify useful lessons from those plans that might inform the development of the watershed plan for the Ventura River.

Cardno ENTRIX concurs that the development of a water budget is a complex issue and underscores the potential value of a budget for the comprehensive management of water resources.

Any inference that the Draft Report suggested that water conservation activities are not being implemented was unintentional. Cardno ENTRIX acknowledges that Casitas and other water agencies have ongoing water conservation programs and remain committed to the continued implementation of those programs.

The inclusion of numerous citations throughout the body of the report was at the request of the District. Development of the report was subject to a QA/QC process to confirm the validity of the cited materials.

From: Bill O'Brien [mailto:billo@hawkscivil.com]
Sent: Monday, January 16, 2012 4:28 PM
To: Mark Horne
Subject: Followup Comments for Ventura River Watershed Protection Plan Report

Mark,

I realize I am late for your cut off date so will just submit a clean copy of the map I gave to Lorraine Woodman of your team when you gave the Dec. 13 presentation to the Ventura River Council.

I'd like to submit the pdf version for your use or reference in the water budget section of the report.

My comment at the River Council was that the answer to the water budget is in the reservoirs. We may not have, and may never have some of the detailed inputs – or outputs, but we do have the change in storage as represented by the groundwater levels (or better if we have isohyets), and in the case of surface water, the storage in Lake Casitas. This leads to the recommendation of a lumped parameters approach to the water balance may be the next best step.

Also attached is a map we did for the May 2010 Ventura River Watershed U. that shows the largest water related agencies in the watershed.

Please credit these comments or either of these drawings to the City of Ojai, Public Works Department if you use them.

Let me know if you have any questions.

Thanks for your work on this report.

Best,

Bill

William (Bill) O'Brien, PE, CFM

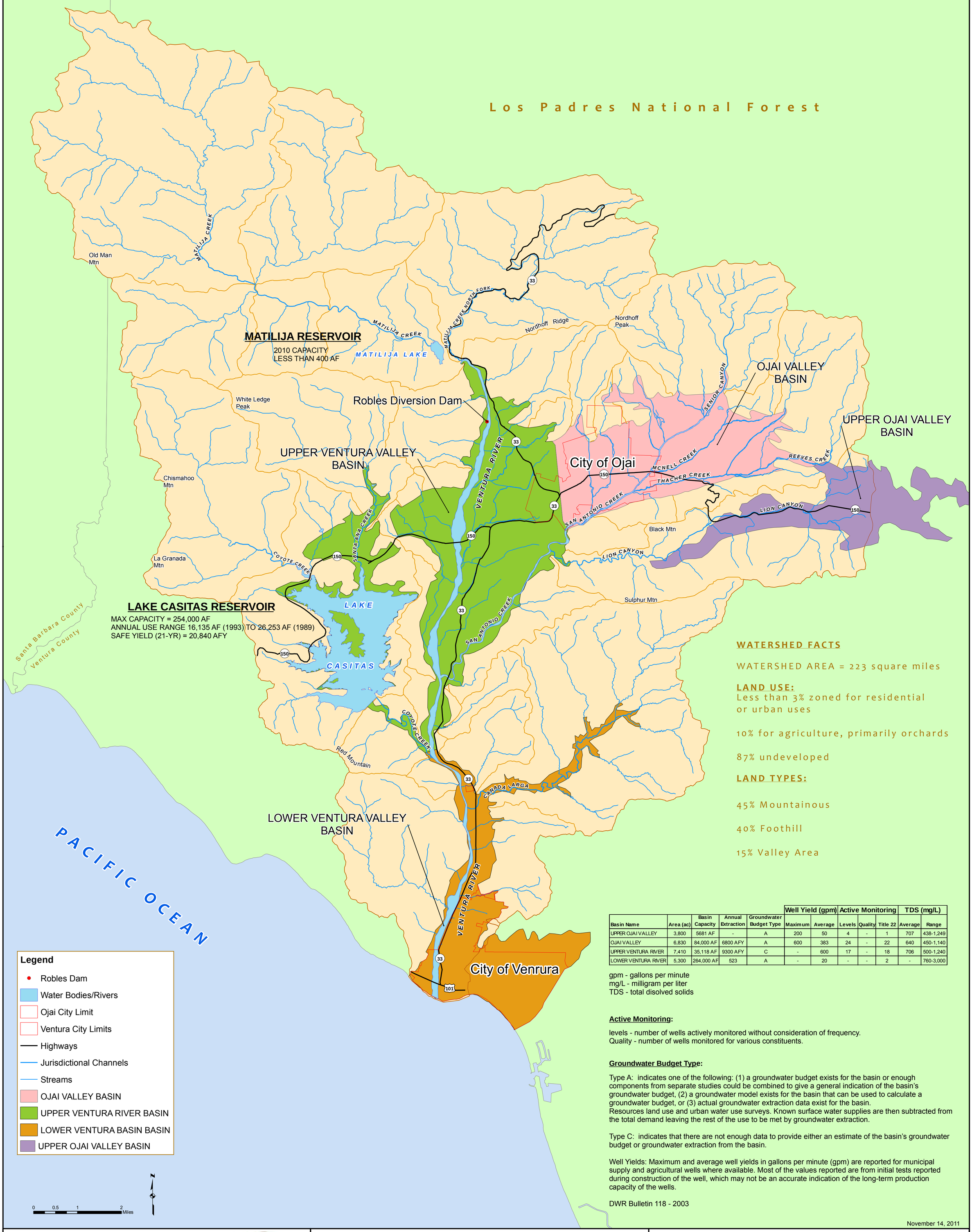
Hawks and Associates
2259 Portola Road, Suite B, Ventura, CA 93003
billo@hawkscivil.com

Office: (805) 658-6611 FAX: (805)- 658-6791

www.hawkscivil.com

VENTURA RIVER WATERSHED

Ground Water Basins And Surface Water Reservoirs



WATERSHED FACTS

WATERSHED AREA = 223 square miles

LAND USE:
Less than 3% zoned for residential or urban uses

10% for agriculture, primarily orchards

87% undeveloped

LAND TYPES:

45% Mountainous

40% Foothill

15% Valley Area

					Well Yield (gpm)		Active Monitoring			TDS (mg/L)	
Basin Name	Area (ac)	Basin Capacity	Annual Extraction	Groundwater Budget Type	Maximum	Average	Levels	Quality	Title 22	Average	Range
UPPER OJAI VALLEY	3,800	5681 AF	-	A	200	50	4	-	1	707	438-1,249
OJAI VALLEY	6,830	84,000 AF	6800 AFY	A	600	383	24	-	22	640	450-1,140
UPPER VENTURA RIVER	7,410	35,118 AF	9300 AFY	C	-	600	17	-	18	706	500-1,240
LOWER VENTURA RIVER	5,300	264,000 AF	523	A	-	20	-	-	2	-	760-3,000

gpm - gallons per minute
mg/L - milligram per liter
TDS - total disolved solids

Active Monitoring:

levels - number of wells actively monitored without consideration of frequency.
Quality - number of wells monitored for various constituents.

Groundwater Budget Type:

Type A: indicates one of the following: (1) a groundwater budget exists for the basin or enough components from separate studies could be combined to give a general indication of the basin's groundwater budget, (2) a groundwater model exists for the basin that can be used to calculate a groundwater budget, or (3) actual groundwater extraction data exist for the basin.
Resources land use and urban water use surveys. Known surface water supplies are then subtracted from the total demand leaving the rest of the use to be met by groundwater extraction.

Type C: indicates that there are not enough data to provide either an estimate of the basin's groundwater budget or groundwater extraction from the basin.

Well Yields: Maximum and average well yields in gallons per minute (gpm) are reported for municipal supply and agricultural wells where available. Most of the values reported are from initial tests reported during construction of the well, which may not be an accurate indication of the long-term production capacity of the wells.

DWR Bulletin 118 - 2003

November 14, 2011

Legend

- Robles Dam
- Water Bodies/Rivers
- Ojai City Limit
- Ventura City Limits
- Highways
- Jurisdictional Channels
- Streams
- OJAI VALLEY BASIN
- UPPER VENTURA RIVER BASIN
- LOWER VENTURA BASIN BASIN
- UPPER OJAI VALLEY BASIN

0 0.5 1 2 Miles

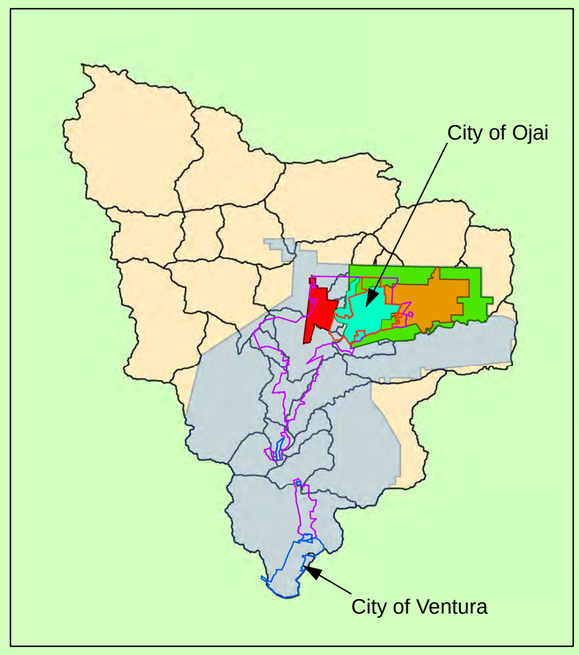
N

HAWKS & ASSOCIATES
2259 PORTOLA ROAD SUITE B
VENTURA, CA. 93003 (805) 658-6611

SOURCES OF INFORMATION:
Ventura River Ground Water Basins from Ventura County (VCWPD) 2010 Ground Water Section Annual Report (Pg5).

Ventura River Watershed Ground Water Basins And Surface Water Reservoirs

T:\PROJECTS\6-2 Ojai Projects\6-2 Ventura River Water Counsul\Ventura River Basins.mxd



Location Map

MATILIJA CREEK
MATILIJA LAKE
LAKE CASITAS
COYOTE CREEK
VENTURA RIVER
SENIOR CANYON
THACHER CREEK
SAN ANTONIO CREEK
LION CANYON
CANADA LARGA
PACIFIC OCEAN

City of Ojai

Foster Park

OVSD Waste Water Treatment Plant

City of Ventura Water Treatment Plant

City of Ventura

33
150
101

WATERSHED DEVELOPMENT

3%	URBAN/RESIDENTIAL
10%	AGRICULTURAL
87%	UNDEVELOPED

Legend

- Ojai City Limits
- Ventura City Limit Within Watershed
- Ojai Valley Sanitary District-sphere of influence
- Highways
- Rivers
- Streams
- Golden State Water Company
- Meiners Oaks County Water District
- Ventura River County Water District
- Ojai Water Conservation District
- Ojai Basin Groundwater Management Agency
- Casitas Municipal Water District Within Watershed

N

0 2,050 4,100 8,200 Feet

1 in = 4,000 feet

March 24, 2010

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2259 PORTOLA ROAD SUITE B
VENTURA, CA. 93003 (805) 658-6611

CITY OF OJAI CALIFORNIA

WATER AGENCIES IN THE VENTURA RIVER WATERSHED

T:\PROJECTS\6-2 Ojai Projects\6-2 Ventura River\Water District Map\Water Distribution District Map.mxd

Response to comment from Bill O'Brien, January 16

The two maps attached to this comment are included on the preceding pages of this appendix for reference.

Cardno ENTRIX concurs that a lumped parameters approach could facilitate the development of a water balance, as it would simply the number of parameters that would be required and could overcome some of the limitations in a traditional approach (which was described in Section 4.3).

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CASITAS
Municipal Water District

January 10, 2012

Norma Camacho, Director
Ventura County Watershed Protection District
800 S. Victoria Avenue
Ventura, California 93009-1600

Comments on the Draft Ventura River Watershed Protection Report – December 2011

Dear Norma,

The Casitas Municipal Water District respectfully submits the following comments and recommended corrections to the December 2011 Draft Ventura Watershed Protection Plan. Our comments are provided with the understanding that the purpose of the Report is to summarize conditions and provide relevant information that can inform development of a comprehensive and integrated Ventura River Watershed Management Plan.

Our comments and corrections are as follows:

Page 2-30, Section 2.6.2.1. The Report perpetuates the opinion that the Coyote stream flow measurements are "not considered reliable". The assessment and the reasoning of this opinion is not accurate. Note that Casitas and the District continued to jointly operate the station after 1988 as one of many original County Alert stations, sharing data and responsibilities for the station. While this statement continues from a previous report, this Report does not recognize the Santa Ana Creek station which also continuously monitors inflow above Lake Casitas. We recommend the removal of the negative bias and instead, the Report should state the fact that these two stations monitor the two main tributaries that flow into Lake Casitas.

Page 2-36, Section 2.6.2.2. The Report makes the statement referring to the Robles Diversions having little effect on large peak flows, "since diversions do not occur under the high-suspended sediment conditions associated with large peak flows." This statement is not accurate or true. The diversions have little effect on high peak flows because the diversion is usually only a small percentage of the high peak flow conditions that occur at the Robles Diversion. Casitas does attempt to divert at peaks if no other obstructions or reasons cause Casitas to shutdown diversions (i.e., clogging of the fish screens). It is recommended to delete the above quoted portion of that sentence.

Also on this page is a reference to the major flood event of 2005 and stating flows of "January (1,826 cfs) and February (1,229 cfs)." These figures do not seem to relate to the flows of 2005, and with no reference for the source of the data, it is difficult to interpret the meaning and significance of the data. Please check the source, accuracy, and meaning of this data.

Page 2-41, Section 2.6.3.2. The Report refers to a basin being depleted. Please indicate or name which basin or basin(s) attained depletion.

Page 2-53, Section 2.9.4. The Report states that "The water balance in Lake Casitas is closely monitored, and daily discharge records have been obtained back to 1970; however, only the records from 1991 on are currently available in electronic form (Tetra Tech 2008a)." First it should be acknowledge that daily records for Lake Casitas have been maintained since 1959 and are available paper form. The Report purpose is limited in this sentence to not stating the fact that additional data is available – just not in digital form (which is one of the primary reasons for the bias regard Coyote Creek data). Recommend stating that the record keeping of the water balance for Lake Casitas dates to the first impoundment of water behind that dam in 1959.

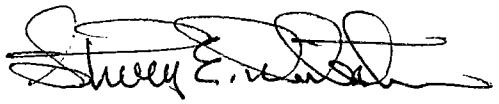
Page 3-25, Component 6. Component 6, last sentence, provides two examples of management objectives. First, no other component in this section provides any examples to help clarify the statement in the component. Secondly, the examples may not be a direction in which the plan proponents proceed. Recommend deletion of the sentence with the two examples.

Page 3-25, Component 11. Component 11 suggests the report frequency be determined by the Watersheds Coalition of Ventura County. There has been no nexus in the Report between previously mentions groups and agencies and the Watersheds Coalition of Ventura County, or the determination authority therein. Suggest deleting "by the Watersheds Coalition of Ventura County" and include an "and" in the sentence.

Page 8-2, Section 8.1.3. In the first bullet, the Report refers separately to the Ojai Valley Land Conservancy, the Ventura River Watershed Council, and the District. To our knowledge, the Ojai Valley Land Conservancy is a member of the Ventura River Watershed Council. Suggest that this bullet be revised to refer to the Council and the District.

If you have any questions in regard to the above comments, please do not hesitate to contact me.

Sincerely,



Steven E. Wickstrum
General Manager

CC: Mark Horn, Cardno ENTRIX

Response to comment from Casitas Municipal Water District, January 10, 2012

Page 2-30, Section 2.6.2.1. The text indicating the Coyote stream flow measurements are not considered reliable was removed. The statement that the two stations monitor the two main tributaries that flow into Lake Casitas was not added, because similar information was not included for other monitoring stations.

Page 2-36, Section 2.6.2.2. The text regarding large peak flows was modified as recommended. The sentence describing flows in January and February 2005 was removed.

Page 2-41, Section 2.6.3.2. As mentioned in the preceding sentence, the text is referring to the Upper Ventura Basin.

Page 2-53, Section 2.9.4. The text was modified as recommended.

Page 3-26, Component 6. The text was modified as recommended.

Page 3-26, Component 11. The text was modified as recommended.

Page 8-2, Section 8.1.3. The text was modified as recommended.

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Arundo donax
Distribution and Impact Report

March 2011

Agreement No. 06-374-559-0
State Water Resources Control Board

Prepared by: **California Invasive Plant Council**

Arundo donax (giant reed): Distribution and Impact Report

March 2011

Agreement: No. 06-374-559-0
Submitted to: State Water Resources Control Board

Submitted by: California Invasive Plant Council (Cal-IPC)

Authors:

Jason Giessow, Dendra Inc. (Chapters 2, 4.2, 5.2, 6-10)
Jason Casanova, Los Angeles and San Gabriel Rivers Watershed Council (Chapters 3, 5.2)
Rene Leclerc, Robert MacArthur, Northwest Hydraulic Consultants (Chapter 5.1)
Genie Fleming, Consultant (Chapter 4.1)
Jesse Giessow (Else), Dendra Inc. (Chapter 1)

With contributions by:

Elizabeth Brusati, Cal-IPC
John Tangenberg, Los Angeles and San Gabriel Rivers Watershed Council
Brad Roth, Consultant
Doug Johnson, Cal-IPC

This report and spatial data set (GIS geo-database) are available for download at:
http://www.cal-ipc.org/ip/research/arundo/index.php

or

http://www.cal-ipc.org/ip/mapping/arundo/index.php

The spatial data set is also viewable at the DFG BIOS web site:
http://bios.dfg.ca.gov/

BIOS project data sets are named:
Invasive Plants (Species) - Central_So. Cal Coastal Watersheds [ds645]
Invasive Plants (Prct Cover) - Central_So. Cal Coastal Watersheds [ds646]

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EXECUTIVE SUMMARY

Arundo donax (giant reed, giant cane) is a large non-native grass found in many coastal watersheds in central and southern California. It is an extremely problematic invasive plant characterized by extensive infestations and a range of severe impacts to both ecosystem and human infrastructure. Even with a significant increase in research and studies on *Arundo* over the past ten years, no large-scale mapping efforts have been completed and no comprehensive analysis of impacts has occurred. This report set out to accomplish these goals within the study area (Monterey to San Diego), as well as to examine watershed-based capacity to implement control programs. Over $70 million dollars have been spent to date controlling *Arundo* within the study area. It is important to document where this work has occurred and assess the resulting reduction in impacts.

Arundo was mapped at a fine scale using high-resolution aerial imagery and field verification across the study area. *Arundo* acreage prior to the initiation of control programs was 8,907 acres (gross). This is a significant area, but is much less than had been speculated by many in the field. Over 34% of this acreage (>3,000 acres) has been treated to date, with two highly invaded watersheds achieving over 90% control. Many other watersheds have more than 50% control. This indicates that watershed-based control is a realistic objective.

Mapping data show that *Arundo* is most abundant in large low-gradient river areas, where it averages 13% cover. Within specific reaches, there are sections greater than a half-mile in length that have over 40% *Arundo* cover.

This study carried out additional field work to characterize *Arundo* stands and infestations. This work verifies relationships explored by other studies, as well as generating new findings. *Arundo* within the study area was taller (average 6.5 m, maximum 9.9 m) than many previous studies reported. Biomass was confirmed as being extremely high per meter (15.5 kg/m^2). Leaf area was extremely high at 15.8 m^2/m^2 (LAI), which is consistent with other studies in California, but higher than reported in Texas where stands are shorter. Mature stands comprise most of the *Arundo* mapped in the study area. The leaf area of secondary branches is the majority of the leaf area in mature *Arundo* stands, based on leaf area and cane density of new and old canes.

This abundance of growth and cover generates many abiotic and biotic impacts. Mapping *Arundo* at high resolution allows examination and quantification of a number of these specific impacts, including water use, fluvial processes, fire, and listed species.

Spatial data, used in conjunction with stand leaf area measurements and published leaf transpiration rates, generated an *Arundo* stand-based water use value that was extremely high (40 mm/day) compared to most other plants. There are very few studies that have measured *Arundo* water use. Our results agree with one paper (from a study in California, 41.1 mm/day) and are higher than a study in Texas on the Rio Grande (9.1 mm/day). When translated into potential water savings per year from restoration, net savings of 20 ac-ft/yr was estimated. This estimate includes adjustments for replacement vegetation, as well as a reduction of *Arundo* water use to bring it into alignment with other forms of vegetation that consume large amounts of water. This is a large potential water use reduction that could have significant implications for both the ecosystem and human water use.

This study expended significant effort in broadening the understanding of how *Arundo* is impacting geomorphic and fluvial processes. These abiotic processes are particularly significant because they regulate the entire riparian ecosystem. Any changes to fluvial processes have the potential for system-wide ramifications. Large stands of *Arundo* were found to functionally increase bed elevations by five feet (based on field investigation and model re-calibrations following flood events in 1998). In addition to this *Arundo* stand-based modification of elevation, a high roughness coefficient for flows higher than

five feet was supported. This results in a significant reduction in flow capacity and represents an alteration of how *Arundo* stand function is characterized during flow events. New modeling was carried out for this study under four scenarios. Results indicated that *Arundo* stands constrain flows to the low-flow and bar-channel portions of the river profile. Over time this results in a deepening of the channel and a transformation of the system from a braided unstable channel form to a laterally stable single-thread channel form. Mapping of geomorphic forms on the larger systems documented that *Arundo* stands occur predominantly in the floodplain and terrace forms, and are nearly absent from the low-flow and active channel forms. Additional modeling using stream power indicated that over-vegetated floodplains and narrow, stable deep channels result in modifications of sediment transport during flow events. Sediment appears to be lost (removed) in channel areas and gained (aggregated) on floodplains/terraces with *Arundo* stands on them. These impacts to riverine fluvial processes change vegetation succession following flow events, sediment transport budgets, and the geomorphic structure of the habitat, all of which alter the ecosystem in a un-natural way. Such alterations are usually negative for native species that are adapted to pre-invaded ecosystem function. One system has had extensive *Arundo* control since the late 1990's, allowing examination of post-control system response. Active channel areas widened and portions of the floodplain with active flows increased. These are important post-control responses to flood events, indicating a 'normalization' of fluvial processing is occurring.

A historic review of large riparian systems using spatial mapping indicated that floodplain and low terrace forms have become much more vegetated on most systems over the last eighty years. This transformation has been observed in other systems, such as the Rio Grande, and is a result of water importation and a 'compression' of riverine systems. This dense vegetation is both native woody vegetation and *Arundo*. Mature *Arundo* stands, however, have much higher stem density and biomass per unit area, generating the observed flow reduction effects noted above. The historic analysis also showed a significant decline in acreage over time, on most systems, of the active channel area (low-flow and bar-channel areas with little vegetation). Most riverine systems have also become significantly compressed (narrower) over time as terrace and floodplain forms have been permanently separated from the river system by levees that protect both urbanization and agricultural land use. *Arundo* impacts to bridges, levees, and beaches were also described and documented. These impacts are from *Arundo* biomass and reduced flow capacity (*Arundo* stands and sediment trapping).

Impacts associated with fire were thoroughly explored with significant new findings. *Arundo*'s high biomass and stored energy were established based on field and published data. In addition to a high fuel load, *Arundo* stands have a tall, well ventilated fuel structure containing dry fuels throughout the year. This study specifically documented that transient encampments and highway overpasses are key ignition sources for fires that start in *Arundo*. This is a new class of fire events that are fully ascribed to *Arundo*. This study documented that fires are now starting in riparian areas, which did not occurred historically. Fire events were mapped over an eight year period on the San Luis Rey watershed. It was also demonstrated that *Arundo*-initiated fires are occurring on other watersheds. *Arundo*-initiated fires also burn un-invaded riparian habitat and fire suppression impacts were spatially quantified. Over a ten year period *Arundo*-initiated fires were estimated to impact 557 acres of *Arundo* and 732 acres of riparian habitat. Wildfires also burn *Arundo* stands. These fire events burned 544 acres of *Arundo* over a ten year period for the study area. *Arundo* stands that burn during wildfires burn hotter than native vegetation due to the high fuel load, and are very likely conveying fires through riparian corridors. The Simi fire in the Santa Clara watershed was one of the clearest examples of an upland wildfire spreading across a riparian zone dominated by *Arundo*, and then igniting fuels on a separate mountain range. *Arundo*-initiated fires and wildfires together burned 12% of *Arundo* acreage in a ten year period within the study area. The high acreage of burned *Arundo* and native vegetation, as well as suppression impacts, has significant impacts on the ecosystem and listed species.

Impacts to plants and animals were explored by examining 22 federally listed species from five taxonomic groups. Detailed biological assessments examining habitat, life history, distribution and abundance were carried out for these species. Listing documents and spatial occurrence data were used to evaluate *Arundo* impacts on each species. An *Arundo* impact score was calculated for each listed species. An additional metric examining the specific co-occurrence of *Arundo* and each species was derived for each watershed. The impact rank and the co-occurrence rank were then multiplied to generate an overall cumulative impact score. From this analysis, the taxonomic group, individual species, and watersheds were ranked based on scores. Avian and fish species were found to be the most impacted by *Arundo*, with amphibians also ranking high. Plants and mammals ranked very low in cumulative scoring. The two most severely impacted species were least Bell's vireo and the arroyo toad, followed by the southwestern willow flycatcher, southern steelhead, and tidewater goby. Several species that occur in estuary and beach habitat near river mouths also had impacts from *Arundo* identified. The watersheds with highest impacts to federally listed species were the Santa Margarita, Santa Ana, San Luis Rey, and Santa Clara watersheds. Three of the four watersheds have the oldest and most complete *Arundo* control programs in the study area.

A rudimentary cost-to-benefit analysis was also completed using *Arundo* spatial data. Cost of *Arundo* control was determined based on completed control work on numerous watersheds over the past 15 year. The $71 million expended to control 2,862 acres generates a per acre control cost of $25,000. Benefits derived from controlling *Arundo* are based on each impact (water use, sediment trapping, flood damage, fire, habitat, and beach debris). Valuations were conservative and a rationale was given for each impact class. Impacts that were difficult to quantify or value were not included. The benefit to cost ratio for *Arundo* at its pre-control distribution level was 1.94 to 1 ($380,767,747 to $196,481,844). Current *Arundo* distribution (reflecting 3,000 acres of control to date) generates a similar benefit to cost ratio of 1.91 to 1 ($239,461,270 to $124,934,194). A roughly 2:1 return ratio on funds invested is a significant benefit, particularly considering the additional impacts that were not assessed (due to complex valuation), as well as the conservative valuation of factors that were included.

The report concludes with a discussion of treatment priorities that include: continuing treatments of areas that have already been treated (protecting initial investment), controlling *Arundo* on watersheds where it is not abundant but could spread (early control is more cost effective), and prioritization of watersheds with large *Arundo* infestations. Programs are encouraged to use a top-down watershed implementation approach (starting in the upper reaches of the watershed), particularly if the watershed is heavily invaded. The watershed priority rankings are based on four impact classes (water use, geomorphology, fire, and listed species) and two classes of program capacity (experience and regulatory permits). Watershed-based control is most effective when there is a lead organization that can implement comprehensive control, acquire permits, obtain right of entry agreements, and secure funding.

1.0 INTRODUCTION

Arundo donax (giant reed, giant cane) is one of the largest grass species. A clonal plant that grows in dense stands, it is found in many subtropical and warm-temperate areas of the world. It is thought to be native to eastern Asia (Polunin & Huxley 1987), but the precise extent of its native distribution is unknown. *Arundo* has been introduced around the world as an ornamental/crop species, for erosion control, and for the production of reeds (musical instruments, construction, paper and pulp). It has become invasive in many places throughout the world, primarily in riparian habitat. Where *Arundo* invades, it often forms dense stands, resulting in a wide range of impacts to natural ecological systems (biotic and abiotic) as well as human created infrastructure. The Invasive Species Group of the World Conservation Union includes giant reed in its top 100 Worst Invaders of the World (Lowe et al. 2000).

Arundo was first introduced to California by Spanish colonists in the 1700s (Newhouser et al. 1999), and in the early 1800s for erosion control in drainage canals (Bell 1998). It is now a major threat to riparian areas in California, as well as other southwestern states. Two portions of the United States have particularly significant *Arundo* infestations (characterized as >40% of riverine habitat over areas longer than a river mile): coastal California (Monterey to San Diego) and the Rio Grande (Texas).

This study is the first research to take a broad range of impacts caused by the invasive non-native plant *Arundo*, and apply them to a significant portion of the plant's distribution in California. This was not previously possible because detailed *Arundo* spatial distribution data did not exist prior to this study. Mapping *Arundo* in high resolution from Salinas, California to the Mexican border in all coastal watersheds was the initial task. This captures *Arundo*'s primary distribution in coastal California.

There has been a significant increase over the past ten years in studies examining *Arundo*'s impacts and quantifying aspects of its productivity, structure, physiology, genetics and reproduction. We compiled information, and completed additional research and data collection to fill gaps in understanding or documentation. New research was primarily related to fluvial/geomorphic impacts, leaf area, biomass water use and fire impacts. Data collected also allowed verification that relationships described in the literature, such as biomass and structure data, applied to the study region. Many studies and reports have alluded to impacts related to fire, but this study explicitly quantifies fires that started in *Arundo*, as well as wildfires that burned *Arundo*, over the entire study area. Impacts to 22 federally-listed sensitive species were examined using spatial data for the species, spatial data for *Arundo*, and current understanding of the biology of the species. From this the magnitude of impact on listed species from *Arundo* is described and scored. Scores of cumulative impact are examined by species, taxa group, and watershed. To date, this is the largest suite of species over the broadest area to examine *Arundo* impacts.

This report presents the entire range of impacts over the entire study area, as well as each watershed. A coarse Cost Benefit Analysis is presented and made possible due to the explicit quantification based on acreage for each watershed, and the range of impacts that were quantified (with a cost assigned to them based on previous studies).

Finally this report provides a review of each watershed's *Arundo* control program, including: completed work to date, status of permits allowing work, and the identification of the lead entities carrying out the work. The spatial data set and impact quantification is used to highlight priority watersheds and actions. This is also examined in the context of current capacity to implement *Arundo* control projects. The need to implement sustainable watershed control programs with eradication as an obtainable goal is explored, as well as an evaluation of the challenges in completing programs, which is a process that can take over 20 years.

2.0 *ARUNDO* BIOLOGY

2.1 Physiology

Arundo is generally a hydrophyte, achieving its greatest growth near water. However, it adapts to many different habitat conditions and soil types, and once established is drought tolerant and able to grow in fairly dry conditions (Lewandowski et al. 2003). It can also tolerate saline conditions (Perdue 1958, Peck 1998), and in California it is found growing along the edges of beaches and estuaries (Else 1996). *Arundo* is a C_3 plant, but it shows the unsaturated photosynthetic potential of C4 plants, and is capable of very high photosynthetic rates (Papazoglou et al. 2005, Rossa et al. 1998).

Arundo's stems and leaves contain a variety of noxious chemicals, including triterpenes and sterols (Chandhuri & Ghosal 1970), cardiac glycosides, curare-mimicking indoles (Ghosal et al. 1972), and hydrozamic acid (Zuñiga et al. 1983), as well as silica (Jackson and Nunez 1964). These likely reduce herbivory by most native insects and grazers where *Arundo* has been introduced (Miles et al. 1993, Zuñiga et al. 1983).

Arundo responds strongly to excess nitrogen from anthropogenic and fire sources (Ambrose & Rundel 2007). Most studies on growth and transpiration indicate that water availability is the primary factor affecting metabolic rates and productivity (Abichandani 2007, Perdue 1958, Watts 2009). *Arundo* generally has a shorter stature and is less productive when there is limited water availability, such as on higher elevation riparian terraces or drier portions of the watershed. This observation is based on the distribution of these less productive stands on many watersheds within the study area.

2.2 Genetic variation

Isozyme and RAPD analyses of *Arundo* on the Santa Ana River in California indicated genetic diversity comparable with those in the literature for clonal species, supporting asexual reproduction as the primary means of *Arundo* spread (Khudamrongsawat et al. 2004). Samples were also taken from one out-group on a separate watershed (Aliso Creek, Orange County). Several phenotypes were dominant and were found spread along the Santa Ana River. These dominant phenotypes were also found in the out-group population, possibly due to spread by humans. The moderate levels of genetic diversity in *Arundo* are likely explained by multiple introductions over time, with early introductions as a building material, and more recent use for erosion control and as a landscape ornamental (Bell 1997; Frandsen 1997). The moderate level of genetic diversity and the asexual mode of reproduction increases the potential for application of biological agents for control of *Arundo* (Tracy and DeLoach 1999).

2.3 Physical Structure

For this study, data were collected from fourteen *Arundo* plots on five watersheds (Figure 2-1). A variety of measurements were taken, and canes were collected from these plots. These data are presented in this section, section 2.4, and Chapter 4.

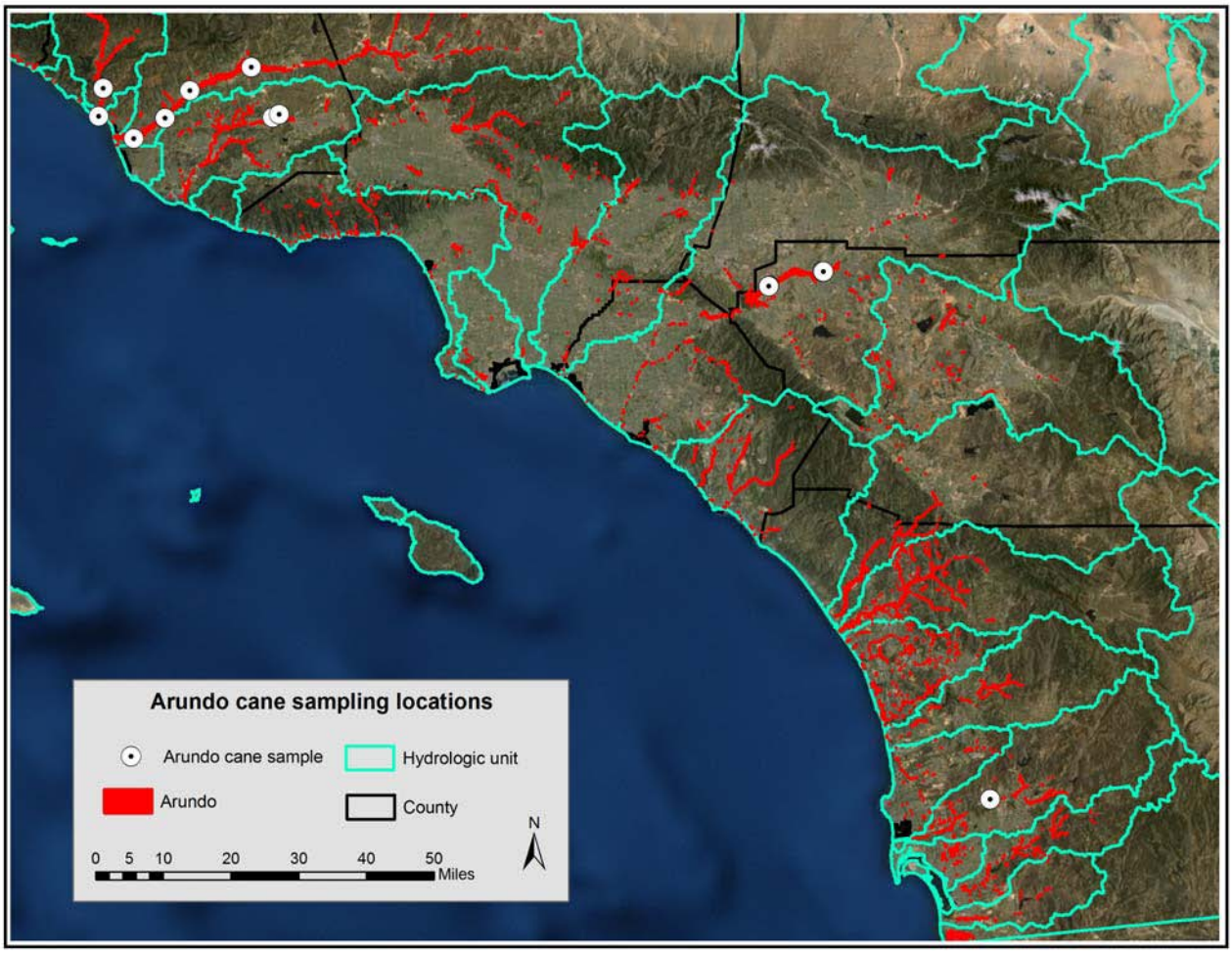


Figure 2-1. *Arundo* sampling locations in southern California.

Arundo is a clonal organism, so the plant will be examined at both the individual level (ramet) and at the stand scale (colony).

The individual plant or ramet:

Arundo is one of the largest herbaceous grasses, and is often mistaken for a bamboo (Figures 2-2 to 2-6). It is a tall, erect, perennial grass, 2 to 8 m high (Perdue 1958). Canes frequently attain lengths of 8 to 9 m in coastal California, as this study shows (Table 2-1). The main stems, or culms, are hollow with walls 2 to 7 mm thick and are divided by partitions at the nodes. In this study the culms were on average 23.8 mm wide (measured between nodes one and two). First year canes are un-branched, and in the second year single or multiple lateral secondary branches may form from the nodes (Figures 2-2 to 2-3) (Decruyenaere & Holt 2005). The secondary branches are a much smaller diameter than the main canes (typically <10mm versus >20 mm). In canes that are two years and older, the secondary branches bear a significant proportion of the leaves (this study). These secondary branches can themselves give rise to third degree and even fourth degree branches, but this is uncommon (Decruyenaere & Holt 2005, this study). Once a cane generates secondary branches these become the primary area of new growth, and continued growth of the main cane (leader) is slow to non-existent (Decruyenaere & Holt 2005).

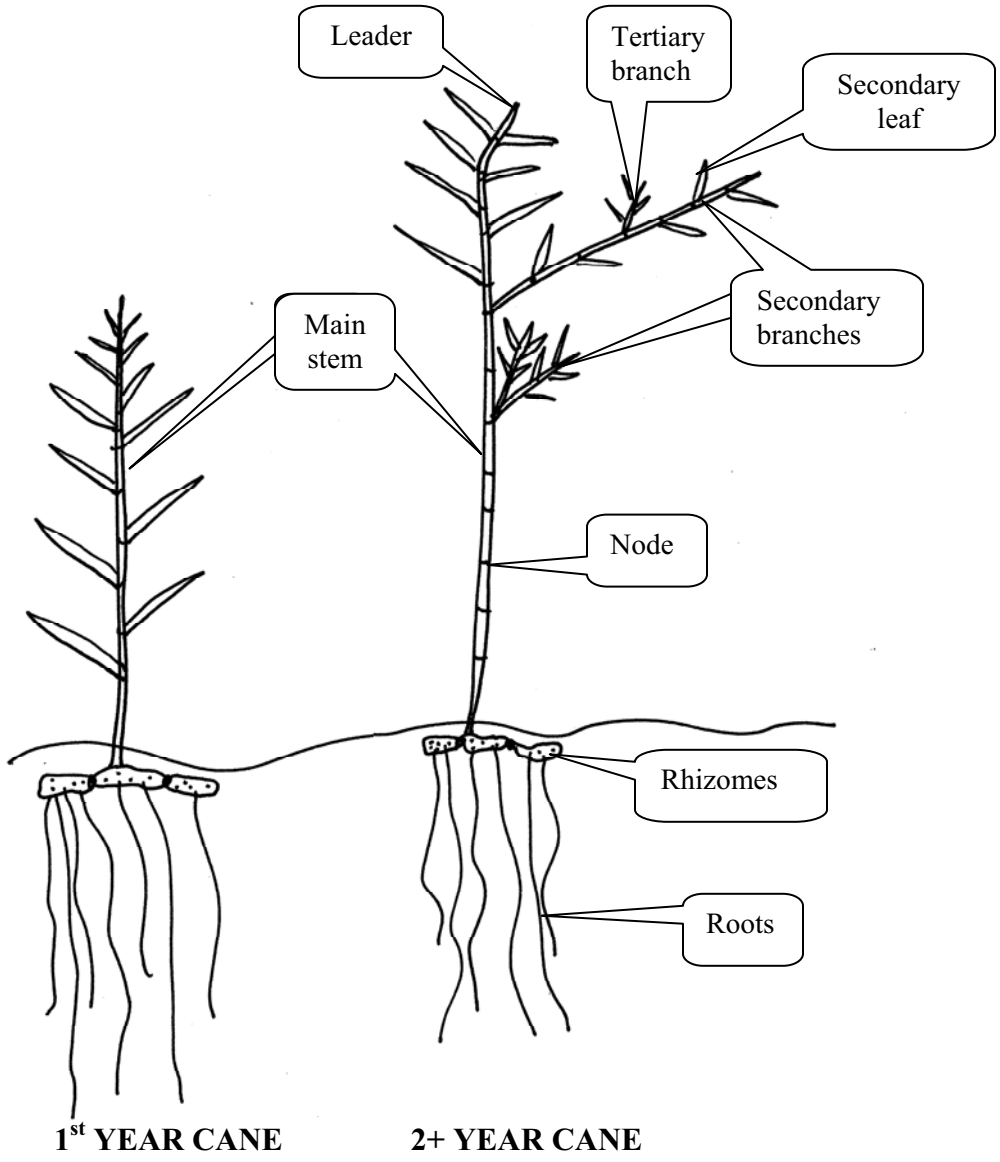


Figure 2-2. Illustration of *Arundo* structure for first year and 2+ year old stems. Older canes would have many secondary braches. Drawing by J. Giessow.

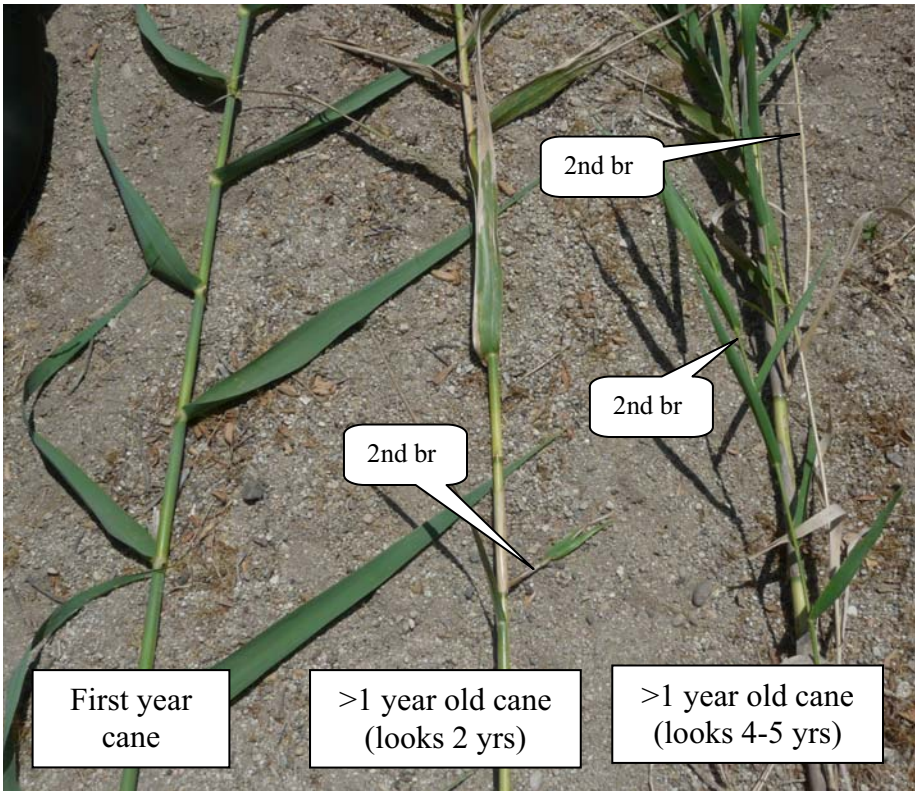


Figure 2-3. First year and >1yr year old *Arundo* canes, showing leaf and branching structure. First year canes have only cauline leaves. Older canes have an increasing number of secondary branches with leaves on them, and leaves on the old leader are often damaged and dying.



Figure 2-4. A single older cane with all secondary branches (25), leader, and main stem. This was cane SD#1b from the San Diego River with a height of 8.1m.



Figure 2-5. New first year canes often protrude from the *Arundo* canopy.
Older canes with extensive secondary branching cannot support the weight of the branches and leaves, and usually flop over and do not stand upright, especially in the upper portions of the stand's canopy.

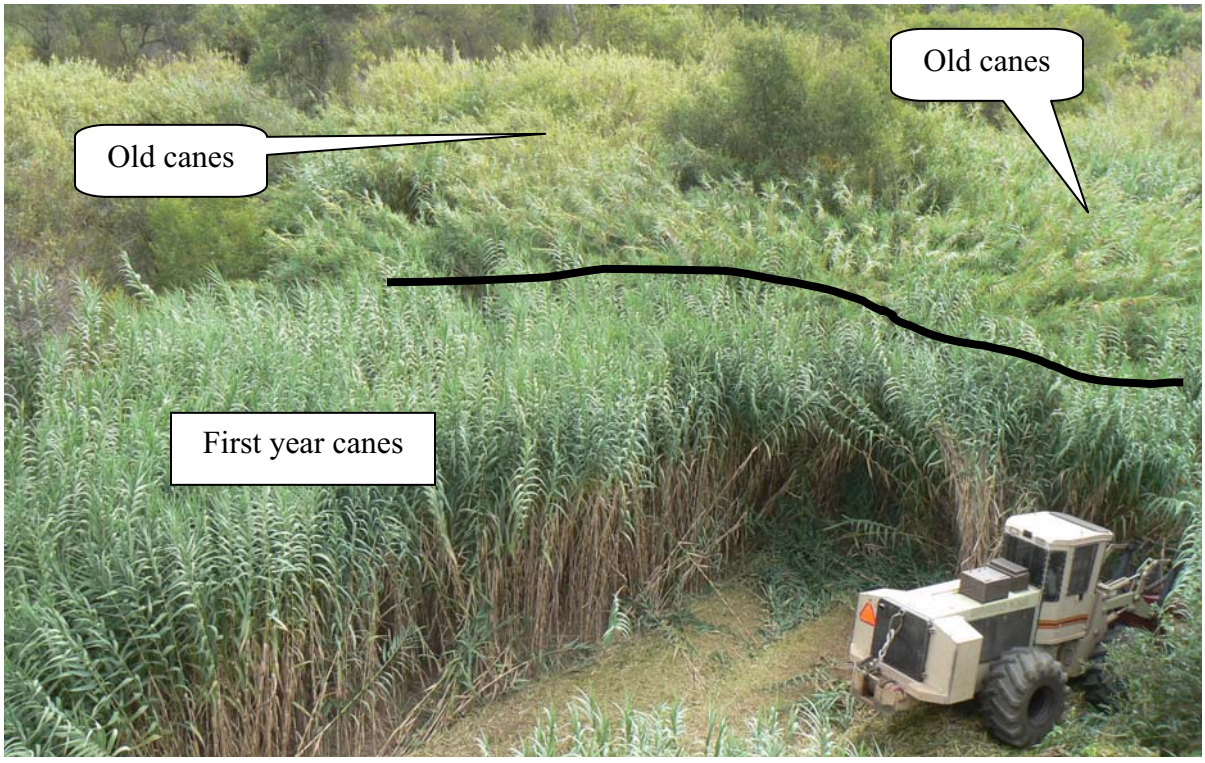


Figure 2-6. First year *Arundo* canes at full height (6+ m).
The tractor is 10' high. This area had been cut as a fuel break the year before and is being cut again. Energy stored in rhizomes underground allow this rapid regrowth after cutting or fire events. Note simple unbranched vertical structure, very high cane density, and deep green color of the new, resprouted canes. Older canes in the background are less vertical and are a more yellowish color.

Table 2-1. Summary of *Arundo* cane data from the fourteen locations sampled for this study. Locations of sampling plots are shown in Figure 2-1.

Plot	Cane height (m)	Cane diameter (mm)	Leader length (cm)	Leader # leaves	Mean leader single leaf area (cm^2)	# secondary branches	Mean branch length (cm)	Mean branch # leaves	Mean branch single leaf area (cm^2)	New cane # leaves	Mean new cane single leaf area (cm^2)
CC1	5.1	20	19	10	-	15	47.7	-	-	21	168.7
CC2 #1	9.7	28	90	23	83.7	57	11.7	4.5	10.5	-	-
CC2 #2	8.5	27	82	23	117.3	9	70.9	13.0	63.2	-	-
SA1	6.1	25	45	17	-	34	21.4	-	-	-	-
SA2	6.1	25	32	15	58.5	31	36.2	23.0	44.4	-	-
SA3	7.7	27	74	28	-	33	10.7	-	-	-	-
SA4	7.4	26	33	12	-	48	20.0	13.5	29.5	-	-
SC1	9.9	25	23	12	-	31	46.0	11.0	34.8	-	-
SC4	4.2	22	0	0	-	34	41.3	14.0	19.2	-	-
V1	8.4	26	0	0	-	28	43.4	-	-	21	216.2
V2	6.2	24	76	20	-	14	41.8	-	-	-	-
SD#1a	8.1	26	65	16	-	29	56.1	10.9	34.9	-	-
SD#1b	8.1	24	66	13	-	25	60.0	-	-	-	-
SC2	4.3	22	11	7	-	11	37.0	-	-	-	-
SC3	4.2	18	19	7	-	7	37.1	-	-	27	227.9
SC5 Lg	3.8	25	13	8	-	10	26.2	-	-	-	-
SC5 Sm	2.6	15	12	7	-	5	22.8	-	-	-	-
Mean	**6.5**	**23.8**	**38.8**	**12.8**	**86.5**	**24.8**	**37.1**	**12.8**	**33.8**	**23.0**	**204.3**
StdDev	**2.2**	**3.5**	**30.5**	**7.8**	**29.5**	**14.8**	**16.8**	**5.5**	**17.1**	**3.5**	**31.4**

CC = Calleguas Creek, SA = Santa Ana River, SC = Santa Clara River, V = Ventura River, SD = San Diego River.

Leaves are borne at nodes along the main stem and on the secondary branches. In this study, leaves found on the main stem were 5-6 cm (up to 8cm) broad toward the base, up to 61 cm long, and tapered to a fine point. Leaves on first year canes had an average width of 5.0 cm and length of 54.4 cm (n = 69) (Table 2-2). The main stem of older canes (>1 year) had much smaller leaves, average of 2.8 cm wide and 41.5 cm long (n = 60). As expected, secondary branch leaves were the smallest, average length of 27.9 cm and width of 1.7 cm (n = 200).

Table 2-2. Length and width of leaves of *Arundo* sampled in this study, by age and location.

Cane age and leaf location	# leaves sampled	Max (cm)	Min (cm)	Ave (cm)	SD
1st year cane: Leaves on stem					
Leaf length	69	74	15	54.4	14.5
Leaf width	69	6.8	2	5.0	1.2
>1yr cane: Leaves on main stem					
Leaf length	60	57	24	41.5	10.3
Leaf width	60	3.8	1.3	2.8	0.6
>1yr cane: Leaves on secondary branches					
Leaf length	200	52	4	27.9	10.8
Leaf width	200	2.8	0.1	1.7	0.5

This reduction in leaf size as canes mature is more than made up for by the much higher number of leaves found on secondary branches. Leaf density on the main cane decreased from an average of 23 for first year canes to 12.6 for older canes (Table 2-3), and leaf size also decreased. However, an entire new secondary branch class of leaves is present on canes >1 year. Leaf density on secondary branches was >270 on canes >1 year (Figure 2-4, Table 2-3). Canes older than one year had a leaf area that is greater than that of first year canes, and was predominantly made up of the secondary leaf area.

As canes mature, the leaves on the main cane become less important to photosynthetic production. The contribution of secondary branches to cane leaf area is an important observation that is not well documented in the literature. Decruyenaere and Holt (2005) note that the main canes have little growth once they generate secondary branches, and that the secondary branches become the primary areas of new growth. Leaf area is used to estimate water use and photosynthetic activity. This study will examine transpiration levels using leaf area data (Section 4.1). The field samples for this study were composed primarily of old canes. The large contribution of old canes with their secondary branches to stand leaf area can be seen in Figure 2-5, where the bulk of the leaves are secondary, and only a few new canes emerge out the top of the stand. First year and >1 year old canes can also be seen in Figure 2-6. The first year canes have a simpler structure with no branching, while the older canes in the background are more complex.

The underground structure of *Arundo* is composed of fleshy rhizomes from which arise roots that penetrate deeper into the soil (Figures 2-2 & 2-7 to 11). Rhizomes are generally shallowly buried, spreading out horizontally from the plant and forming a dense underground mat. Rhizomes are generally found 5-15 cm below the soil surface, with a maximum depth of 50 cm, while roots can be more than 100 cm deep (Sharma et al. 1998, this study).

Table 2-3. Density of leaves on *Arundo* stems sampled for this study, by class.

Cane Age and Leaf Location	# Sampled	Max	Min	Mean	StdDev
1st year cane: Leaves on					
Leaf density per cane (count)	3	27	21	23	3.5
Leaf area per leaf (cm^2)	69	352	29.6	206.3	
Leaf area per cane (cm^2)	3	6,153	3,542	4,740	
>1 year old cane: Leaves on culm					
Leaf density per cane (count)	3	23	15	12.6	8.3
Leaf area per leaf (cm^2)	60	141	30	86.5	
Leaf area per cane (cm^2)	3	2,580	877	1,000	
>1 year old cane: Leaves on secondary branches					
Leaf density per branch (count)	19	15	3	11.1	3.3
Leaf area per leaf (cm^2)	200	102	1.8	33.9	
Leaf area per branch (cm^2)	18	837	12	406	240
Leaf area per cane (cm^2) calculated	14	8,904	906	4,699	2,628

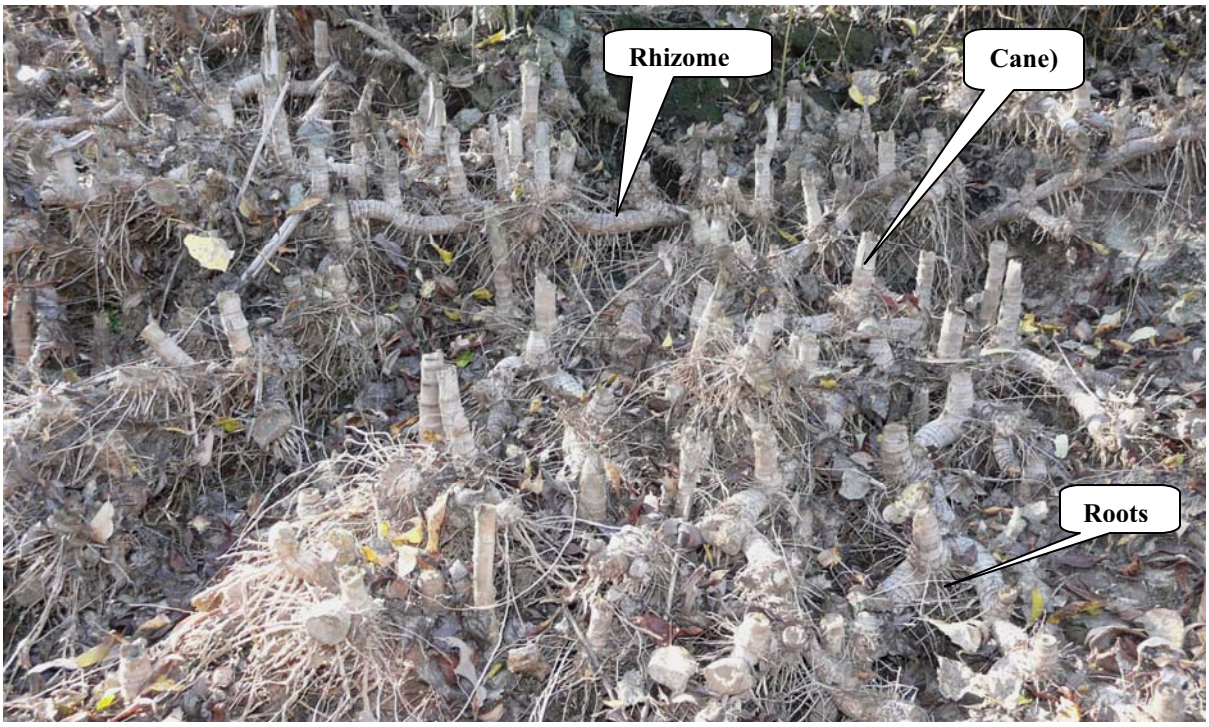


Figure 2-7. Dense rhizome and root network of an *Arundo* clump that was scoured during a flow event, removing the upper soil matrix and canes.

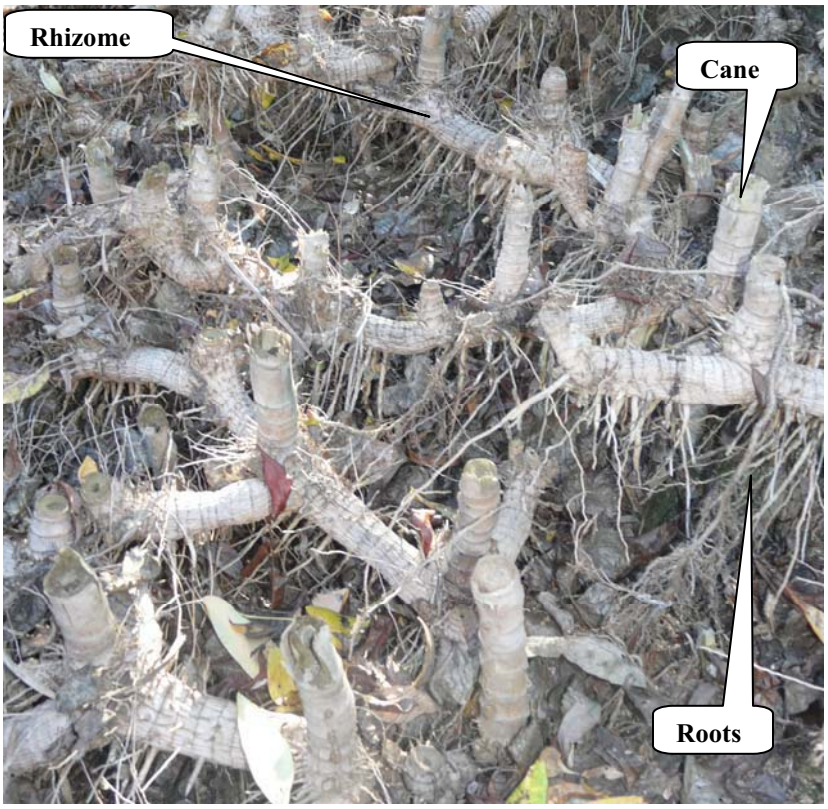


Figure 2-8. Close up of rhizomes showing emerging canes and roots.

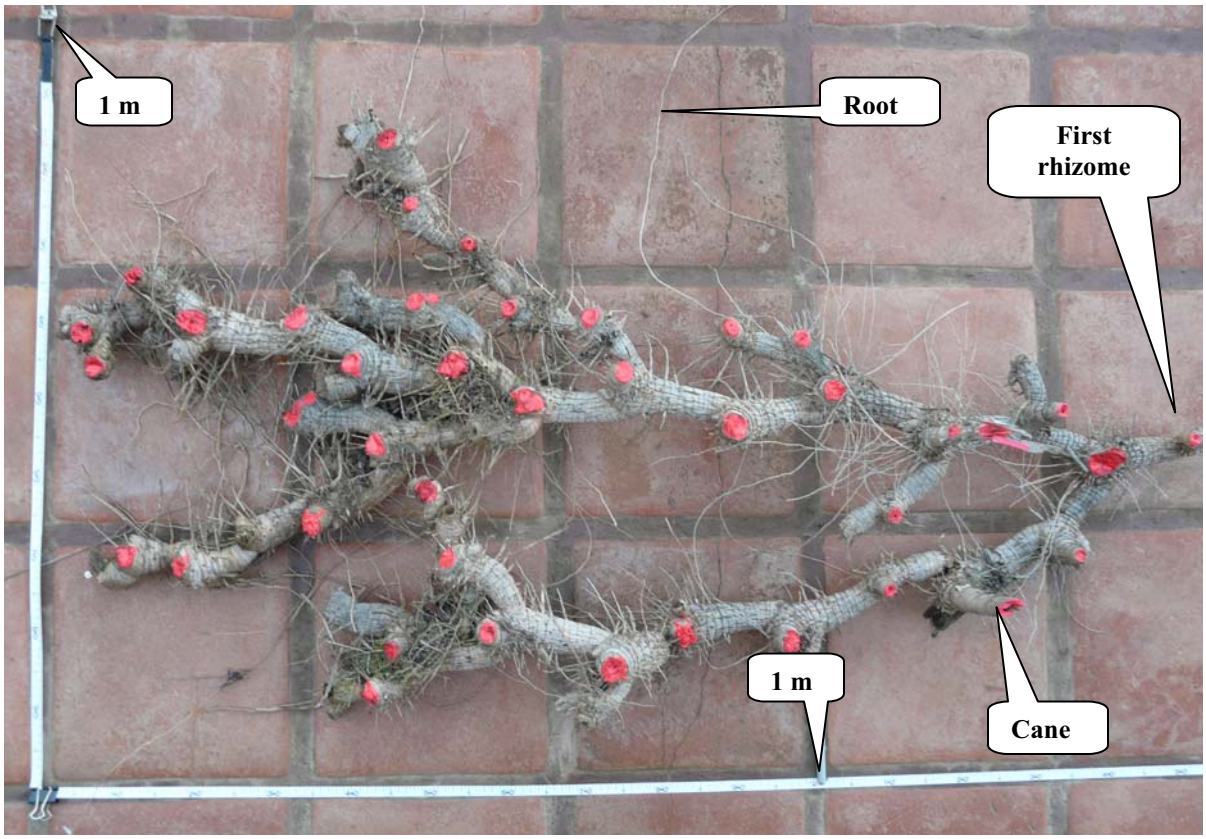


Figure 2-9. Rhizome network arising from a single growth point.
33 canes emerged from the marked 1 x 1m area (painted red).



Figure 2-10. Close-up of slightly desiccated *Arundo* rhizome.
The cane emergence points at the nodes are painted red, and long thin roots are visible.

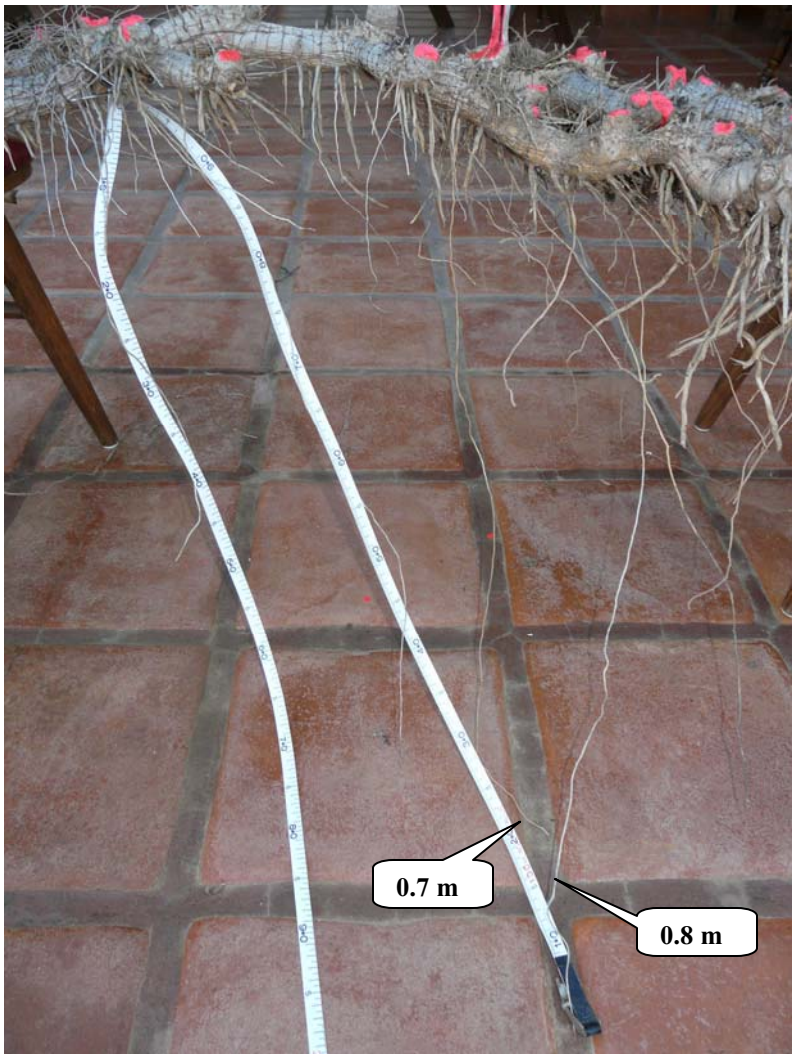


Figure 2-11. Rhizome network showing root length of up to 80 cm.
This was a dislodged rhizome network scoured out by flood action, so many of the roots have already been broken off, but it gives an idea of root density (near the rhizome) and length.

Arundo flowers are borne in large (3 to 6 dm long) plume-like terminal panicles, generally between March and September. However, many plants do not seem to ever flower, or at least not every year (Else 1996). The spikelets are several-flowered, approximately 12 mm long with florets becoming successively smaller.

Plants generally become dormant during the colder months, signified by the leaves turning brown/yellow, and the stems fading from their green color. These leaves and stems then turn green again in spring as temperatures rise and daylight lengthens. In areas with hard freezes during winter months, *Arundo* generally dies back to the ground and then re-sprouts in the spring. Deep freezes can kill the plant, probably by destroying the rhizome network.

The stand or clonal mass:

Few studies have specifically examined stand structure. Quantification of stand structure is critical in the scaling up of information derived from specific canes, leaves, or rhizomes to the stand scale. Specific information on biomass, leaf area, transpiration, and other data derived on a per cane basis cannot be converted into per unit land area without an understanding of stand structure. Some recent studies have specifically accounted for stand structure in scaling up cane-specific data (Abichandani 2007, Watts 2009, Spencer et al. 2006) although it was not always clear how they defined the stand area.

Scaling up from cane to stand (land area) based data is very sensitive to the measured cane density per land area. Determining cane density for a stand is not as straightforward as one might expect. Overestimations of cane density may be generated if one only samples in areas where canes emerge. Extrapolating specific data on a given parameter to spatial data, such as the GIS data set produced in this study, requires that the same definition of "stand area" be used when measuring cane density, or that adjustments be made to account for the sampling of canes from only the portion of the stand that has cane emerging.

In this study the *Arundo* stand is defined as its aerial extent as viewed from above, and all areas that have *Arundo* cover are classified as part of the stand footprint (Figure 2-12). This is the spatial extent of the stand as recorded in the GIS spatial data that was mapped for this project (more details can be found in Chaper 4). However, data on *Arundo* is typically collected on a per cane basis. To use cane data to represent an entire stand, we must understand cane distribution within the spatial area of the stand and if there is variation by stand size and/or age.

Arundo canes are not uniformly distributed within the aerial extent of the stand. There are two portions of the stand footprint that have no or very few canes. The first area we will examine is the edge of the stand. This area, when viewed from above, has *Arundo* canopy cover, but the canes are not rooted within the edge area, rather they are draping over into this space (Figures 2-12 & 13).

When individual ramet (cane) based data is scaled up to represent stand or clonal mass, adjustments need to be made to account for the areas that have no canes within the stand (if these areas were not sampled). This adjustment can occur as a reduction in cane density for the stand, or as an adjustment applied to account for the percentage of the stand that has no cane emergence. Most studies do not specify what was done with edge areas and gaps within the *Arundo* canopy. If these areas were sampled they would have cane density accounts of zero. Most studies seem to sample within the cane emergence zone only. The importance of the edge areas depends on stand size, which is usually a function of age. A small stand has significant edge (areas with aerial vegetation cover but no canes emerging from the zone, Figure 2-14). Over 70% of the stand area may have no canes emerging from it. Large stands, as long as they are not linear, have much less edge area as a proportion of the total stand area. Only 5% of the stand area might not have canes emerging from it.

The second area that has no canes in the aerial canopy of a stand occurs as alleys or gaps and is less predictable to specific locations of the stand (Figures 2-12 & 14). These areas are important in mid to large-sized stands that often form as multiple clumps grow into each other. As the stands grow older, these 'alleys' or gaps fill in. *Arundo* stands older than 10 to 15 years have fewer and fewer areas within the stand that have no canes. *Arundo* stands older than 20 years are difficult to sample internally, as these areas are not accessible from the ground. Old *Arundo* stands are more easily traversed across the top of the canopy than on the ground, where cane density precludes movement (Figures 2-15 & 16). Vegetation sampling crews on the Santa Margarita River could walk across the *Arundo* canopy for hundreds of meters in 1996 (Cummins pers. comm. 1998).

Gaps within *Arundo* stands also occur where there are low-flow channels (primary and sometimes secondary. These would technically be defined as separate stands as they have different rhizome systems, but they may appear as one stand when mapping. The 10 meter wide low flow channel of the San Diego River was crossed within *Arundo* canopy, attesting to the strength and density of the aerial cane network (Giessow pers. comm. 2009).

Cane density also varies within the portion of the stand where canes emerge. This makes sense since a stand starts as an individual (single fragment) or group of individuals (larger rhizome fragment with many nodes), and continually expands outward. Lateral growth creates a pattern of greater density within the older portions of the stand and lower density toward the edges (Figure 2-17). However, this variation is fairly minimal compared to the variation in cane density between different stands (field observation J. Giessow, this study). Data from this study recorded an average cane density of 6.5 m (maximum 9.9 m, minimum 2.6 m, Table 2-1). *Arundo* cane density is significantly higher than that of native vegetation (Ambrose 2006, NHC 1997a,b & 2001), and this has multiple effects such as restricting wildlife movement and blocking water flow. Sampling bias may also be occurring in many studies where cane density is not sampled from the interior of older stands which are hard to access. This study was able to sample deep interior portions of stands that were accessible during biomass reduction with heavy equipment. However, cane density does not increase indefinitely; eventually new canes that emerge do not reach light and they senesce each year (Decruyenaere1 & Holt 2005). Cane data collected in this study indicates that each square meter within the rhizome/cane emergence zone generates 3.4 (n=14, ± 2.7) canes per year. Dead canes were not common, with a density $<1/m^2$ on the study plots (Table 2-4). This study will adjust stand based calculations by multiplying the cane per me^2 by 70% to account for areas with no canes emerging from them (adjusting for edge drape and areas with no cane emergence within the aerial footprint of the stand).

Some areas are near a typical mature density (center), while edges and runners are expanding outward, creating lower density. Also see Figure 2-9 to look at rhizome growth pattern. This is a small 3 x 3 m clump, but similar patterns occur in larger stands. The canes drape and extend well outside of the central cane emergence footprint indicated in red.

This study will make scaling up adjustments of 70% to account for cane density measurements from sampling only carried out within the cane emergence zone. This will occur for stand-based biomass and water use calculations.

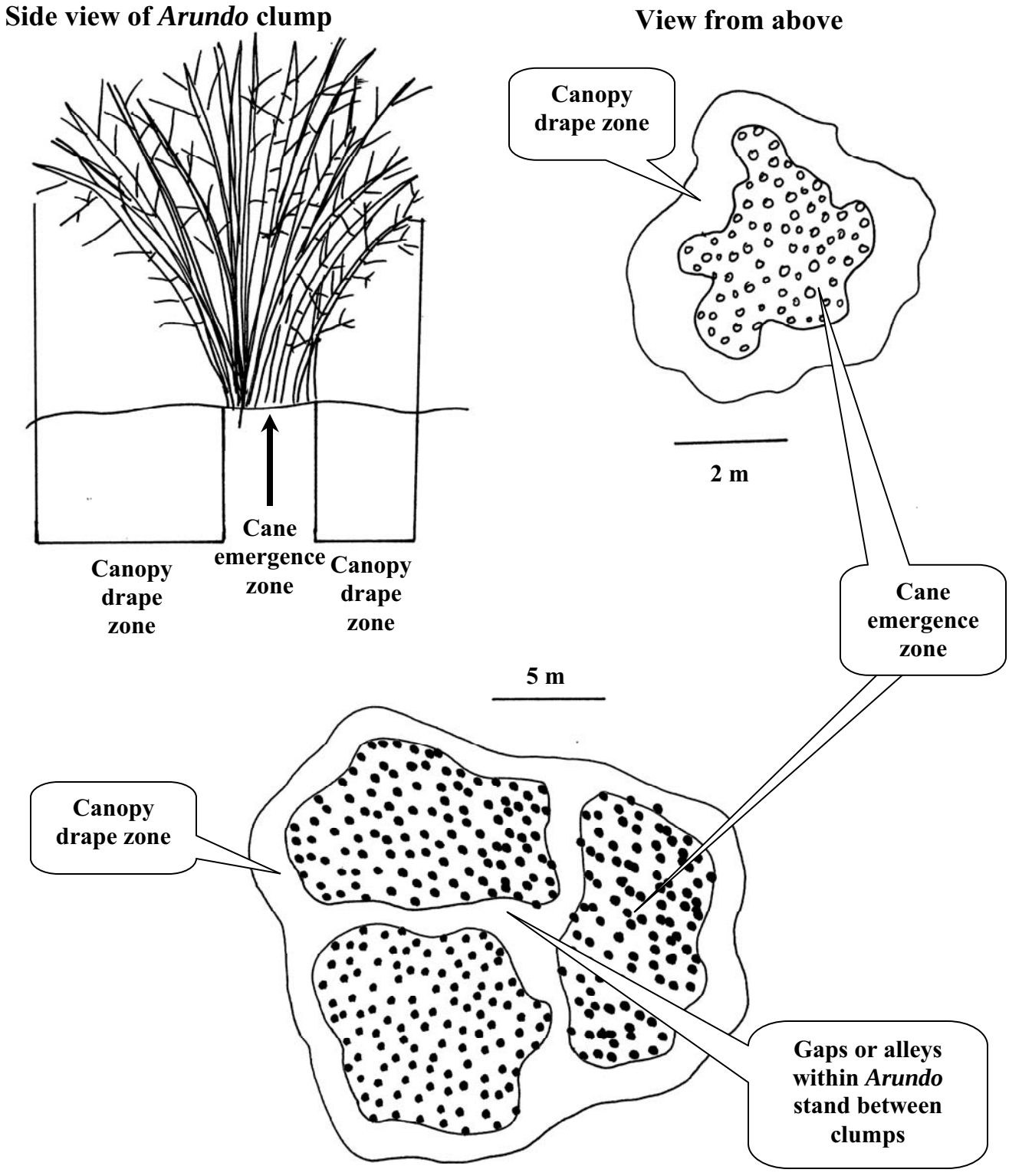


Figure 2-12. Draping effect of *Arundo* on the edge of the stand and gaps between clumps within a stand.
Drawing by J. Giessow.

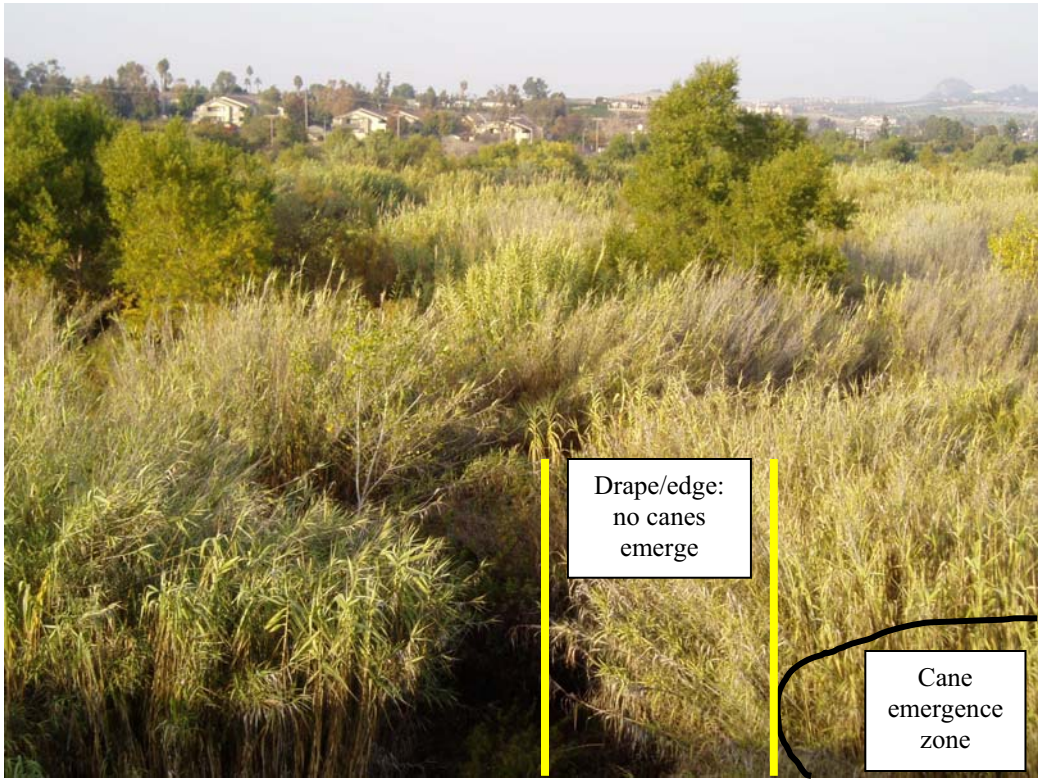


Figure 2-13. A mature *Arundo* stand showing draping of *Arundo* canes along an edge.



Figure 2-14. Oblique aerial photo showing patchiness of *Arundo* stands, particularly farther from the low-flow channel.
Greater patchiness means greater edge area composed of *Arundo* cover without actual canes emerging. The left side of image is unmowed/reduced *Arundo* and the right is immediately after reduction/mowing (San Luis Rey River 2007, J. Giessow).



Figure 2-15. View from bridge over San Luis Rey River showing the top of a mature *Arundo* stand. This stand is >10 years old, > 9 m height, and 100% cover. Note the high amount of leaf surface area and non-vertical (nearly horizontal) position of the upper portion of the canes with secondary branches.



Figure 2-16. *Arundo* stand being prepared for foliar herbicide treatment.
The crew is pushing the stand away from the native trees. *Arundo* canes are supporting the worker on the left. Canes are 8-9 m long and density is typical of a mature stand (about 40 canes/m^2). San Diego River, Giessow 2010.



Figure 2-17. A cut *Arundo* clump showing uneven cane density.

Table 2-4. Summary of *Arundo* cane density measurements from this study and others. This study and others typically sample cane density from the cane emergence zone.

Source	Location	New	Old	Dead	Total
Giessow et al.(2010)	S. California, coastal	3.4	38.1	<1	41.5
Spencer eta al. (2006)	Across U.S.				74.5
Ambrose & Rundel (2007)	S. California: Santa Clara River (post fire)				31.6
Abichandani (2007)	S. California: Santa Clara River				34.9

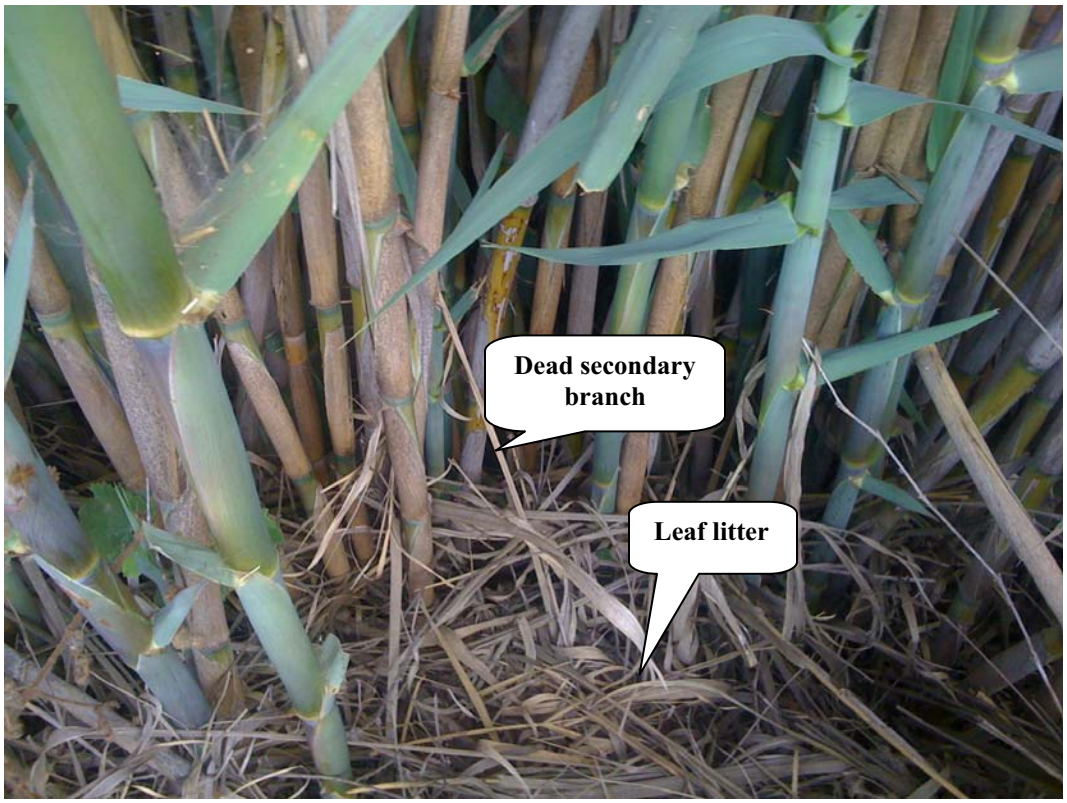


Figure 2-18. Cane density and dead leaf litter within a dense *Arundo* stand.

2.4 Biomass and Cane Density

Biomass (above and below ground) generated from *Arundo* is important as it sheds light on several factors related to impacts caused by the plant. It provides information on productivity, resource consumption (nutrients, light, and water), physical presence in the system (with impacts to flows, sediment, wildlife, light, wind, and other physical parameters), as well as indicating issues with the fate of the biomass material itself (both in aquatic and terrestrial portions of the watershed system).

Arundo has very high amounts of biomass per unit of land area as documented in many studies looking at standing biomass of wild infestations and annual productivity of cultivated stands (Table 2-5). This study found an adjusted *Arundo* stand biomass of 15.5 kg/m2, which is corroborated by the most comprehensive study evaluating *Arundo* biomass (Spencer 2006). The large amount of biomass is related to high productivity of the plant, high density of individuals (high cane density), and tall growth form of the plant (average 6.5 m in southern California). In addition to the high amount of biomass per unit of land area, *Arundo* has a large amount of energy per unit of dry weight (17 MJ/kg to 19.8 MJ/kg, see chapter 6). These values compare favorably with other fuel crops (*Arundo* is one of the highest) and are higher than most native tree, scrub, and herbaceous assemblages in the riparian zone. This is why fuel crop producers consider *Arundo* one of the top potential biofuel crops.

Belowground biomass estimates have been less studied, but appear to be in the range of 22.5% of the total plant/stand biomass (Sharma et al. 1998). Applying this proportion of above and below ground biomass generates overall estimates of 20.0 kg/m^2 or 89 t/acre (Table 2-6). These biomass levels are at the upper end of any vegetation class (Table 2-7), and are well above typical riparian vegetation values.

Table 2-5. *Arundo* aboveground biomass from various studies (wild and cultivated).

Location	Description	Above ground dry mass	Source
U.S. - 13 sites across US	Biomass of stands in field: wild	17.1 kg/m^2 171 t/ha 76 US t/ac	Spencer 2006
U.S. - 14 sites, 6 coastal watersheds in southern California	Biomass of stands in field: wild	15.5 kg/m^2 155 t/ha 69 US t/ac	This study
India	Biomass of stands in field: wild	3.6 to 16.7 kg/m^2 36 to 167 t/ha 16 to 74.3 US t/ac	Sharma et al. 1998
Southern CA (Santa Clara)	Annual yield (post fire): wild	49 t/ha 21.8 US t/ac	Ambrose & Rundel 2007
India – wild stands	Annual yield: wild	72 t/ha 32 US t/ac	Raitt 1913
Australia	Annual yield: crop	101 t/ha 45 US t/ac	Williams et al. 2008
Europe	Annual speculated max yield: crop	100 t/ha 45 US t/ac	Shatalov & Pereira 2000
Italy	Annual yield: crop	30 t/ha 13.4 US t/ac	Angelini et al. 2005
Italy – cultivated stands	Annual yield: crop	39.3 t/ha 17.5 US t/ac	Marinotti 1941
Greece	Annual yield: crop	120-230 t/ha 53.4-102.4 US t/ac	Mavrogiapolus et al. 2001
Greece	Annual yield (Yr 1, new crop): crop	15 t/ha 6.7 US t/ac	Hidalgo & Fernandez 2000
Greece	Annual yield (Yr 2): crop	20 t/ha 8.9 US t/ac	Hidalgo & Fernandez 2000
Greece	Annual yield (Yr 3): crop	30 t/ha 13.4 US t/ac	Hidalgo & Fernandez 2000
Greece	Annual yield (Yr 4, mature): crop	39 t/ha 17.4 US t/ac	Hidalgo & Fernandez 2000
Spain	Annual yield: crop	45.9 t/ha (ave) 29.6-63.1 t/ha (range) 13.2-28.1 US t/ac	Hidalgo & Fernandez 2000

Table 2-6. Above and below ground biomass values for *Arundo*, using relationship from Sharma 1998 (22.5% of biomass is below ground).

Study	Above ground biomass	Below ground biomass	Total biomass
This study	15.5 kg/m^2 155 t/ha 69 US t/ac	4.5 kg/m^2 45 t/ha 20 US t/ac	20.0 kg/m^2 200 t/ha 89 US t/ac
Spencer 2006	17.1 kg/m^2 171 t/ha 76 US t/ac	5 kg/m^2 50 t/ha 22 US t/ac	22.1 kg/m^2 221 t/ha 98 US t/ac

Table 2-7. Typical biomass values for different vegetation types.

Study	Above ground biomass	Study
Willow forest (as crop)	4-8 t/ac (annual) 15 t/ac (4 year growth)	Turhollow 1999
Switch grass	5 t/ac	Turhollow 1999

2.5 Growth Rate

Individual Ramet or Cane Growth:

When conditions are favorable, *Arundo* canes can grow 0.3-0.7 m per week over a period of several months (Perdue 1958). Young stems rapidly achieve the diameter of mature canes, with subsequent growth involving thickening of the walls (Perdue 1958). Annual yield studies demonstrate the productivity of *Arundo* stands (Table 2-5). Old canes typically have little new growth on the main leader (Decruyenaere & Holt 2005), but have extensive growth on secondary branches, as well as growing new secondary branches. In colder regions of the world *Arundo* dies back and then resprouts, although frost can damage the plant if it occurs after initiation of new growth (Sharma et al. 1998, Perdue 1958). In southern California dormancy is limited to total to partial browning of the canes and leaves during the winter.

Rhizome Growth:

In mature stands, most new shoots develop from large apical buds at rhizome termini, resulting in relatively evenly spaced, vertically oriented shoots 2 cm or more in diameter (Decruyenaere & Holt 2005). Rhizome growth extends laterally along an axis, but will branch (Figure 2-8). Rhizomes appear to 'self-discriminate', growing into areas with no rhizomes present (Decruyenaere & Holt 2005). Stands expand 7-26 cm/year (Decruyenaere & Holt 2005), as well as generating higher density. Comparisons of imagery over a 10 year period for sites in San Diego showed minor (none visible) to moderate

(0.5m/yr) expansion of established stands. Generally expansion was surprisingly slow, but highly variable. A few studies have examined expansion and lateral spread of rhizomes and canes, but these data are presented as increasing cane density within quadrats. Future studies should more explicitly describe length (m) or area (m^2) of spread.

Stand Growth:

Three general factors seem to affect growth rates of both canes and rhizomes: 1) availability of water, 2) availability of nutrients and 3) temperature regimes (affected by shade). Water availability seems to be the primary factor restricting the growth of *Arundo* stands in coastal California. This is based on field observations across the study area and our review of transpiration and nutrient studies. Generally watersheds in coastal California have favorable temperature ranges and are not nutrient limited. Areas with water available throughout the year develop into dense, tall *Arundo* stands. Areas with low water availability, such as upper terraces that are far from the water table, frequently have *Arundo* stands with lower cane density, shorter stature, and large amounts of dead material in the canopy (an indicator of stress).

Riparian systems are typically not nutrient limited in coastal California (Peterson et al. 2001, Suffet & Sheehan 2000). Artificially high nutrient levels increase growth rates of all riparian vegetation, but *Arundo* with its higher productivity potential (compared to native vegetation) is able to capitalize on this, turning it into a competitive advantage (Ambrose and Rundel 2007).

Nutrient use/nutrient loaded systems:

In the last century, nutrient inputs to river systems have increased dramatically due mainly to agriculture and municipal sewage. These same nutrient inputs are present in high quantities in the rivers of Southern California's watersheds (Pederson 2001, Suffet and Sheehan 2000). Nationwide, the use of fertilizer in agricultural areas has increased from 20 to 40 million tons annually. The average percent of nitrogen, the main constituent in commercial fertilizers, has risen from 6.1 to 20.4 % (Texas Water Resources Institute 1986). This increase in use and composition of fertilizer alone has led to a loading of river systems with nutrients, mainly nitrogen and phosphorus. Nitrogen, found in the form of nitrate in fertilizer, poses unique risks to river systems; it is soluble and moves quickly through soils in the shallow groundwater between agricultural practices and rivers. Phosphorus, on the other hand, is not very soluble and typically adheres to soil particles. Other anthropogenic and natural sources are thought to have also contributed to nutrient loading in river systems, including: nitrogen enriched rainfall and air; manure from animal feedlots and corrals; fertilizer applied to lawns; leaky septic tanks; oxidation of organic materials; and the symbiotic nitrogen fixation by plants.

2.6 Reproduction and Spread

This discussion is separated into spread within a site, spread within a watershed, and spread between watersheds.

2.6.1 Within Stand Spread

Once *Arundo* is present at a given location it grows and spreads laterally. Lateral spread occurs mainly through lateral rhizome growth and budding (forming new ramets or individuals in the asexual colonial

Arundo stand) (Decruyenaere & Holt 2005). In addition, *Arundo* canes can drape/bend over and touch the soil surface, and if conditions are favorable (wet and/or sediment covering a node) a new bud may form (developing into a new ramet or individual) (Boland 2006).

2.6.2 Spread Within A Watershed

Arundo is dependent on asexual reproduction. *Arundo* plants in North America do not appear to produce viable seed. Multiple studies in California have determined that seedlings are not present in the wild (Else 1996, Witje et al. 2005) and that plants that flower do not produce viable seed (Khudamrongsawat et al. 2004). Studies in India indicate that the apparent sterility of *Arundo* seed is caused by the failure of the megaspore mother cell to divide (Bhanwra et al. 1982).

New individuals within a watershed and the colonies they grow into are created through vegetative propagation. This occurs when plant fragments, usually rhizomes, become rooted at new locations and form into separate plants. Dispersal generally occurs during flood events, when floodwaters break off pieces of *Arundo* plants and transport them downstream (Else 1996, Decruyenaere & Holt 2005). Establishment of new *Arundo* stands within a watershed is, therefore, generally limited by the extent of river flow and floodplain inundation. However, *Arundo* fragments can also be moved to new locations within a watershed via human disturbance.

Several studies have shown that almost any segment of stem or rhizome can sprout if it possesses an axillary bud (Boose and Holt 1999, Wijte et al. 2005, Else 1996). Buds occur at the stem nodes and approximately 5-10 cm apart on the rhizomes (Wijte et al. 2005). Both rhizomes and stems can withstand a certain amount of drying out and still sprout. Drying rhizomes to 58.8% moisture loss and stems to 36.5% moisture loss did not affect their ability to sprout (Else 1996). Rhizomes were able to sprout when buried up to one meter deep (Else 1996), but stems have shown reduced sprouting at depths as low as 10 cm due to limited energy reserves in the stem (Boose and Holt 1999).

Else (1996) reported that of *Arundo* vegetative reproduction observed following dispersal by flooding on the Santa Margarita River in San Diego County, 57% was from rhizomes, 33% was from stem fragments, and for the remaining 7% the plant part that gave rise to the new plant could not be identified. Rhizomes are frequently broken off at bank edges when they are undercut (Brinke 2010) or scoured out (Figure 2-7). Any disturbance (natural or human caused) that mobilizes live rhizome material during conditions that are favorable for establishment will likely result in spread of *Arundo*. Flow events will break off rhizome fragments along stand edges and disperse them within flow areas (Brinke 2010). For this reason significant spread of *Arundo* within a watershed is episodic. Flows reach higher geomorphic forms (floodplain and terraces) only during large events. These large hydrologic events mobilize *Arundo* material for potential asexual propagation. Low flow events are confined to channel areas. New *Arundo* establishment in this area is often removed during later flood events. Little propagule material is typically mobilized during these low flow events in comparison to larger events, but undercutting of *Arundo* stand edges does generate a steady amount of propagules downstream.

The combination of within watershed dispersal events and stand growth rates generates a pattern of expansion that increases episodically to the system's maximum carrying capacity for *Arundo*. Larger watersheds with favorably wide floodplains have about 13% *Arundo* cover, but portions of these systems can have cover >44%.

2.6.3 Historic Air photo Analysis: Stand Growth Rates and Spread Within Watershed

Review of historic aerial photography on watersheds in the study area indicated some interesting patterns of spread and growth. The basic pattern that repeated on most watersheds was that there was little *Arundo* present on most systems from the 1930's to the 1960's. It looks as though *Arundo* was present as scattered clumps and small stands. Aerial photography during this time was of low resolution and black and white, limiting our ability to detect and map *Arundo*. Large stands of *Arundo* would have been detectable, but they were not present. The overall historic extent of *Arundo* on most systems was scattered with low total acreage. As will be seen later in this report (Chapter 5), this makes sense, since historically riparian systems were broad and dry.

In the 1960's riverine systems became much narrower (levees and land use change) and water was imported. This resulted in perennial flows on many systems or at minimum, significantly raised water tables. *Arundo* responded to these changes by aggressively spreading and growing into dense stands. This transformation occurred during the 1970's and 1980's on most systems. By the 1990's *Arundo* had achieved an extensive distribution that appears to be at or near the current distribution of the plant.

Lateral expansion of established stands appeared to be fairly slow, on the order of 1 to 2 feet a year. Disturbance events (fire, grading, clearing, flood action) and the subsequent growth seem to be more important to rapid expansion of *Arundo* than the slow lateral growth of established stands. The concurrent use of both growth strategies allows *Arundo* to become abundant on southern California watersheds that are characterized by episodic flow events. Review of historic aerial photos indicated that significant spread of *Arundo* within a watershed appears to be very episodic. Large magnitude flow events (25 to 100 year) are necessary for the plant to actively invade significant new areas in a riparian system, particularly higher floodplains and terraces.

2.6.4 Spread Between Watersheds

The spread of *Arundo* between watersheds is primarily due to humans moving *Arundo* plants (planting or dumping biomass) or soil/fill material contaminated with *Arundo* fragments. *Arundo* fragments can wash up into estuaries, but generally cannot get very far up into the riparian system as river flows push material out of the system.

2.7 Ecological Function: Abiotic and Biotic

2.7.1 Abiotic

Invasive species that modify abiotic ecosystem processes have significantly greater impacts than those that affect only biota (flora and fauna) because abiotic processes shape and control the entire ecosystem. *Arundo* strongly affects riparian abiotic processes, including: hydrology/geomorphology (including flooding - Chapter 5, water use/transpiration - Chapter 4) and fire (Chapter 6). *Arundo*'s strong influence on these ecosystem properties has two main consequences: 1) it modifies the habitat in ways that impact native flora and fauna, and 2) it modifies habitat in ways that benefit its own growth and continued spread. The modification of flows, geomorphology and sediment transport strongly affects successional patterns of vegetation. *Arundo*'s proliferation indicates that it benefits from this alteration of river processes. The significant increase in fire events (area and frequency, as documented in Chapter 6) and intensity also favors *Arundo*, as it is more productive than native vegetation after fire events (Ambrose & Rundel 2007).

2.7.2 Biotic

2.7.2.1 Vegetation

Arundo tends to form dense, monotypic stands that replace native riparian vegetation and naturally occurring open areas between vegetation groups. The displacement of native vegetation results in changes to vegetation composition, vegetation structure, and food resources. These changes have impacts on the native flora and fauna.

When *Arundo* forms dense stands, there is generally less plant diversity in comparison to un-invaded areas. A study in the Russian River in northern California showed that *Arundo* invasion was associated with significantly lower richness of native perennial plant species on stream banks, but not on gravel bars (Cushman and Gaffney 2010). Plots invaded by *Arundo* exhibited significantly lower native and exotic species richness and abundance of both established plants and seedlings than un-invaded plots. In coastal southern California watersheds, *Arundo* often displaces nearly all vegetation, leaving only mature gallery trees, which have a canopy layer higher than the *Arundo* stand (Figures 2-15 & 16). Native vegetation displacement is particularly pronounced in the shrub, perennial herb and annual herb growth form classes. Within dense *Arundo* stands there is generally little or no understory vegetation (Figure 2-19). In addition to displacing native vegetation, *Arundo* also alters the habitat by filling in areas that would naturally be open and unvegetated. Open portions of riparian habitat can be critical for fauna that use these areas for movement (both within and through the habitat). Unvegetated soil substrate can also be a place of refuge (both sand and litter covered).

A system that has dense stands of *Arundo* affects abiotic processes, tending to have a higher fire frequency and intensity, as well as altered flooding patterns. Removal of riparian vegetation by *Arundo* exacerbated flood and fire events alters the natural riparian successional patterns, and generally leads to more dominance of *Arundo*. This is an important positive feedback loop that leads to type conversion (Ambrose & Rundel 2007).

Arundo's impacts on vegetation and federally listed plants will be discussed further in Chapter 7.

2.7.2.2 Arthropods

Several studies have examined the impacts of *Arundo* on arthropods. All have indicated reduced diversity, density and/or productivity of arthropods within *Arundo* stands compared to native riparian vegetation. Native riparian vegetation in Sonoma County in spring contained twice the abundance, biomass, and species richness of aerial insects compared to *Arundo* (Herrera & Dudley 2003). Furthermore, insects recorded in *Arundo* were rarely observed feeding there, indicating that *Arundo* is used for its structure more than as a food source. Ground dwelling insects showed the same responses to *Arundo*, but to a lesser degree than aerial insects. Habitat that contained a mixture of *Arundo* and native riparian habitat showed an intermediate response. The *Arundo* infestation within the study area was at a much lower level than some southern California systems. High cover stands would likely show even less use.

Studies on arthropod use of *Arundo* leaf material indicate it is of low quality for native arthropods. Aquatic caddisfly larva survival was much lower for individuals fed *Arundo* (20%) compared to Alnus, Salicaceae, or Tamarix litter (85%) (Going & Dudley 2008). The high concentration of secondary compounds (tannins, alkaloids) and silica in *Arundo*, and the low nitrogen levels are likely to be poor food resources (Khuzhaev & Aripova 1994, Wynd et al. 1948).

Invertebrate species assemblages within soil and leaf litter in *Arundo* stands tend to be opportunistic forms that generally do not utilize the plant tissue directly and tend to be non-native. Invertebrates associated with *Arundo* rhizomes in southern California followed this pattern (43% non-native), and non-native detritivorous isopods were the most abundant in the Sonoma County study (Lovich et al. 2009, Herrera & Dudley 2003).

The preference of arthropods for native riparian vegetation over *Arundo* stands is likely due to the greater habitat structure, the more complex and massive litter layer, and the higher quality food resources. Despite its large biomass per square meter, *Arundo* appears not to provide much to the food web. This has significant impacts on wildlife. A large reduction in aerial insects, in particular, could have serious negative impacts for insectivorous birds such as the endangered least Bell's vireo (*Vireo bellii pusillus*) and southwestern willow flycatcher (*Empidonax traillii extimus*).

2.7.2.3 Wildlife

Dense *Arundo* stands can negatively impact fauna through a reduction in food resources, alteration in structure for nesting/denning, and creation of a physical barrier to movement within and through riparian habitat to upland areas (wildlife corridor). While there have not been many studies that document all of these impacts, they do seem probable based on the limited research that does exist, coupled with personal field observations and wildlife specialists' assessments as reported in management plans and regulatory documents. *Arundo* biomass has the potential to contaminate pools and areas used by native fish and amphibians for breeding and feeding, and can impact wildlife on beaches and estuaries where it collects after flood events. *Arundo* biomass piles and live plants may also create structure in areas where none naturally occurs, which may impact predation.

Studies on the use of *Arundo*-invaded habitat by wildlife are often compromised by native riparian habitat adjacent to and/or dispersed within the *Arundo* stands. Large continuous stands of *Arundo* do exist, but they are difficult to monitor as the density of canes restricts access to interior portions of the stand. Species frequently have territories/ranges that include *Arundo*-invaded and un-invaded habitat. Even with this caveat, patterns are still apparent.

Many reports and surveys have identified *Arundo* as a factor in reduced habitat fitness for reptiles and amphibians, although there are no specific research studies. Since reptiles and amphibians are highly dependent on specific hydrological/geomorphological processes occurring, they may be severely impacted due to *Arundo*'s complicated, long-term impacts on hydrology, geomorphology, and water use. This report explores these impacts in depth, and the impacts appear to be significant. *Arundo* stands can impact reptiles and amphibians by creating physical barriers to their movement within the riparian habitat, and to adjacent upland areas. Arroyo toads appear to avoid *Arundo* stands on MCB Camp Pendleton (Camp Pendleton Land Management Branch Reports and pers. comm. with land managers), but are dependent on migrating from breeding pools to upland habitat. Specific impacts will be explored for four endangered reptiles and amphibians in Chapter 7.

Arundo impacts on geomorphology/hydrology, especially channel and pool formation, are likely to be significant factors affecting fish species. There may also be impacts associated with contamination by large amounts of *Arundo* biomass within pools and other areas used for breeding and juveniles. It is generally thought that *Arundo* does not shade the waterway in the same way as native vegetation, resulting in increased water temperatures that would negatively affect fish and amphibian species. However, there is no published data on temperature in *Arundo* dominated streams as compared to native vegetation. Of greater consequence would be *Arundo*'s impact on channel depth, width, and number of channels/braiding (Chapter 5). Deeper, narrower channels may be cooler, but they also have reduced feeding opportunities and appropriate substrate may be lacking. Wrong depth and aspect, and higher

water velocity may also impede movement and/or cause reproduction to fail. Four endangered fish are examined in Chapter 7, with a more detailed discussion of *Arundo* impacts on habitat, movement/migration and reproduction.

Arundo impacts bird species due to its physical structure and its apparent reduction in abundance and diversity of insects (available data primarily relate to insectivorous species). In three drainages in southern California, *Arundo* stands contained reduced abundance and species richness of birds compared to native stands (Kisner 2004). The number of non-listed avian species declined by 32-41% as *Arundo* cover increased from 0 to 50%. Species richness of both ground and foliage gleaning birds declined in areas with increased *Arundo* cover. Preliminary results of a study on the lower Santa Clara River in southern California show diminished avian species diversity and fewer total individuals in *Arundo* stands relative to native stands, with intermediate diversity in mixed patches (Orr 2010). *Arundo* may also affect bird abundance as avian species rarely use it for nesting. The branching structure of *Arundo* is very different from native shrubs and trees, and it is presumed that it does not provide the architecture or support required for nesting. In the Prado Basin on the Santa River in southern California, from 1987 to 2006, only 0.8% percent of least Bell's vireo nests were in *Arundo*, compared to 76% in willow and mulefat (Pike et al. 2007). *Arundo* biomass washes downstream during flood events and can collect within estuaries and beaches. On the Santa Margarita River watershed, large piles of dead and sprouting *Arundo* eliminate nesting sites for Western snowy plovers and increase the presence of predators, which use it as perches and prey on rodents in the piles of vegetation (USFWS 2001). Eight endangered bird species will be reviewed in Chapter 7.

Arundo has complicated effects on mammal species. *Arundo* stands may provide areas for dens, but food resources are lower in comparison to native plants due to lack of seed and low quality forage. The dense cover and growth reduces mobility of mammals, which could reduce the use of riparian habitat as corridors for movements. This would be a significant impact and it remains undocumented. One endangered mammal, the San Joaquin kit fox, will be examined in Chapter 7.

2.8 *Arundo* Biology: Conclusions

Several observations were made in field studies, including:

- Mature stands are taller than has been typically reported in the literature: 6.5 m mean and a range of 2.6 – 9.9 m. (Section 2.3)
- Adjustments need to be made when scaling up from cane specific data to stand data due to canes not actually emerging within all areas of the *Arundo* canopy. Areas along edges and gaps within stands few to no canes. (Section 2.3)
- Biomass per unit area measured in this study is very high for mature *Arundo* stands: 15.5 kg/m^2. This is in general agreement with the literature. (Section 2.4)
- Reviewed literature demonstrates that *Arundo* spreads through asexual propagation (fragments of rhizomes and, infrequently, canes). Seeds are not viable. This makes *Arundo* spread dependent on flood action or anthropogenic disturbance. (Section 2.5)
- Review of historic aerial photography indicates that spread of *Arundo* within a watershed is very episodic. Large magnitude (50 to 100 year) events are necessary for the plant to actively invade significant new areas in a riparian system, particularly floodplains and terraces. (Section 2.6.4)

3.0 SPATIAL DATA SET: The Distribution and Abundance of *Arundo* from Monterey to Mexico

3.1 Methodology

Arundo was mapped for all coastal watersheds from the Salinas River in Monterey County in the north to the Tijuana River in the south (Figure 3-1). Four additional large-form riparian invasive plant species (*Washingtonia robusta, Phoenix canariensis, Cortaderia selloana, and Cortaderia jubata*) were also extensively mapped due to their presence and high abundance within a majority of the riparian corridors that were surveyed. Due to limited high-resolution aerial photo coverage, only partial mapping of all five species occurred in the Bolsa Nueva, Pajaro River, and Big Basin watersheds just north of the Salinas River Watershed. In addition, mapping of both *Cortaderia* species was limited to the immediate coastline above Santa Barbara County. For *Cortaderia* species, central coast populations north of Santa Barbara were mapped as jubata grass (*C. jubata*), and populations south of Santa Barbara were listed as pampas grass (*C. selloana*). The photo resolution that was available for most of this region (Central Coast) was too coarse to differentiate *Cortaderia* populations to species.

The mapping methodology utilized for this project borrows techniques from previous large-scale, watershed-based weed mapping efforts that have taken place in San Diego and Los Angeles Counties. Each plant population was captured using one of the following digital mapping approaches: (a) in-house surveys compiled by heads-up digitizing on high resolution aerial photography within a GIS; (b) field surveys using high resolution aerial photography on an integrated Tablet PC/GPS or; (c) a combination of option a. and b. (in-house surveys followed up by field checking).

3.1.1. Step-by-Step Process

1) In-office Surveys

Initial mapping efforts took place in the office. The database was generated within ESRI's desktop GIS application (ArcGIS 9.3) using a geodatabase (GDB) as the chosen file format. Domains (i.e. a data dictionary) were setup before mapping commenced to help ensure data integrity by limiting the choice of values within each field. Target species were then digitized within the GIS implementing a dual-monitor workstation setup. A primary tablet monitor (Figure 3-2) hosts the GIS application where plant populations are delineated as defined areas (i.e. polygons). High-resolution (1 ft or better) vertical aerial photos[1] were the primary base layer used for delineating plant population boundaries in the GIS. After a population was digitized, key attributes were noted (Table 3-1). Relevant supporting data was also captured during this phase that included "area mapped" to discern presence/absence and homeless encampment locations within the riparian zone. A secondary reference monitor was used as an additional aid to help distinguish smaller clumps as well as those populations partially covered by thicker tree canopy cover. High-resolution oblique imagery from four directions served as the reference. These images were freely available for all urban and wildland-urban interface (WUI) areas across the project extent courtesy of Microsoft's Bing maps "bird's eye view" function (*www.bing.com/maps*). The California Coastal Records oblique imagery database *(www.californiacoastline.org)* also served as a reference source for the immediate coastline (particularly for the central coastline *Cortaderia* species mapping).

[1] Two to four time periods (2004, 2005, 2006, and/or 2008) were available depending on the given area.

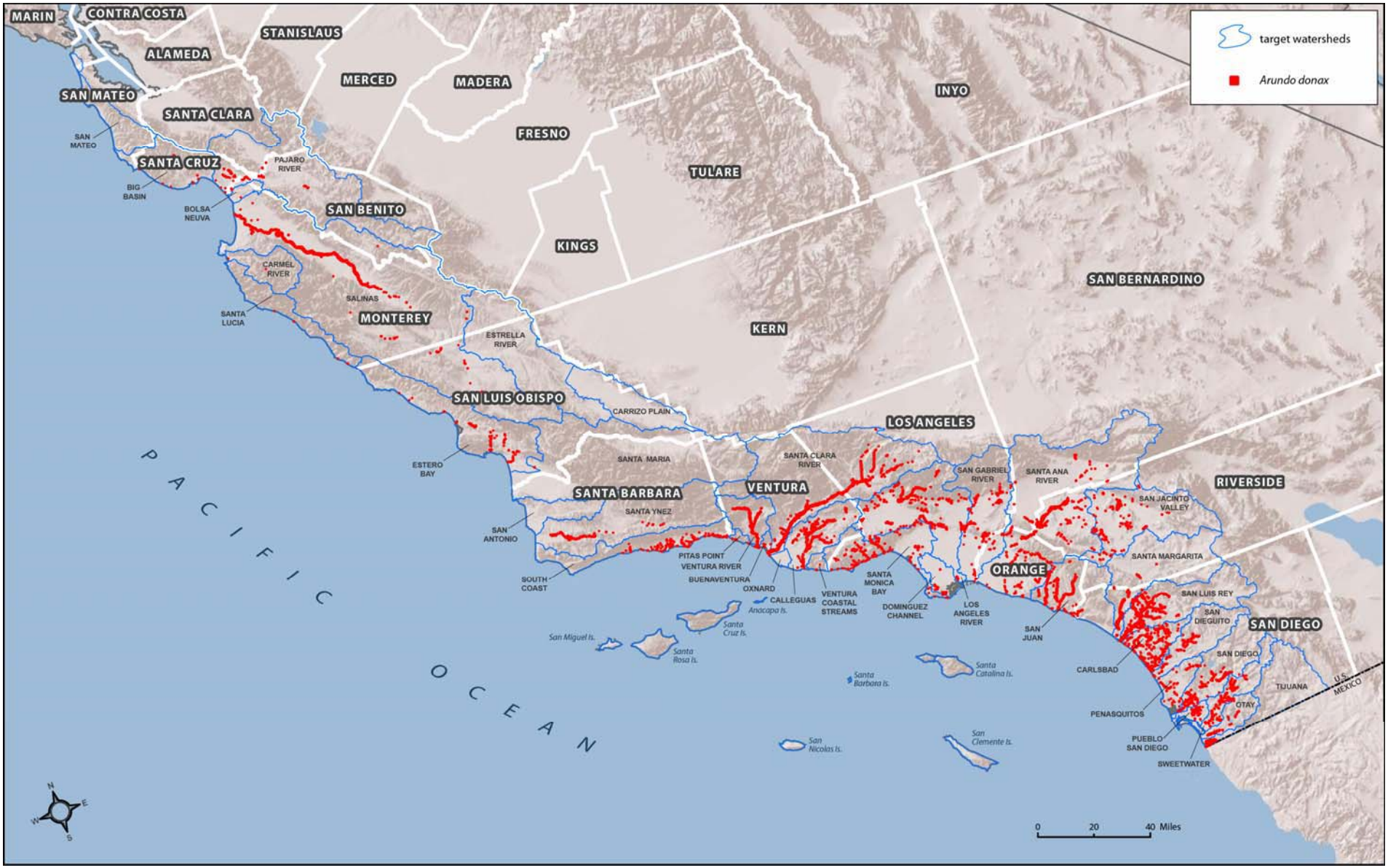


Figure 3-1. Distribution of *Arundo* mapped within the study area from Monterey to San Diego, CA.

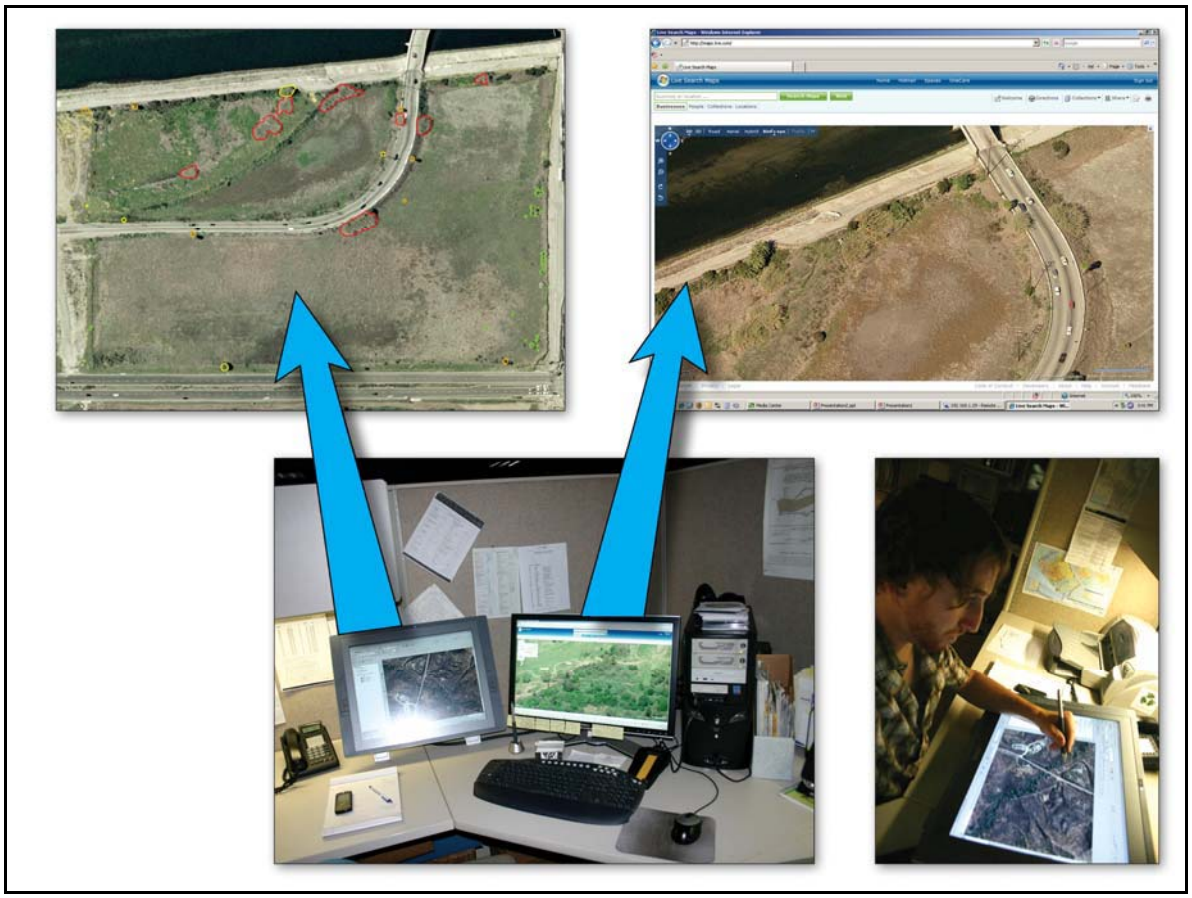


Figure 3-2. In-office surveys using a dual-monitor workstation.

Table 3-1. Data dictionary used for plant mapping.

Attribute	Notes
Plant Species	Common and scientific names are noted.
Percent Cover	70-100%= 100%; 50-69%= 50%; 15-49%=20%; 2-14%=5%
Plant Count	Estimated number of trees within a polygon
Average Height	Estimated tree height
Treatment Status	Status was marked as: treated, untreated, funded for treatment, or status unknown
Comments	Supplementary information
Observer	Person responsible for the last edit of a particular record
Mapping Methodology	Method was noted as: in-office survey, field survey, or combination
Date Mapped	Records that were only collected in-office took the date of the base photography as the map date; all other records used their observed field date
Data Source	Organization that collected the record
Watershed Name	HUC unit name
Gross Area (Acreage)	Total overall area in acres
Net Area (Acreage)	Total net area (factoring in percent cover) in acres

2) Data Transfer to Tablet

After the initial survey of a watershed was completed, the data was "checked out" of the GIS database and transferred to a ruggedized tablet PC. The field tablets used for this project (Xplore's iX104c3) were outfitted with GPS receivers (mounted or bluetooth) with an accuracy of 2-5 m (with real-time corrections) (Figure 3-3). The most current vertical aerial photography from the GIS database was also transferred onto the tablet as a base layer for the field mapping software. ESRI's ArcPad 8.0 was chosen as the mapping application because of its seamless integration between the field computers and central database back in the office. Toolbars in ArcPad were customized to optimize the time spent collecting data in the field.



Figure 3-3. Field surveys with ruggedized tablet PCs and integrated GPS.

3) Field Verification

After data was transferred to the field tablets, crews were sent out to verify the accuracy of the in-office surveys if locations were accessible and a line-of-sight could be established. Records were checked for spatial accuracy, percent cover estimation, and current treatment status. New populations and edits to existing populations were also collected by sketching directly on the tablet with a digital pen (Figure 3-4). The GPS functionality was only used only as a reference to orient the mapper's position on the basemap (i.e. high-resolution aerial photograph). Tracklogs in ArcPad (digital "breadcrumbs") were used to document surveyed areas and track progress/time spent mapping in the field.

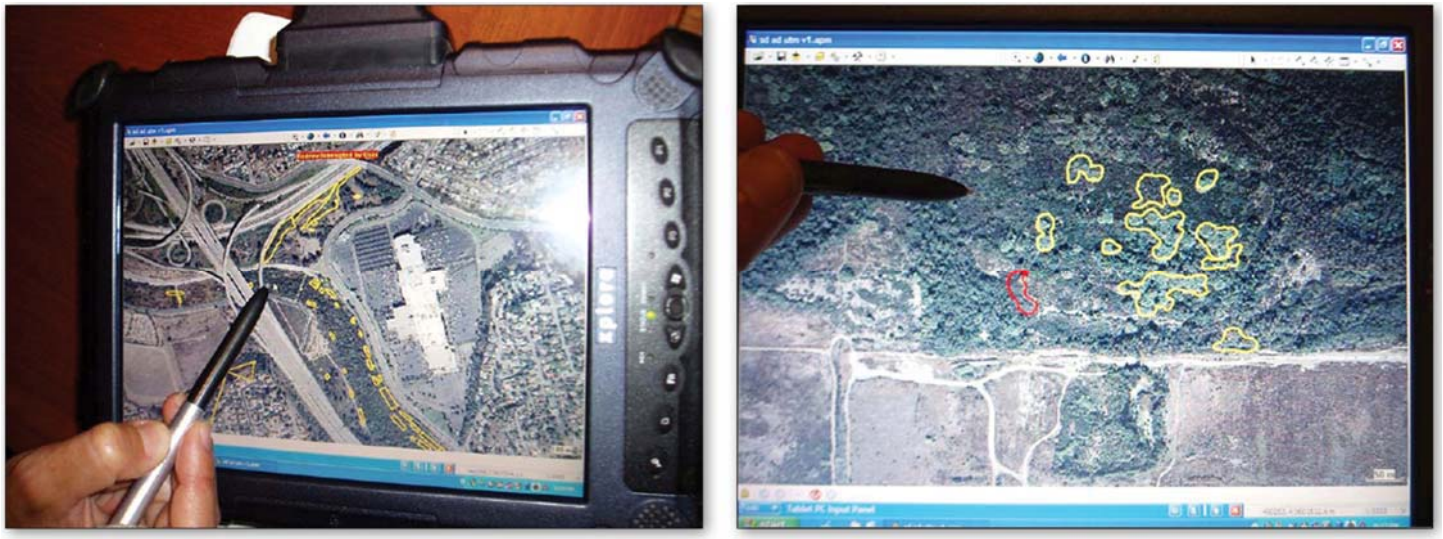


Figure 3-4. Digital sketch mapping.

4) Data Transfer To GIS

After field verification was completed for a given watershed, data is "checked" back into the GIS database at the office. Additional data attributes (watershed name, mapping status, acreage) were added through an automated process and existing attributes were re-checked for consistency.

3.1.2. Data Quality

The combination of methodologies mentioned above is the obvious choice for capturing the highest possible accuracy, but there were instances where either the in-house or field surveys were not feasible. In-house surveys were not completed when high-resolution imagery (6 in-1 ft vertical or 1 m plus oblique photography) was not readily available for a particular region. As field checking commenced, it became apparent that smaller clumps were often misidentified or omitted when high-resolution imagery was unavailable.

There were instances when field surveys were not achievable due to access (i.e. private property, difficult terrain, etc.) and/or general project time constraints. For instance, the Salinas River has thousands of smaller disconnected clumps of *Arundo* that were widely dispersed across several miles. Field checking all of these populations was not practical, nor was it achievable within the given timeline and budget. Preselected locations along the Salinas River were visited and field checked where it was inherently difficult to distinguish *Arundo* populations in-office. *Cortaderia* populations along the Central Coast also were not field verified. There are hundreds of miles of coastline covered by steep bluffs in this region that have a significant amount of *Cortaderia* present throughout the landscape. Given the time constraints, the area that needed to be covered, and the fact that this was species was a lower priority in terms of project goals, ground-truthing this extent was not achievable for the project.

It should also be noted that all species mapped were defined by their full footprint extent as interpreted from a vertical perspective. For *Arundo* in particular, this means capturing both the cane emergence zone and cane drape zone (as shown in Fig 2-13). Mapping populations in this manner can have an effect on acreage estimates, depending on the photo resolution used to delineate the footprint extent. Because individual canes are much more identifiable on the 6in. and 1ft. aerial imagery, the delineated

footprint of a population can be wider than a delineation of that same population using 1m imagery. Higher resolution, in turn, will boost acreage estimates, especially in areas where individual clumps are widely dispersed and cane drape zones are more extensive.

Attribute Accuracy

"Percent cover" was determined based on a rough visual interpretation from the ground. In some cases, values may be moderately under or overestimated because of issues with access to property and/or line-of-sight due to other vegetation cover, structures, etc. This holds true for *Arundo* and *Cortaderia* in particular. Based on local field comparisons of previous surveys that used a similar methodology, overall acreage totals tend to be underestimated by approximately 15-20% (Giessow pers. comm. 2010). Because the resolution of the base photography has significantly improved over time (1 m in 2001 compared to the present standard of 1 ft/6 in), it is expected that the acreage calculations now have a higher degree of accuracy.

"Treatment status" may not represent current ground conditions due to ongoing treatment programs that are currently unknown or not being tracked by the project team. Because this is intended to be a living database, the plan is to update treatment information periodically as the data becomes available.

There may be misclassifications of species because of the inability to ground truth a particular population, or because the field mapper misidentified the species. This holds true for the *Washingtonia robusta* and two *Cortaderia* species in particular. It is currently not possible to accurately distinguish between *W. robusta* and *Washingtonia filifera* when conducting in-office surveys alone.

Positional Accuracy

Positional accuracy may vary across the project extent due to fluctuating base imagery resolutions that were available when the in-house mapping took place. Data collected during the project is no better than that of the base photography's accuracy used to delineate a population's extent.

Cartographic offsets may be present in the data due to several conditions including (a) GPS accuracy affected by quality of unit, and/or poor signal due to canopy cover, terrain, cloud cover, time of day, etc; (b) scale and legibility constraints due to the basemap aerial photography's resolution and quality, and/or; (c) field mapper interpretational errors due to line-of-sight issues caused by dense vegetation, terrain, structures, etc.

Completeness

In order to accurately quantify impacts within each system, one goal for the project was to map the full baseline extent of all *Arundo* populations present within any given system over time. While the mapping team used 2006 imagery as the starting point for developing this baseline extent, some watersheds previously had large watershed-scale eradication programs in place. These include the Santa Ana, Santa Margarita, San Luis Rey, and Carlsbad watersheds. Subsequently, earlier datasets provided by local program managers as well as historic aerial photographs were used to fill in gaps for areas that were treated and re-vegetated prior to 2006. Therefore, it should be noted that the final data output is not a single snapshot for one specific year. There may be several time periods represented for a given area, particularly in San Diego County. Santa Ana Watershed *Arundo* acreage was also adjusted higher to reflect *Arundo* control (in the mid 1990's) that could not be documented in aerial photography. The acreage adjustment estimation was based on existing program management documentation and annual reports available through the Santa Ana Watershed Authority (SAWA).

It should be noted that *Arundo* stands were certainly missed within the study area, particularly small clumps and stands that were obscured by native tree canopy or scattered stands in areas with little *Arundo*. The mapping data set captures a majority of the population that occurs in the project area, but it does not capture all *Arundo*. For instance, a majority of neighborhoods outside of the immediate urban-wildland interface were not extensively surveyed for *Arundo*. Because these areas may be connected to streams and rivers, projects should re-evaluate this data set prior to utilizing it for a specific project or use.

Data set availability at BIOS and Cal-IPC

The GIS database (ESRI geodatabase) is currently hosted on the Department of Fish and Game BIOS (Biogeographic Information & Observation System) web-based mapping application. (http://bios.dfg.ca.gov/). The data sets are named:

Invasive Plants (Prct Cover) - Central_So. Cal Coastal Watersheds [ds646]

Invasive Plants (Species) - Central_So. Cal Coastal Watersheds [ds645]

It can be viewed and printed from this platform along with a multitude of other spatial data. The geodatabase is also available for download at Cal-IPC (http://www.cal-ipc.org/ip/mapping/arundo/index.php). This website also hosts a PDF version of this report and associated map books tied to the distribution and listed species co-occurrence with *Arundo*). There is currently no funding to maintain or update the invasives GIS data set. If future revisions do occur, updates will be indicated on the Cal-IPC website.

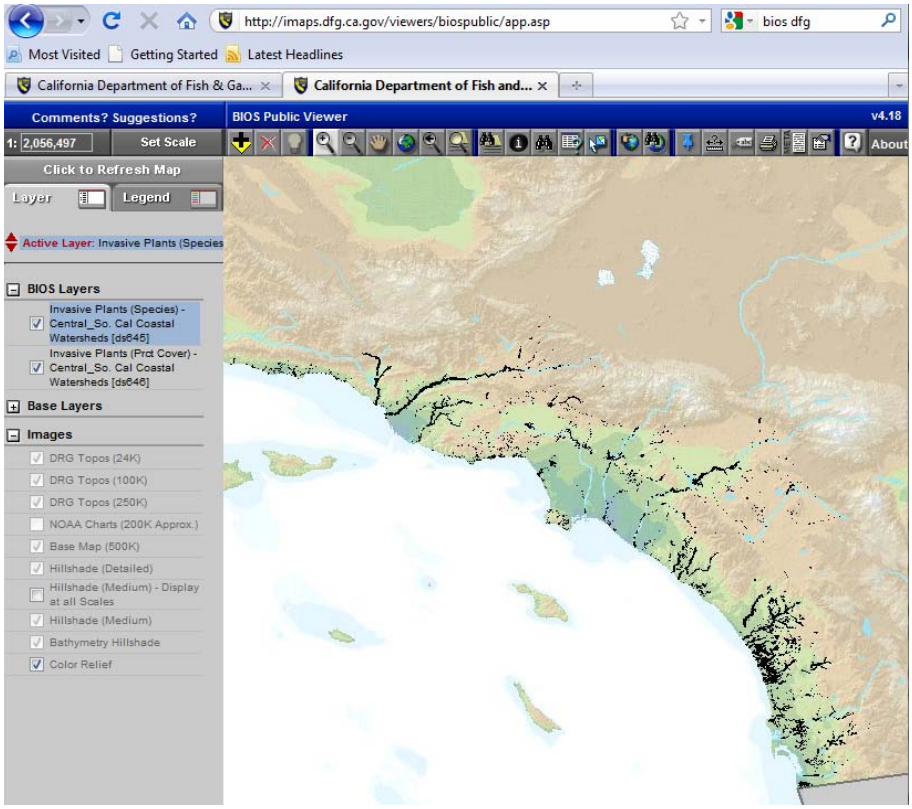


Figure 3-5. DFG BIOS data viewer with invasive plant data set active.



Figure 3-6. Cal-IPC web site project page for *Arundo* mapping downloads.

3.2 Results: Acreage by Watershed and Region

Arundo acreage for coastal watersheds from Monterey to San Diego was estimated to be 8,907 acres at its peak distribution (Table 3-2). This captures the 'full maximum extent' of *Arundo* on all watersheds within the study area prior to the initiation of control programs (Figure 3-1). This data will be used to examine and quantify impacts in the chapters that follow. In most areas mapped, dense stands (>80% cover) were the 'typical' stand structure. This is not surprising given the clonal nature of the plant. The largest exception to this observation was the Salinas River, which had many expansive areas with low *Arundo* cover. This is unusual for *Arundo* and may reflect water management practices on the river that have made flows seasonal over the last 20 years. For this reason, 'net' acreage is also given (gross acreage multiplied by the noted stand-specific *Arundo* cover). Examination of Table 3-2 shows that most *Arundo* stands on watersheds were mapped as having high cover, such that gross and net acreage values are similar. Later sections of the report use acreage values that are most relevant to the particular effect being looked at. The fire chapter uses gross acreage, while biomass and water use (which are sensitive to cane density) use net figures.

This study's mapped value of 8,907 acres, although high, is far lower than some estimates of *Arundo* acreage, even for individual watersheds. Santa Ana River has been reported as having over 10,000 acres of *Arundo* (Iverson 1993). This highlights the need for a more standardized and consistent approach to mapping *Arundo*. Many programs continue to map *Arundo* in mixed vegetation classes. This can lead to drastic overestimation of *Arundo* biomass and distribution. Vegetation mapping is very different then species-specific mapping and they should not be used interchangeably. Newer programs, such as on the Ventura and Salinas Rivers and in the San Diego region, use *Arundo*-specific mapping. This data set will aid all programs in using a standardized approach to gauging *Arundo* distribution and abundance.

The *Arundo* mapping also tracked treatment status. Impressively 36% of *Arundo* distribution is already under management/control (Table 3-2). This reflects a substantial investment of federal, state, and local

resources. It is encouraging to see significant acreage has been controlled. Several watersheds have achieved particularly high rates of initiated control including: Santa Margarita (99%), San Luis Rey (90%), Carlsbad HU (67%), San Dieguito (51%), Ventura (47%), and Santa Ana (40%). Several watersheds that are heavily invaded have had little or no work occur in them, such as Salinas, Santa Clara, and Calleguas. A later section of this report will examine watershed-based programs and their status.

The *Arundo* mapping acreage is an important tool for not only quantifying impacts but also planning and implementing control efforts. These accurate estimates of *Arundo* acreage allow for better project descriptions, budgets and rationalization of project needs. High quality spatial mapping also assists with environmental planning and permitting. Agencies can more precisely see where *Arundo* occurs, and sensitive species and other concerns can be addressed more specifically. State level funding and project prioritization decisions may also be made in a broader context. Multiple factors still need to be weighed, but this high-resolution mapping gives land managers a stronger quantification of both benefit and cost, much more than was possible prior to the project.

As noted under the discussion of accuracy, this data set under-represents the acreage of *Arundo*. The *Arundo* mapped only accounts for stands that were visible in imagery and field reconnaissance. While there are very few instances of misclassification, there are *Arundo* clumps and portions of stands that are missed due to obstructed views and/or it was too small to see. Previous work by the authors has indicated that detailed re-mapping of areas during control has typically indicated a 15-20% underestimation of *Arundo*. This data set may be slightly more accurate (10-15% underestimate) in many areas as aerial imagery has improved in quality and resolution within the last several years. It is highly unlikely that *Arundo* acreage has been over estimated by this study.

3.3 Conclusions: Distribution and Abundance

- *Arundo* mapping documented a total (gross) of 8,907 acres of *Arundo* within the study area. Net acreage, adjusted for *Arundo* cover, was 7,864 acres. This represents the peak distribution of *Arundo* in the study area prior to control activities. (Section 3.2)
- Over 3,000 gross acres of *Arundo* have been treated to date within the study area. This is 34% of the peak *Arundo* acreage occurring within the study area. (Section 3.2)
- Three large, contiguous watershed units have the highest levels of *Arundo* control observed in the study area: Santa Margarita at 99%, San Luis Rey at 90% and Carlsbad HU at 70 %. (Section 3.2)
- Most other invaded watersheds in the study area with more than 100 acres of *Arundo* have had at least 30% of their *Arundo* treated. Noted exceptions to this are Calleguas, Salinas and Santa Clara watersheds, which have less than 10% of their *Arundo* acreage under treatment. (Section 3.2)

Distribution and abundance data is extremely valuable because it quantifies past and current levels of invasion on watersheds, allows detailed examination and quantification of impacts, and facilitates watershed based control. Programs can use the spatial data to implement watershed based control, develop proposals and budgets, and manage control programs.

Table 3-2. *Arundo* acreage in central and southern California by hydrologic unit.

Hydrological Unit	Total Area (Acres)	Treated *Arundo*		Untreated *Arundo*		Total *Arundo*		Percent treated
		Gross Acres	Net Acres	Gross Acres	Net Acres	Gross Acres	Net Acres	
Big Basin[3]	235,181			0.3	0.3	0.3	0.3	0%
Bolsa Nueva	32,649			0.2	0.2	0.2	0.2	0%
Buena Ventura	13,226			0.5	0.5	0.5	0.5	0%
Calleguas	220,527	1.4	1.4	230.0	227.7	231.5	229.1	1%
Carlsbad[3]	135,753	103.7	103.7	44.0	44.0	147.7	147.7	70%
Carmel River	163,643			0.0	0.0	0.0	0.0	0%
Carrizo Plain	278,848							
Domigz Channel	81,760			2.6	2.6	2.6	2.6	0%
Estero Bay[3]	480,544	1.2	1.2	15.0	8.6	16.1	9.8	12%
Estrella River	610,278							
Los Angeles	533,834	16.3	16.3	116.5	115.1	132.8	131.4	12%
Otay	98,380			18.6	18.6	18.6	18.6	0%
Oxnard	18,721							
Pajaro River	838,942			8.1	8.1	8.1	8.1	0%
Penasquitos	103,790	2.2	2.2	21.4	21.4	23.6	23.5	9%
Pita's Point	14,051			0.5	0.5	0.5	0.5	0%
Pueblo S. Diego	37,546	0.0	0.0	15.4	15.0	15.4	15.0	0%
Salinas	2,272,492	137.4	106.4	1,868.7	1,225.3	2,006.1	1,331.7	8%
San Antonio	135,624							
San Diego	278,977	56.2	56.2	94.0	93.3	150.2	149.5	38%
San Diego Bay	10,931							
San Dieguito	221,555	89.8	89.8	85.2	85.2	175.0	175.0	51%
San Gabriel	456,886	3.5	3.5	41.0	40.8	44.6	44.3	8%
San Juan[3]	317,261	13.2	13.1	161.9	160.3	175.2	173.4	8%
San Luis Rey	358,662	612.4	612.4	71.4	71.4	683.9	83.9	90%
San Mateo[3]	164,484							
Santa Maria	1,188,373			0.1	0.1	0.1	0.1	0%
Santa Ana[1]	1,752,490	1,083.1	1,006.9	1,640.7	1,526.8	2,723.9	2,533.8	40%
Santa Clara	1,037,141	0.3	0.3	1,081.0	1,018.5	1,081.3	1,018.8	0%
Santa Lucia[3]	193,641			0.1	0.1	0.1	0.1	0%
Santa Margarita	475,449	684.7	684.7	4.2	4.2	688.9	688.9	99%
Santa Monica[3]	267,152	0.4	0.3	18.3	18.2	18.6	18.5	2%
Santa Ynez	576,066			21.4	6.0	21.4	6.0	0%
South Coast[3]	240,092	7.8	7.8	22.0	22.0	29.8	29.8	26%
Sweetwater	146,781	5.7	5.7	36.7	36.1	42.3	41.8	14%
Tijuana[2]	299,181	41.1	41.1	94.5	89.5	135.6	130.6	31%
Ventura[3]	22,475			0.1	0.1	0.1	0.1	0%
Ventura River	144,669	143.6	117.4	188.4	132.5	332.0	249.9	47%
Totals:	**14,458,055**	**2,995.5**	**2,861.9**	**5,911.7**	**5,001.8**	**8,907.2**	**7,863.7**	

[1]Adjusted- added 400 ac treated for older treatments that were not detectable; [2]Adjusted- added 40 ac treated for older treatments that were not detectable; [3]Hydrologic Unit composed of many smaller coastal streams/watersheds.

4.0 IMPACTS OF *ARUNDO*: *Arundo* Water Use and Stand Transpiration

4.1 Determining *Arundo* Water Use (Stand transpiration)

Water loss from watershed systems resulting from *Arundo donax* invasion is a topic of serious concern, but realistic or direct estimates of such losses are scarce. This chapter attempts to estimate water loss (in mm per day per m^2 of ground area) from *Arundo* stands in southern California as a function of *Arundo* leaf transpiration. Study estimates utilize reported transpiration rates for *Arundo* from a variety of areas coupled with leaf area indices and cane densities measured in the study area. Comparisons are also made between this study's estimates of stand-level water loss to those reported by others.

4.1.1 Background:

Vegetation in a system contributes to water loss primarily as function of *transpiration* through the leaves (E), but *evaporation* of water from exposed soil (i.e., not covered by plant canopy or litter) is also a contributing factor. Combined water loss via plant transpiration and surface evaporation is termed *evapotranspiration* (ET). Measuring ET is often a complicated process (Allen et al. 1998), but plant physiology studies often directly measure E using individual plant leaves and gas analyzers. The leaf-based measurements (E_l) can then be scaled up, based on leaf area per unit area of ground ("leaf area index" or LAI), to yield estimates of water loss at the stand scale via plant transpiration (E_{stand}, or water lost per unit area of ground). In a mature vegetation stand, where much of the ground is shaded, E_{stand} will account for the majority of total water loss via ET (Allen et al. 1998).

4.1.2 Methods

In an effort to estimate water loss from *Arundo* stands in the study area, published scientific and unpublished gray literature was searched for direct estimates of *Arundo* transpiration (E) or evapotranspiration (ET) from *Arundo* stands. The search yielded three Master's thesis studies that measured *Arundo* E_l (Abichandani 2007, Watts 2009, Zimmerman *unpublished data*), two of which then scaled up to E_{stand}. One direct measurement of ET was also found from a Mediterranean region study reported in a conference proceedings (Christou et al. 2003) and one additional internet report in which stand-scale *Arundo* water loss was estimated using data from Zimmerman's thesis work (Hendrickson & McGaugh 2005). LAI values are a very important factor in calculating stand transpiration rates. Additional data on *Arundo* stand LAI is also reported for papers that examined stand structure (Sharma et al. 1998, Spencer 2006).

The *Arundo* leaf-scale transpiration rates (E_l) reported in the three Master's theses were fairly similar. To be conservative, the lower measured value from the Abichandani study was used to estimate stand-scale water loss via transpiration (E_{stand}) for this study. In order to scale up from the average reported E_l to E_{stand} for the study area LAI for the study area was calculated based on filed sampling of *Arundo* stand structure. *Arundo* cane density and a number of structural traits on canes taken from 14 sites in the southern California study area were measured (Figure 2-1). Sites were selected in the field to represent mature *Arundo* stands, not areas that had been previously controlled, burned or otherwise disturbed. Mature *Arundo* stands are the majority of the acreage in the study area. The goal of this study is to measure water use of mature *Arundo* stands. Mature *Arundo* stands do vary significantly in cane density and robustness of growth- predominantly as a function of water availability. For this reason samples were taken from 11 'wet' sites (73%) and 3 'dry' sites (27%). This is approximately the proportion of wet and dry stands observed in field mapping within the study area.

One or two representative "old" (>1yr) *Arundo* canes were collected from each of the 14 sites (17 canes total) and one "new" (1st year) cane from three of the sites (Table 4-1). Leaf area was calculated as length*width*0.74 based on an examination and measurement of leaf shape. Structural traits measured on old canes included (a) length of and number of leaves on the leader portion (i.e. the portion of the central branch with green leaves) and (b) number and length of secondary branches. Individual leaf area for all leaves was then measured on a subset of leader canes (3 canes, 60 leaves) and secondary branches (18 branches, 200 leaves). Only the green photosynthetic area was measured on leaves. Cane (stem) surface and leaf sheaths were not included in calculations of photosynthetic area. The sum of measured leaf areas for each leader or branch was used to determine the average total leaf area per unit length of leader cane or secondary branch (26.8cm^2 leaf area/cm leader and 5.7cm^2 leaf area/cm secondary branch). Total expected leaf area was then calculated for all 17 old canes collected as a function of their leader and total secondary branch lengths multiplied by the appropriate leaf area/cm branch value.

Structural traits measured on new canes included the length of the cane, number of leaves and total leaf area, calculated as the sum of areas measured for each individual leaf (3 canes measured, 69 leaves). An average leaf area for a new cane was then calculated. To determine site-specific LAI, the total expected leaf area of each collected old cane was multiplied by the number of old canes counted in a representative square meter within the site and added to the average total leaf area of a new cane multiplied by the density of new canes in that same square meter (Table 4-2). Stand adjusted LAI is also given, representing for true stand-based leaf area (adjusts for area with no canes emerging, see Section 2.3). As there are significantly more old canes per unit area in a mature *Arundo* stand, greater effort was expended in calculating old cane leaf area.

Secondary branch leaf area relationships were explored using three different formulas: a linear regression, a quadratic regression and the branch length to leaf area relationship that was used. All three relationships were fairly consistent, generating final secondary branch LAI values ranging from 15.0 (linear), 19.0 (quadratic), and 17.0 (average leaf area per cm) (Figure 4-1, Table 4-2).

While leaf-based transpiration (E_l) is often reported in mmol $m^{-2}_{\text{leaf area}}$ s^{-1}, different studies utilize discrete (and sometimes unspecified) methods for scaling up to the level of the stand. Consequently, there appears to be no clear convention in units used to report such water loss (e.g., kg m^{-2} hr^{-1} or mm/day, etc.). For ET water loss is often reported in mm/time (Allen et al. 1998), which is roughly equivalent to a water loss of 1 liter/m^2/unit time. Following the assumption that the bulk of evapotranspirative loss in a mature stand is accounted for by transpiration, mm/day was used to report this study's calculated E_{stand} for *Arundo*. To scale from E_l to E_{stand} in mm/day: (1) average E_l was multiplied by the molar mass of water, giving grams H_2O $m^{-2}_{\text{leaf area}}$ s^{-1}; (2) divided by the density of water at 25C, giving m^3 H_2O $m^{-2}_{\text{leaf area}}$ s^{-1}; (3) multiplied by the LAI (in m^2 leaf area per m^2 ground area), giving m^3 H_2O $m^2_{\text{ground area}}$ s^{-1}; (4) divided m^3 H_2O by 0.001 to yield mm H_2O $m^{-2}_{\text{ground area}}$ s^{-1}; and (5) multiplied by 34,679 s/day of daylight (9.6 hrs or 3,516 hrs/yr - this value is based on average sunlight per day for the study area with 932 hours subtracted for winter dormancy. To compare this study's E_{stand} estimate with those reported in the other papers, reported E_{stand} values were sometimes converted from other units. Thus, some conversion error should be expected. However, when possible and for the greatest consistency in comparisons, E_{stand} was recalculated using average E_l and LAI values from the paper and following the general method above. These recalculated values are reported along with those given directly in the paper (Table 4-3). This re-calculation of values for other studies validates the process being used in this study to scale up from leaf-based transpiration to stand-based transpiration.

Table 4-1. Structural characteristics measured on *Arundo* canes collected from 14 sites in southern California study area.

Plot	Cane height (m)	Cane diam (mm)	Leader Length (cm)	Leader # leaves	Ave leader single leaf area (cm^2)	# secondary branches	Ave branch length (cm)	Ave branch # leaves	Ave branch leaf area	New cane # leaves	Ave new cane single leaf area
CC1	5.1	20	19	10	-	15	47.7	-	-	21	168.7
CC2 #1	9.71	28	90	23	83.7	57	11.7	4.5	10.5	-	-
CC2 #2	8.45	27	82	23	117.3	9	70.9	13.0	63.2	-	-
SA1	6.11	25	45	17	-	34	21.4	-	-	-	-
SA2	6.06	25	32	15	58.5	31	36.2	23.0	44.4	-	-
SA3	7.74	27	74	28	-	33	10.7	-	-	-	-
SA4	7.42	26	33	12	-	48	20.0	13.5	29.5	-	-
SC1	9.9	25	23	12	-	31	46.0	11.0	34.8	-	-
SC4	4.16	22	0	0	-	34	41.3	14.0	19.2	-	-
V1	8.41	26	0	0	-	28	43.4	-	-	21	216.2
V2	6.21	24	76	20	-	14	41.8	-	-	-	-
SD#1a	8.08	26	65	16	-	29	56.1	10.9	34.9	-	-
SD#1b	8.1	24	66	13	-	25	60.0	-	-	-	-
SC2	4.33	22	11	7	-	11	37.0	-	-	-	-
SC3	4.22	18	19	7	-	7	37.1	-	-	27	227.9
SC5 Lg	3.77	25	13	8	-	10	26.2	-	-	-	-
SC5 Sm	2.61	15	12	7	-	5	22.8	-	-	-	-

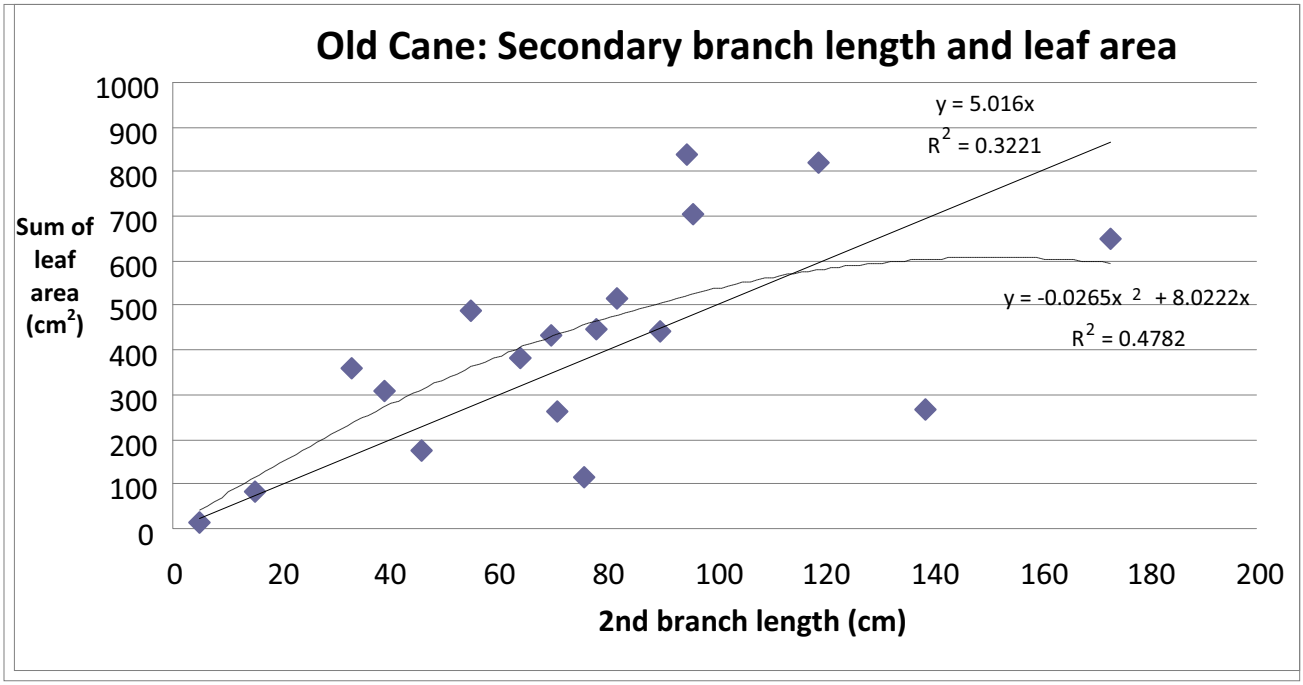


Figure 4-1. Secondary branch leaf area to length relationship.

Table 4-2. *Arundo* cane densities and leaf area indices (LAI) for 13 of the 14 study sites.
The contribution of leader canes, secondary branches, and new canes toward the total LAI for the site is shown. Cane densities were not measured on the San Diego site, thus LAI could not be computed.

Plot	Hydrology	Leaf area (m^2) per cane				Cane density/m^2		Leaf area/m^2 ground (LAI)				
		Leader: old cane	2ndry branch	Total old cane	New cane (<1yr)	Old cane	New cane (<1yr)	Leader old cane	2ndry branch	New cane	Total: old+new	Stand adjusted (70%)
CC-1	Wet	0.05	0.41	0.46	0.47	53	4	2.7	21.6	1.9	26.2	18.3
CC-2	Wet	0.23	0.37	0.6	0.47	29	4	6.7	10.8	1.9	19.4	13.6
SA-1	Wet	0.12	0.41	0.53	0.47	66	2	7.9	27.4	0.9	36.2	25.4
SA-2	Wet	0.09	0.64	0.73	0.47	30	2	2.6	19.2	0.9	22.7	15.9
SA-3	Wet	0.20	0.20	0.4	0.47	84	11	16.6	16.9	5.2	38.8	27.1
SA-4	Wet	0.09	0.55	0.64	0.47	19	4	1.7	10.4	1.9	14.0	9.8
SC-1	Wet	0.06	0.81	0.87	0.47	25	2	1.5	20.3	0.9	22.8	15.9
SC-4	Wet	0.00	0.80	0.8	0.47	36	4	0.0	28.8	1.9	30.7	21.5
V-1	Wet	0.00	0.69	0.69	0.47	28	5	0.0	19.4	2.4	21.8	15.2
V-2	Wet	0.20	0.33	0.53	0.47	30	5	6.1	10.0	2.4	18.5	12.9
SD1	Wet	0.18	0.89	1.07	0	44	0	7.7	39.2	0.0	46.9	32.8
SC-2	Dry	0.03	0.23	0.26	0.47	24	2	0.7	5.6	0.9	7.2	5.1
SC-3	Dry	0.05	0.15	0.2	0	40	0	2.0	5.9	0.0	8.0	5.6
SC-5	Dry	0.03	0.09	0.12	0.47	26	2	0.7	2.4	0.9	4.0	2.8
	Mean:	**0.09**	**0.47**	**0.56**	**0.41**	**38.1**	**3.4**	**4.1**	**17.0**	**1.6**	**22.6**	**15.8**
	StdDev:	**0.08**	**0.26**	**0.27**	**0.17**	**18.3**	**2.7**	**4.6**	**10.3**	**1.3**	**12.4**	**8.7**

Table 4-3. Summary of *Arundo* transpiration (E) and evapotranspiration (ET) reported in literature or calculated as described in the text.

Study	Location	Stand biomass (t/ha)	Average single leaf area (cm^2)	Average # leaves per cane	Leaf area per cane (m2)	Average # canes per m^2	LAI (m^2 leaf/m^2 ground)	Peak (mid-day) E_l (mmol/m^2/s)	E_{stand} (mm/day)
Direct Measurements of transpiration (E)									
Abichandani 2007	Santa Clara River, CA		163.3 (132.5-215.9)[l]	25.0 (21.5-28.4-27.9)	Newer (1 to 3 yr): 0.4082	Ave 34.9 (riverbed 29.2, n= 43; terrace 40.6, n=26)	14.25	4.03 (1.89-5.80)[a]	41.1 (36.4)[a]
Watts 2009	Rio Grande River, TX						4.1 (3.4-6.1) and 4.5	4.3 (1.6-8.4)[b]	9.1 (11.0)[b]
Zimmerman (unpublished)	Napa River, CA							6.3 (2.5-11) Summer only	
Indirect calculation of stand-level transpiration									
Cal-IPC (this study)	Southern California	155	1st yr: 206.3 > 1 yr: leader 86.5, 2ndry branch 33.9	1st yr: 23 (SD3.5) >1 yr old: leader 12.6 (SD8.3) + 2ndry branch lvs 271.6 (SD 174.9) = 284.2	1st yr: 0.474 >1yr: 0.556 (leader 0.100, 2ndry branch: 0.457)	41.5 (SD 19.7)	15.8	Used 4.03 in calcs	40.0
Iverson 1998	Based on rice								4.7[d]
Hendrickson & McGaugh 2005	Cuatro Cienegas, Mexico								17.3[d]
Other structural data									
Spencer 2006	16 sites across US (leaf area is north CA)	171	1st year: 520.7	1st yr:10.3(SD 6.1) >1 yr old: 100.6	1st yr: 0.5362 > 1yr old: 0.1162	74.5	11.22	Used 4.03	28.3[c]
Sharma et al. 1998	India	36-167				53 to 82	12.6 to 28.7		
Direct Measurements of Evapotranspiration									
FAIR 2000-EU study	Europe								3.22
Christou et al. 2003	Greece & Italy	21.1							1.6 (ET)

[a] Average across season, and wet and dry sites; [b] E_{stand} as calculated using formulas applied to this study; [c] E_{stand} calculated using formulas from this study using LAI from the that paper; [d] E_{stand} reported in paper, but insufficient additional data to use formulas in this study.

4.1.3 Results and Discussion

Examination of calculated water loss values for *Arundo* (both reported and results from this study) reveals a substantial amount of variation in E_{stand} (Table 4-3). While some of this variation may be an artifact of differences in scaling procedures and conversion factors, variation should be expected. Both *Arundo* transpiration (E) and evapotranspiration (ET) are affected by prevailing ambient conditions (temperature, humidity, wind, and available soil water) as well as characteristics of the vegetation. For example, both Abichandani (2007) and Watts (2009) found higher leaf-based transpiration (E_l) rates for *Arundo* in areas with higher available soil moisture. Zimmerman's unpublished *Arundo* transpiration data showed E_l also increases with temperature, while Abichandani and Watts found higher E_l rates in summer and spring when temperatures are higher. Thus, variation should be expected among regions where such conditions are likely to vary both within a season and on average across a year. Nonetheless, the average E_l rates (accounting for seasonal and hydrological variation) reported by Abichandani and Watts are quite similar despite the different study regions (Table 4-3). Zimmerman's average E_l is higher, but those measurements were only taken during the summer while the others studies included cooler seasons.

Given the similarities in E_l, variation in E_{stand} across studies must be primarily driven by factors other than leaf-scale transpiration rates. Watts (2009) showed much lower E_{stand} than either Abichandani (2007) or this study, and it should be noted that Watts' estimate includes refinements that would lead to a lower average. Specifically, prior to scaling-up transpiration rates, Watts divided the *Arundo* canopy into vertical layers and adjusted E_l rates downward for shaded leaves. In addition, Watts accounted for diurnal fluctuations in E_l in his scaling operations. It is unclear whether Abichandani's tabled E_{stand} values include such refinements, but this study's calculations are based on average peak E_l rates for sunlit leaves without any adjustment downward for shading or diurnal drops in leaf transpiration. As a result, the E_{stand} estimate for this study is probably more representative of an average maximum water loss, rather than an overall average. Yet, these adjustments are still unlikely to be the primary cause of the large differences seen in E_{stand} among studies. It is reported LAI that appears to be driving different stand based transpiration estimates. The average LAI reported by Watts (4.1) is much lower than that reported by Abichandani (14.25), which is slightly lower than results found on this study's sites (15.8) (Table 4-3). Consequently, differences in *Arundo* stand structure are likely the primary factor driving variations in E_{stand} across all studies reviewed.

Structural differences probably explain the lower estimate of E_{stand} reported by Hendrickson & McGaugh (2005) despite their likely use of a higher E_l rate than used in this study (i.e., Zimmerman's summer measures). However, it is not clear exactly what E_l rate they used or exactly how their scaling-up from leaf to stand was performed, though some adjustments for lower daily and seasonal E_l rates were incorporated. Variation in *Arundo* stand structure could also partly explain the lower daily ET rate derived by Christou et al. (2003) in the Mediterranean (Table 4-3). For example, the studies by both Abichandani (2007) and Christou et al. were performed on relatively young, artificially created *Arundo* stands, which may have shorter canes or less leaf area overall than naturally-occurring, mature stands. In Abichandani, the stand was 3-4 years old. Average cane densities were similar to those found in this study (Table 4-3), but the average area of a single leaf was larger and more comparable to leaves on new canes from this study (Table 4-1, average = 206.3cm^2). In addition, the average number of leaves per cane reported by Abichandani (Table 4-3) is comparable to the average number of leaves counted on just the leader portion of a cane plus only one secondary branch in this study (Table 4-1). Thus, it seems likely Abichandani's planted stand had bigger but far fewer leaves overall, as reflected in the lower LAI compared to this study. This may also be true of the Mediterranean stands reported in Christou et al., which were 1-3 years old during the study. Christou et al. did not report any leaf area data, but their reported average *Arundo* biomass (21.1 tons/ha) is roughly 7 times lower than the average biomass

estimate generated for this study's stands (156.8 tons/ha). Given such large differences in stand structure among the study regions, it is likely that even a more refined measurement for this region would still be much higher than those in the other regions reviewed.

However, the large disparity between the daily ET rate derived from Christou et al. and the E_{stand} rates reviewed here becomes more pronounced when one considers that water lost via transpiration and evaporation combined should be higher, even if only slightly, than transpiration alone. It is unlikely that structural differences, differences in regional climate, and errors in converting data from one unit convention to another can fully explain the large differences seen here in E_{stand} versus ET. Instead, the comparison demonstrates the difficulty of generating realistic estimates of water loss from *Arundo* stands. Utilizing locally measured rates of leaf transpiration and stand structure is a good start, but complex scaling procedures will likely yield better estimates of stand-scale transpiration losses. Ultimately, though, actual locally measured ET may be more reliable, though perhaps more costly. Future studies need to focus on determining ET of mature *Arundo* stands that are comparable to *Arundo* stands in the field that have high leaf area and high biomass per unit area.

4.2 *Arundo* Water Use Across Study Area

This study found an average leaf area (LAI) for *Arundo* stands of 15.8 m^2/m^2. This value was within the range of LAI values reported by other studies (4.1 - 28.7; Table 4-3). The study area LAI value was then used with published leaf transpiration values to generate a stand-based transpiration value of 40 mm/day (Table 4-3). There are only two published studies for *Arundo* stand based transpiration. One study found a similar stand transpiration value of 41.1mm/day (Abichandani 2007). It was conducted on the Santa Clara Watershed which is one of the watersheds within this studies project area. Stand structure, density and leaf area were all comparable to data collected for this study. The other published paper found a much lower stand based transpiration value of 9.1 mm/day (Watts 2009). This study was on the Rio Grande River in Texas. Stands there were shorter and had significantly lower leaf area (Table 4-3).

The current study and the two other published studies would be classified as 'leaf area transpiration measurements scaled up using LAI'. Additional studies looking into stand based water use are definitely needed and would preferably utilize a range of methods used to measure stand based transpiration/water use. Other methods include: lysimeters (tank with soil and plants with controlled water supply), base flow separation studies (stream inflow and outflow studies), analysis of diel groundwater fluctuations, semiemperiacal models, micrometeorological approaches (Brown Ration Energy Balance) and eddy covariance (as outlined in Shafroth 2005).

Using the stand-based transpiration values from this study to calculate water use per acre generates water use estimates that are very high (Table 4-4). Water consumption per acre of *Arundo* is 48 ac ft/yr, and this is far above published values for most vegetation (Johns 1989). Even with the high LAI values measured in this and other studies, an average annual stand-based transpiration is likely to be closer to 20 mm/day, which equals 24 ac ft/yr/ac of water use. The value of 20 mm/day is still at the high end of values published for other 'water hungry' vegetation types such as *Phragmites* (Moro et al. 2004), which is similar in structure and habit to *Arundo*, albeit smaller (less biomass and lower LAI values reported).

Water loss via ET in an *Arundo* stand would not equal the water gained or 'saved' through *Arundo* control. Removal of *Arundo* from riparian systems would likely increase water lost to evaporation, runoff, and any water use of re-colonizing vegetation (see Watts 2009 and/or Shafroth 2005 for additional discussion and references).

A replacement vegetation water use value of 3.3 mm/day or 4 ac-ft/yr/ac was used in our analysis (Table 4-4). This was based on a 'typical' vegetation mix that replaces *Arundo*, which is composed of: 25% trees, 25% shrubs, 25% herbs, and 25% open/un-vegetated. Water use was estimated based on data collected in a major water use review paper that compiled data from hundreds of studies using a wide range of water use measuring methods (Johns 1989). This data, along with a review by Shafroth et al. (2005), were used to approximate replacement vegetation water use. Compared to the estimates shown here for *Arundo,* the lower and more restricted range of replacement vegetation water use estimates suggests that most types of replacement vegetation will potentially use significantly less water.

As within *Arundo* stands, water loss under alternative states is probably best determined through direct measurement or complex models, and very few reports of such exist for riparian vegetation within the study area. Reported estimates of ET or E_{stand} for native riparian vegetation in other areas may be a good starting point for comparison, but many of these studies were conducted in the more arid southwestern portion of the U.S. where water availability may be significantly less than the coastal watersheds of southern California (especially considering the artificial water augmentation from urban and agricultural runoff that has transformed most systems into perennially flowing rivers and streams).

Willow water use from eight studies ranged from 0.9 to 3.3 mm/day (Johns 1989). Mixed riparian vegetation water use from three studies ranged from 0.9 to 1.6 mm/day (Johns 1989). Cottonwood water use from three studies ranged from 2.8 to 6.5 mm/day (Johns 1989). *Typha* (cattail) water use from six studies ranged from 2.4 to 13.8 mm/day (Johns 1989). Mulefat water use from two studies ranged from 2.2 to 3.9 mm/day (Johns 1989). Other riparian/wetland studies looking at other non-native plants found widely ranging water use. E_{stand} based on eddy-covariance from a site dominated by *Tamarix ramosissima* (salt cedar) reached up to 7 mm/day (Cleverly et al. 2002). In a similar study, E_{stand} from sites dominated by mixtures of native and invasive woody species reached peak values of approximately 9 mm/day (Dahm et al. 2002). E_{stand} in a pond lined by *Phragmites australis* in Nebraska was estimated at 4 mm/day in a stand that had a maximum LAI of 2.6 (Burba et al. 1999). E_{stand} in *P. australi*s in Germany was estimated at 10 to 16 mm/day in stands with summertime LAI of about 5 (Herbst and Kappen 1999). *P. australis* in semi-arid Spain has been shown to have average midsummer E_{stand} values of about 23 mm/day in a stand with LAI values of 8.9 (Moro et al. 2004).

The final estimated net water savings from removing an acre of *Arundo* was 16.7 mm/day or 20 ac ft/yr/ac (Table 4-4). This represents a very large potential water savings, even if it represents a peak or maximum savings yield. If future studies are able to corroborate water savings of similar magnitude, *Arundo* control could represent an important water conservation action that will benefit multiple uses including habitat, urban and agricultural water use.

Arundo Impacts: Transpiration and Water use

- Due to high leaf area of mature stands, stand-based transpiration is very high (E_{stand} 40 mm/day). There are two other studies evaluating stand-based *Arundo* transpiration. One study on the Santa Clara watershed (within this project's study area) is in agreement (41.1 mm/day). The other study on the Rio Grande River is lower (9.1 mm/day). (Section 4.1).
- Stand-based transpiration rates of *Arundo*, when used to calculate total water over larger areas, indicate very high levels of water use: 48 ac-ft/ac per year. (Section 4.2)
- Net water savings for areas after *Arundo* removal are high (16.7 ac-ft/yr), even when *Arundo* water use is lowered to 20 mm or 24 ac-ft/ac per year to reflect levels that may be closer to physiological water transpiration limits. (Section 4.2)
- New studies using different approaches to measure stand-based water use of *Arundo* are needed to corroborate and refine stand-based water use found in this and other studies. New studies

need to be on mature stands of *Arundo*. Stands under treatment or in post-fire or flood recovery should be excluded, as these are not representative of the majority of *Arundo* stands within the study area. (Section 4.2)

Water use by *Arundo* appears to be a significant impact on invaded systems. Water use by vegetation is difficult to measure. Additional baseline and comparative studies are needed.

Table 4-4. Estimated water use by *Arundo*, replacement vegetation and net water savings from *Arundo* control.

Hydrologic Unit	Net *Arundo* Acreage	ESTIMATED WATER USE (Ac-ft/yr/ac)			
		***Arundo*: This study** (using 40mm)	***Arundo*: likely maximum** (using 20mm)	**Native vegetation** (using 3.3mm)	**Net gain from *Arundo* control** (using 16.7mm)
One acre of Arundo	*1*	*48*	*24*	*4*	*20*
Calleguas	229	10,983	5,487	905	4,582
Carlsbad	148	7,088	3,542	584	2,957
Los Angeles River	131	6,297	3,146	519	2,627
Otay	19	891	445	73	372
Penasquitos	24	1,129	564	93	471
Pueblo San Diego	15	719	359	59	300
Salinas	1,332	63,828	31,890	5,262	26,628
San Diego	149	7,164	3,579	591	2,989
San Dieguito	175	8,387	4,190	691	3,499
San Gabriel	44	2,124	1,061	175	886
San Juan	173	8,312	4,153	685	3,468
San Luis Rey	684	32,778	16,377	2,702	13,674
Santa Ana	2,534	121,442	60,675	10,011	50,664
Santa Clara	1,019	48,829	24,396	4,025	20,371
Santa Margarita	689	33,018	16,497	2,722	13,775
Santa Monica Bay	18	886	443	73	370
Southcoast	30	1,429	714	118	596
Sweetwater	42	2,002	1,000	165	835
Tijuana	131	6,261	3,128	516	2,612
Ventura	250	11,977	5,984	987	4,997
Other watersheds	28	1,359	679	112	567
TOTAL:	**7,864**	**376,948**	**188,333**	**31,075**	**157,258**

5.0 IMPACTS OF *ARUNDO*: Hydrology, Geomorphology and Flooding

5.1 Hydraulics, Sediment Transport, Geomorphology

5.1.1. Introduction

Arundo is a highly aggressive, non-native plant species that has invaded riparian areas and floodplains, displacing native plants, degrading habitats, and altering channel characteristics. The biology and ecology of *Arundo* have been fairly well studied and reported, but comparatively few studies have examined the effects of *Arundo* on river form and process. The changes in river geomorphology, flood risk, and sediment erosion, storage, and delivery that follow *Arundo* invasion are not well understood.

The overall goal of this study is to describe the potential effects of *Arundo* invasion on river processes in selected of Southern California watersheds. The specific objectives are to:

- Develop an understanding of the typical response of river forms and processes to invasion by *Arundo*, or other non-native plants (tamarisk), from review of published literature and reports
- Summarize the geomorphic environments and extent of *Arundo* infestation for three of the Southern California study streams – the Santa Margarita, San Luis Rey, and Santa Ana Rivers – from GIS
- Prepare a case study of the effects of the *Arundo* invasion on the hydraulic characteristics, geomorphology, sediment budgets and sediment transport capacity of the Santa Margarita River
- Based on the GIS analyses and the case study results, develop a simplified scoring system to evaluate the potential response of the San Luis Rey and Santa Ana Rivers to their *Arundo* infestations.

This section relies on existing information from previous reports and studies, as well as information collected for this study. This information included review of the existing literature on the effects of *Arundo* on geomorphology. Data generated for this study included: GIS databases and maps of river environments and *Arundo* distributions (mapped for this project: Section 3), a HEC-RAS model of the Santa Margarita River initially developed by NHC (1997a), and other reports on the Santa Margarita River. The documents reviewed for this study are listed in the References Section.

Work completed specifically for this project included: additional HEC-RAS runs for different vegetation scenarios and analysis of RAS model output to assess hydraulic and sediment transport capacity characteristics. The Santa Margarita River was inspected on October 1st, 2010. Study methods and their limitations are described further in the text.

To the extent practical, the analyses and results for this study were prepared in a GIS environment. We relied on GIS support from other team members for the analysis and mapping of *Arundo* and fluvial landforms on the three Southern California Rivers included in this study. Further details on their methods and procedures are described in Sections 3 and 5.2.

Section 5.1.2 summarizes the effects of *Arundo* infestation on river form and process from a review of published and unpublished literature and develops a general understanding of riverine response to infestation. Section 5.1.3 summarizes the riverine and riparian or floodplain vegetation characteristics of three of the Southern California study streams. Section 5.1.4 provides a case study of the Santa Margarita River, briefly describing its watershed and historical geomorphology before analyzing the

potential effects of *Arundo* infestation on hydraulic conditions, sediment transport capacity and long-term sediment budgets. The relationship between changes in hydraulics and sediment transport and river form and process are summarized at the end of this chapter.

Section 5.1.5 then combines the geomorphic analyses of the three rivers studied herein with the trends and observations on hydraulics and sediment transport along the Santa Margarita River to predict likely impacts of *Arundo* on the San Luis Rey and Santa Ana Rivers. Section 5.1.6 provides conclusions and recommendations.

Elevations are reported in feet and refer to the North American Vertical Datum of 1988 (NAVD 88). Elevations originally reported in the National Geodetic Vertical Datum of 1929 (NGVD 29) were approximately converted to NAVD 88 by adding 2.74 feet, a value obtained for the Santa Margarita study area using the datum and coordinate system conversion software program Corpscon (USACE 2004). All GIS data for this project are in the UTM Zone 11N NAD 83 (m) coordinate system.

The Marine Corps Base, Camp Pendleton and U.S. Naval Facilities Engineering Command are gratefully acknowledged for their support of this study which included the use of hydraulic and sediment transport models previously developed by NHC. In addition, Base Command and the Navy granted access to Camp Pendleton and permitted discussions with base personnel involved with *Arundo* control and management on the Santa Margarita River.

5.1.2 Arundo and River Morphology

This chapter briefly summarizes the establishment, spread, and distribution of *Arundo* in the river environment and the observed effects of the spread of *Arundo* on the morphology and characteristics of rivers and streams from existing literature. The riverine response to *Arundo* infestation focuses on large, low-gradient, braided rivers in the American Southwest that are similar to selected coastal rivers being studied in Southern California.

The general purpose of this chapter is to develop a qualitative understanding of river morphology evolution under *Arundo* infestation and identify gaps in our understanding. This conceptual model will be used to help extend and interpret specific hydraulic and sediment studies on the Santa Margarita River, which are discussed in Section 5.1.4.

5.1.2.1 *Arundo* in the River Environment

General Characteristics

Arundo donax (Giant Reed) is a member of the grass family (Poaceae) and is native to tropical and subtropical areas of Asia and Europe. *Arundo* was introduced to America in the 1800s for use as construction material and for erosion control along streams and ditches. Tamarisk (*Tamarix* spp.), or salt cedar, is another invasive, non-native species with a similar distribution to *Arundo*. The two species are often found together and studies of *Arundo* in the river environment often also include this species. Tamarisk includes several shrub and tree species native to drier areas of Eurasia and Africa that were introduced to North America in the 1800s as an ornamental shrub, windbreak, and for shade.

Arundo tends to be found on bare, moist substrate where water is plentiful, including the bed, banks, unvegetated bars and islands, and the floodplain of rivers (Else 1996; Stillwater Sciences 2007). *Arundo* requires significantly more water than native plants to support its very fast growth rate (Iverson 1994, Watts 2009, Abichandani 2007). Once established, *Arundo* plants grow very quickly, as much as 10 cm per day in its early growth stages (Quinn and Holt 2004), and mature stands reach heights of 6 m to 10

m (Rieger and Kreager 1998, Lawson et al. 2005, this study-Chapter 2). *Arundo* stands spread laterally via rhizomes (Rieger and Kreager 1998), often resulting in extremely dense, monotypic stands. Growth rates are so high that it often out-competes other species, particularly when colonizing sites that have been disturbed by erosion or wildfire.

Tamarisk grows in similar environments to *Arundo* and appears as shrubby trees growing as high as 35 ft tall along rivers in the American Southwest (Graf 1978). Tamarisk spreads by both adventitious roots and by seeds that are dispersed by wind or flowing water. Tamarisk is salt tolerant and survives in dry conditions by growing roots that extend up to 100 feet deep, as they follow a slowly receding ground water table (Graf 1982).

Dispersal & Establishment

Arundo relies on downstream dispersal of stem or rhizome fragments for vegetative propagation, which primarily occurs during seasonal floods. *Arundo* seeds are thought to be infertile (Khudamrongsawat and Holt 2004, Bhanwra et al. 1982). Thus, new *Arundo* stands are limited to the lateral extent of river flows and floodplain inundation. *Arundo* can be widely dispersed into disturbed soils when large floods occur, such as those in Southern California in 1969 (Ambrose and Rundel 2007).

The dynamics of *Arundo* establishment in the river environment have been examined on the Santa Margarita and Santa Clara Rivers in Southern California. Else (1996) examined *Arundo* establishment after a large flood on the Santa Margarita River. She found the density of establishment was greatest on depositional bars, followed by channel banks, and floodplain areas nearest to the river. Establishment was least common on the channel bed. *Arundo* dispersal was directly correlated with flood magnitude and it was most widely distributed in broad, unconfined reaches of the Santa Margarita River with low stream gradients. Steeper confined reaches showed less *Arundo* establishment, presumably as a result of greater flow velocities that provided fewer areas for *Arundo* propagules to deposit and grow.

Rates of Spread

Over a period of decades, *Arundo* stands can laterally propagate throughout the floodplain from points where it was deposited during flood events. Large floods can cause much more extensive lateral spreading of *Arundo* in a single season but these events are infrequent. Based on mapping of *Arundo* extents on the Santa Margarita, Santa Ana, and San Luis Rey Rivers by Cal-IPC (2010b), the maximum coverage of the floodplain by mature *Arundo* along a river reach may be from 40% to 55% of the total area occupied by the floodplain and active channel.

Erosion of *Arundo* Stands by Floods

During floods, large rafts of *Arundo* are observed to float downriver and deposit on the inundated floodplain. It is also common for tidal currents and wave action to cover beaches with *Arundo* that was transported downstream during a large flood (Else 1996; Cal-IPC 2010a). While *Arundo* stands are eroded during large, infrequent floods, it is not known what velocities or shear stresses can be resisted by the *Arundo* stands. It appears floods remove the plants and roots, and in some situations only the above-ground vegetation is mobilized.

5.1.2.2 Observed Effects on Rivers

Introduction and Context

Arundo (and to some extent, Tamarisk) is typically found in rivers and streams in Southern California to elevations of 1,000 feet. This elevation range, and geographic area, includes a broad range of river types and environments. However, the focus of this study is on large, low-gradient coastal rivers where *Arundo* was found to be most abundant (Chapter 3). As described in the next section, the riparian systems of the Southern California coastal study streams are dominated by *Arundo*, which often occupies most of the surrounding low floodplain (Jackson et al 1994). Effects may be very different in other river types and environments where the dispersal and establishment of *Arundo* is limited by channel or flood characteristics.

Most of our understanding of the effects of *Arundo* on river morphology is based on historical case studies, generally from analysis of maps or air photographs. These studies have two weaknesses. One is that the study period is relatively short, generally less than 70 years, so the role of large floods in eroding existing stands or distributing propagules is not well understood.

The second complicating factor is that the study period also includes human impacts on watersheds and flows that may reinforce the observed riverine response to *Arundo*. The effect of *Arundo* on river morphology in these human-modified streams would be correctly interpreted as the difference between the channel evolution that would have occurred without *Arundo* and that which occurred with *Arundo* present. We found no studies that had adequate control or had completed sufficient analyses to resolve this issue.

Long-term Historical Studies

The effects of *Arundo* and Tamarisk infestation on long-term geomorphic change have been studied on several large rivers in the American southwest, including the Rio Grande in Texas (Dean and Schmidt 2010), the Green River in Utah (Graf 1978; Allred and Schmidt 1999; Birken and Cooper 2006) and the Rio Puerco in Arizona (Friedman et al. 2005). These studies relied on interpretation of historical aerial and ground photographs to assess and measure changes in the river planform. Information on channel profiles, invert elevations and cross-section areas was often not available.

General Observations

Historically, rivers in the arid southwest were often dry during the summer and fall and they typically exhibited a wide, shallow, laterally unstable channel, with multiple flow paths around large, unvegetated sand and gravel bars. Studies on these rivers reported similar trends following *Arundo* and Tamarisk infestation, with the planform showing long-term channel narrowing coupled with a simplified channel form and increased lateral channel stability.

The braided channels transformed into a narrower, more laterally stable single thread channel with root-stabilized, steep banks supporting both native and non-native vegetation. Few unvegetated bars remained and secondary channels were eventually filled in with sediment, covered by vegetation, and attached to the adjacent floodplain. In some cases, bed scour and channel deepening occurred due to confinement of flows.

Channel narrowing primarily occurred through the development of floodplains from vertical accretion of bar surfaces along the river bank. Plant colonization, by *Arundo* and Tamarisk, stabilized the bar

surface and increased floodplain and bar roughness and sediment trapping efficiency, creating a mechanism for further sediment capture, deposition and vertical accretion.

Trends in Width and Planform

Allred and Schmidt (1999) noted a long-term trend to narrowing and bed aggradation on the Green River, based on comparing re-surveys of cross-sections. Similarly, Friedman et al (2005) found long-term channel narrowing and bed aggradation along the Rio Puerco, which led to a 27% decline in cross-section area at their study site. In contrast, Pollen-Bankhead et al. (2009) reported channel narrowing and incision following non-native plant infestation in Canyon de Chelly, Arizona. At this site, channel incision may have resulted from flow confinement and erosion-resistant banks, the latter resulting from root reinforcement and vertical accretion of fine-grained, cohesive bank sediments.

The relationship of the channel width and area following *Arundo* infestation has not been related to the local flood regime and to typical dominant discharges and it is not clearly understood how the rivers have adjusted to narrowing, increased bank strength, and dense vegetation on the floodplain. It has been noted on the Green River, Rio Grande and Rio Puerco, that channel narrowing and floodplain accretion after infestation have resulted in a more frequent overbank flooding than occurred historically, suggesting that channel dimensions have not adjusted to the local flood regime. Further adjustments, likely to channel depth, might be expected.

On the Rio Grande, Dean and Schmidt (2010) reported that large floods acted as a negative feedback mechanism or 'reset' event, restoring the channel condition to a previous wider and more laterally unstable state but that channel narrowing resumed immediately thereafter. Since the last large flood in 1991, they found as much as 90% of unvegetated sand and gravel bars in the active channel bed had become part of the vegetated floodplain (which is dominated by *Arundo*). No such effect was observed following large floods in Tamarisk infested sections of the Green River (Birken and Cooper 2006). Whether this is a result of the differing resistance to erosion of the two species or to the differing hydraulic forces exerted on the floodplain vegetation is not known. It is also not known if floodplain and bed elevations are "re-set" by these large floods.

The above indicates that large floods do not always 'reset' channel and floodplain characteristics in river reaches altered by non-native plant infestation. Little is known of the hydraulic forces that can be resisted by these invasive plants so it is not possible to predict a particular flood frequency or magnitude that will lead to their erosion and partial removal. However, the Dean and Schmidt (2010) study suggests that the time to return to the channel form observed under *Arundo* infestation is much less than the typical period between large floods that disturb the channel and floodplain.

Vertical Adjustments of the Bed and Floodplain

Dean and Schmidt (2010) measured sediment accretion on the floodplain of the Rio Grande that occurred during a rapid invasion of *Arundo* and Tamarisk. Average rates of vertical floodplain accretion of 0.6 ft/yr to 0.77 ft/yr were estimated using anatomical changes to tree rings caused by burial. The accretion occurred over a 15 year period following a large flood 'reset' event. Friedman et al. (2005) measured rates of channel filling in response to hydrologic changes and Tamarisk infestation on the Rio Puerco, New Mexico. Channel filling occurred in two phases, a period of channel narrowing with little change in thalweg elevation followed by vertical accretion of the floodplain and channel bed at an average rate of 0.26 ft/yr from 1962 to 2000.

Lateral Migration and Bank Erosion

Gran and Paola (2001) conducted flume experiments that documented how vegetation affects channel form and process in braided stream environments. In general, they observed channel responses that were similar to those following *Arundo* and Tamarisk infestations discussed above. They found that vegetation reduced the number of channel braids because smaller channels were choked with sediment and could not reestablish themselves. Gran and Paola (2001) noted a direct relationship between channel stability and the density and extent of vegetation. Vegetation also created less variability in flow velocity through the channel cross-section and resulted in increased bank strength (associated with dense root mats that are characteristic of these species) and decreased bank shear stress due to added roughness effects. Consequently, lateral migration rates declined. Increased bank strength also increased channel relief through the formation of higher and steeper banks and promoted channel scour, increasing maximum channel depths.

Additional studies examining the effects of invasive plant colonization on bank stability were conducted by Pollen-Bankhead et al (2009) and Brinke (2010). Pollen-Bankhead et al (2009) documented the effects of invasive plants on bank stability and bank retreat rates in Canyon de Chelly National Monument, Arizona. They found that tamarisk and Russian Olive, another invasive plant species, significantly increased bank stability through root reinforcement of the sand banks in the study area. Bank retreat rates doubled from an approximate rate of 2.5 ft/yr to 5 ft/yr following vegetation removal.

Brinke (2010) measured the root density and tensile strength of *Arundo* on stream banks of the Santa Clara River, California. When compared with Red Willow, a common native species, *Arundo* had a denser root mass and provided 40% greater tensile strength in the upper 10 cm of the bank. The converse was true below 10 cm depth, where Red Willow showed higher root density and greater tensile strength. Brinke (2010) concluded that *Arundo* contributed to less bank cohesion on stream banks exceeding one vertical foot and speculated that undercutting and cantilever failure were a primary bank erosion mechanism for *Arundo*-topped stream banks.

5.1.2.3 Observed Effects on Hydraulics and Sediment Transport

We found very few studies that compared hydraulic and sediment transport characteristics of large, low-gradient rivers; either prior to or following *Arundo* infestation. NHC (1997a,b; 2001) did complete geomorphic, hydraulic, and sediment transport studies of the lower Santa Margarita River in support of bridge and levee improvement projects at the Marine Corps Base Camp Pendleton (MCBCP). Section 5.1.4 discusses these studies in detail.

Although they do not specifically address the effects of *Arundo* on hydraulic capacity, numerous HEC-RAS models that include estimates for the hydraulic roughness effects of non-native vegetation have been used to support flood control and river management applications (USACE 2009). Few studies have reliable flow and water level data available to accurately calibrate hydraulic models for the effects of *Arundo*. However, where adequate calibration data are available, analysis of the specific effects of *Arundo* infestation scenarios may be possible with these existing HEC-RAS models.

Spencer (2010) investigated the hydraulic effects of *Arundo* on Manning's *n*, flow velocity and flow direction at study sites on Cache Creek and Stony Creek, California. Flow velocity measurements were collected around five *Arundo* plants growing in Cache Creek and a set of artificial *Arundo* stalks placed in the river bed on Stony Creek. Measured Manning's *n* roughness coefficients were found to vary between 0.019 and 0.121 with an average roughness of 0.066. Channel roughness was higher when *Arundo* was present, resulting in higher water surface elevations for the 2-year and 100-year flood

events when modeled using HEC-RAS, a software program that simulates one-dimensional, open channel flow (USACE 2010).

Response to *Arundo* Removal or Eradication

Despite a number of programs to eradicate *Arundo* on rivers throughout California, we did not find any reports in the literature that documented the geomorphic, hydraulic or sediment transport effects of widespread *Arundo* removal. In particular, the period between *Arundo* eradication and re-establishment of native vegetation presents significant opportunity for local and downstream channel adjustment and changes in sediment transport processes, particularly if large floods occur during this period.

5.1.2.4 Summary of Understanding

Since its introduction in the late 1800s, *Arundo* (and to some extent, Tamarisk) has flourished on rivers and streams in Southern California to elevations of about 1,000 feet. This elevation range, and geographic area, includes a broad range of river types; however, our focus has been on large, low-gradient, braided rivers similar to the Southern California study rivers. It is in this river type that *Arundo* is likely to best disperse and establish most rapidly.

These river types have also been altered by humans. For instance, water development projects that divert flows, reduce flood flows or capture coarse sediment from the upper watershed are expected to narrow channels and convert braided rivers to simpler forms, among other effects, even in the absence of *Arundo*. Channel confinement through levees and construction of bank protection or river training structures may also have similar effects on river morphology. Other factors, such as altered seasonal flow patterns, changes to groundwater elevations, or more frequent and greater low flows, may also affect riparian vegetation, *Arundo* establishment, and channel form. The effects of some these changes may be confounded with those that directly result from *Arundo* establishment and growth.

Based on the existing literature, the response of this river type to *Arundo* infestation consists of a simplification of channel form, increased lateral stability, floodplain accretion, and long-term channel narrowing. Bed aggradation and shallower channels have been observed in some studies; channel incision or deepening in others. The long-term expectation would be for a deeper channel following narrowing and confinement of flows. However, this may be obscured by changes in watershed hydrology, the time required to erode sufficient sediment to deepen the main channel, or by rapid floodplain accretion.

Historically, braided and laterally unstable channels prior to infestation transform to narrower, more laterally stable single thread channels with root-stabilized, steep banks following infestation. Plant colonization stabilizes bar and floodplain surfaces, increasing channel roughness and sediment trapping efficiency, thereby creating a mechanism for further sediment capture, deposition and vertical accretion. Observed long-term rates of vertical accretion vary widely in the reported literature and are as high as 0.8 ft/yr. Long term average annual accretion rates likely vary with the magnitude and frequency of flooding, volume of sediment in transport, as well as the specific river conditions.

The local depths of deposits following large floods can be much greater, NHC (1998, 2001) observed several feet of sediment deposition in many locations on the floodplain adjacent to the Santa Margarita River following the 1993 flood that flooded the Marine Corps Air Station (MCAS).

There may be an upper limit on vertical accretion, which would about correspond to the elevations of typical floods. This may be reached fairly soon if the channel bed incises or does not accrete as rapidly

as the floodplain. If the channel bed fills as the floodplain accretes, this limit may not be reached for a long time.

Most research on the effects of *Arundo* and Tamarisk on river systems is limited by the duration of study (about the last 70 years) and the simultaneous occurrence of human-caused changes affecting basin hydrology and sediment load. These changes often produce river responses that are similar to those from *Arundo* infestation and may obscure identification of geomorphic change specifically due to *Arundo*.

5.1.3 Southern California Study Streams

5.1.3.1 Introduction

This chapter summarizes geomorphic and vegetation characteristics of the three Southern California study streams: the Santa Margarita, Santa Ana and San Luis Rey Rivers. These study streams were selected because they contain some of the greatest observed concentrations of *Arundo* found in Southern California coastal rivers (Chapter 4, Cal-IPC 2010b). The geomorphic and vegetation characteristics presented in this chapter form the basis for comparing results from the Santa Margarita River case study (Chapter 4) to other study streams (Section 5.1.5).

5.1.3.2 Study Streams

The Santa Margarita, Santa Ana and San Luis Rey are large, sand bed, Southern California Rivers that cross coastal lowlands before discharging into the Pacific Ocean. Cal-IPC has identified specific sections of the lowland portions of these rivers as areas of interest (AOI). These management sections ranged from 17 to 37 miles in length and either ended at the Pacific Ocean or, in the case of the Santa Ana River, at a reservoir.

The AOIs were divided into broad reaches based on changes in channel planform, the degree of confinement by hillslopes or levees, and the extent of *Arundo* infestation. Geomorphic and riparian vegetation characteristics from the GIS analysis are summarized by reach in Tables 5-1.1, 5-1.2 and 5-1.3. The management sections and stream reaches are shown in Figures 5-1.1, 5-1.2 and 5-1.3; yellow areas in each figure represent the extent of the floodplain mapped in the GIS for each reach.

5.1.3.3 CAL-IPC GIS Analysis

Cal-IPC (2010b) mapped geomorphic and vegetation characteristics of the study streams in a GIS (see Methods in Section 5.2). They divided channel and floodplain into the categories described below from 2009 aerial photos and digital elevation models (DEM) from the U.S. Geological Survey (USGS 2010). No field verification was completed.

Fluvial Landforms

- *Low Flow Channel* – The part of the main channel where water was flowing at the time of the aerial photos.
- *Bar / Channel / Floodplain - unvegetated* – Main channel or floodplain areas with less than 50% vegetation cover, usually consisting of bar surfaces, dry channel beds or recent flood deposits or erosion
- *Floodplain - vegetated* – Areas on the river floodplain with more than 50% vegetation cover.

- *Floodplain / Low Terrace – vegetated* – Areas on either the river floodplain or an adjacent low terrace with more than 50% vegetation cover.
- *Upper Terrace - vegetated* – Areas on higher ground adjacent to the low terraces with more than 50% vegetation cover.

The above mapped landforms were used to calculate river characteristics by reach. Channel width was defined as the area of the low flow channel divided by the reach length. This width may not be representative of the active or main channel width commonly adopted for river studies. This is discussed further throughout the text.

Floodplain area was defined as the sum of the "low water channel", "bar/channel/ floodplain unvegetated", "floodplain – vegetated" and "Floodplain/ low terrace" areas. The average floodplain width was defined as the above area divided by the reach length. A width ratio (expressed as a percentage) was then constructed for each reach by dividing the average channel width by the average floodplain width.

Anthropogenic Features

- *Line Features* – Levee crests, bridge berms, in-stream grade control weirs, and dams
- *Point Features* – bridge crossings, water infiltration ponds, stormwater and treatment pond inflow points

Longitudinal Profile – Longitudinal stream profiles of each study reach were generated from USGS 10 m grid DEM data (USGS 2010).

Arundo Coverage – The spatial extent of *Arundo*, as mapped by Cal-IPC (2010b) from 1996 to 2009. The quoted coverage in Tables 5-1.1 to 5-1.3 represents the maximum observed extent of *Arundo* infestation. *Arundo* coverage has changed on the study streams in recent years because of eradication programs.

5.1.3.4 Study Stream Characteristics

General Morphology

In the late 1990s, the study streams had single thread channels at low flows that were bordered by well-vegetated floodplains; only a few reaches had less than 50% vegetation cover. Except where the rivers were confined by natural topography or levees, the low flow channel width (See definition above) was generally less than 10% of the floodplain width (see Width Ratio; Tables 5-1.1 to 5-1.3); alternatively, the floodplain was at least 10 times as wide as the low flow channel.

The San Luis Rey and Santa Ana Rivers study streams are about twice as steep as the Santa Margarita River, on average. However, the three study streams have a common pattern of steeper slopes in their upstream reaches and shallower slopes near the mouth. Along the study stream, slopes near the mouth are about one-fourth to one-eighth of those in the most upstream reaches.

Floodplain widths averaged 1,100 feet in the Santa Margarita River, 800 feet in the San Luis Rey River and 1,300 feet in the Santa Ana River (removing the very wide Reach 1) and they varied considerably from one study reach to another, as a result of both human and topographic confinement. Width ratios and the portion of the floodplain that was not vegetated were greatest in the Santa Ana study reaches; the portion of the floodplain that was vegetated was greatest in the San Luis Rey study reaches, where less than 15% of the floodplain and channel area has less than 50% vegetation coverage.

Arundo Characteristics

Arundo coverage varied from 15 to 23% of the total floodplain and channel area in the three management sections. The percentage *Arundo* cover was not a consistent portion of the total vegetation cover and it covered from less than 1% to more than 50% of the total floodplain area when averaged over the study stream reaches. *Arundo* was uncommon within the low flow channel width (Section 5.2).

All three study streams show a marked decline in *Arundo* coverage in the upstream study reaches compared to the downstream ones. Such an observation may result from slow upstream propagation, flood history, or the role of steeper stream slopes in limiting the establishment and development of *Arundo*. The relative importance of these two factors cannot be resolved with the existing information, but Tables 5-1.1 to 5-1.3 suggest that *Arundo* is an insignificant portion (in terms of geomorphic processes) of total cover in those study reaches where slopes exceed 0.004, including those steep reaches on the San Luis Rey River that have much of their floodplain covered with other vegetation.

There also appears to be a pattern along the study streams, and particularly on the Santa Margarita River, where the reaches with the highest *Arundo* concentrations occur where slope declines or the floodplain widens considerably when compared to the reach upstream. The best example is on Reach 7 of the Santa Margarita River which has the highest percent *Arundo* coverage of the study reaches (Table 5-1.1). The slope in Reach 7 is about half of that in Reach 6 and the floodplain is about twice as wide. This pattern is thought to occur because the less steep, wider reach has much lower average velocities which promote deposition of *Arundo* propagules and increase the likelihood of *Arundo* establishment and propagation. Section5.1.5 discusses this observation in more detail.

Table 5-1.1. Santa Margarita River summary of GIS analysis.

Reach No.	Reach Length (mi)	Average Slope	Average Floodplain Width (ft)	Ave Low Flow Channel Width (ft)	Width Ratio (%)[1]	Vegetated Area (%)[2]	*Arundo* Area (%)[3]
1	1.52	0.0008	1270	163	12.8%	59.7%	1.5%
2	1.47	0.0017	773	66	8.5%	91.0%	14.7%
3	1.70	0.0015	1444	58	4.0%	87.4%	21.5%
4	0.42	0.0015	2493	52	2.1%	91.5%	18.9%
5	0.90	0.0014	1929	72	3.8%	87.5%	44.3%
6	1.30	0.0024	2505	61	2.4%	92.2%	28.2%
7	0.42	0.0015	2213	87	3.9%	93.1%	54.8%
8	1.60	0.0023	1045	73	7.0%	71.7%	44.6%
9	0.77	0.0024	630	52	8.2%	66.9%	18.2%
10	1.21	0.0031	823	58	7.0%	73.9%	10.2%
11	1.89	0.0026	664	105	15.7%	68.7%	24.9%
12	4.11	0.0033	424	48	11.3%	69.7%	21.0%
Weighted Ave		**0.0023**	**1,078**	**73**	**8.7%**	**76.3%**	**23.1%**
Total	**17.32**						

[1] – Width Ratio = Average Floodplain Width / Average Low Flow Channel Width
[2] – Vegetated Area = Percent area of the floodplain and channel surface with more than 50% vegetation cover
[3] – *Arundo* Area = Percent area of the floodplain and channel surface occupied by *Arundo* (Cal-IPC 2010b)

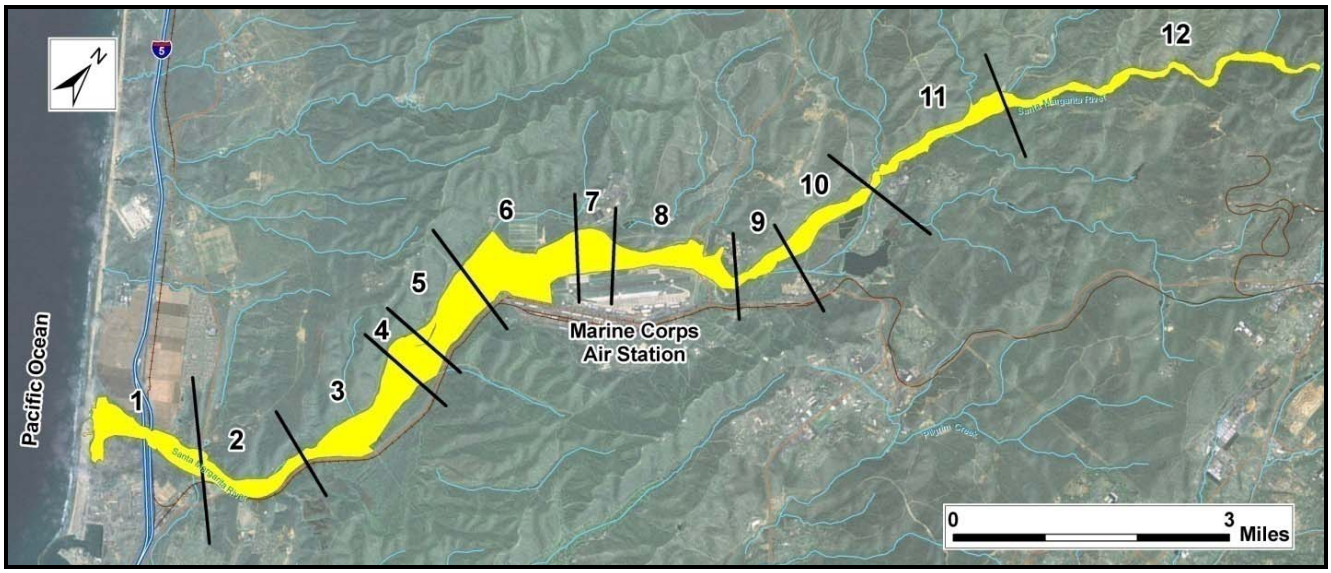


Figure 5-1.1. Santa Margarita River study reaches, with yellow denoting extent of mapped floodplain.

Table 5-1.2 Santa Ana River summary of GIS analysis.

Reach No.	Reach Length (mi)	Average Slope	Average Floodplain Width (ft)	Ave Low Flow Channel Width (ft)	Width Ratio (%)[1]	Vegetated Area (%)[2]	*Arundo* Area (%)[3]
1	3.16	0.0012	9146	90	1.0%	98%	12.5%
2	12.17	0.0025	1758	136	7.7%	82%	41.2%
3	2.08	0.0030	733	207	28.3%	56%	10.5%
4	2.35	0.0047	2312	219	9.5%	76%	19.4%
5	9.67	0.0038	749	197	26.3%	30%	0.2%
6	3.98	0.0058	529	151	28.5%	36%	0.4%
7	3.44	0.0097	1441	133	9.3%	49%	0.0%
Weighted Average		**0.0039**	**1942**	**159**	**15.7%**	**59.8%**	**16.6%**
Total	**36.86**						

[1] – Width Ratio = Average Floodplain Width / Average Low Flow Channel Width
[2] – Vegetated Area = Percent area of the floodplain and channel surface with more than 50% vegetation cover
[3] – *Arundo* Area = Percent area of the floodplain and channel surface occupied by *Arundo* (Cal-IPC 2010b)

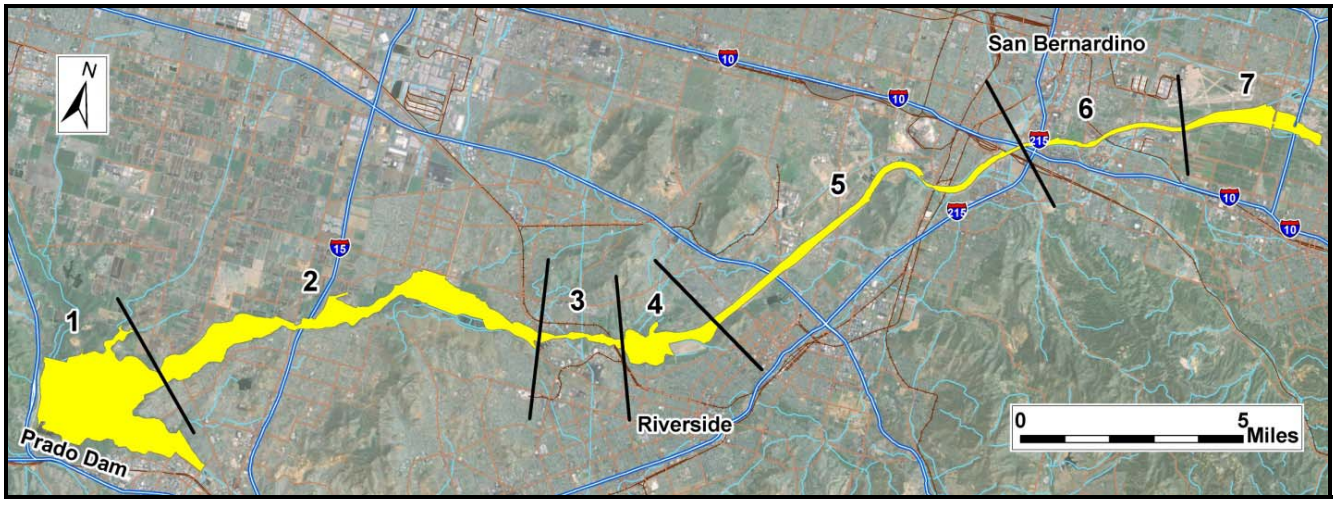


Figure 5-1.2. Santa Ana River study reaches with extent of mapped floodplain denoted in yellow.

Table 5-1.3 San Luis Rey River summary of GIS analysis.

Reach No.	Reach Length (mi)	Average Slope	Average Floodplain Width (ft)	Ave Low Flow Channel Width (ft)	Width Ratio (%)[1]	Vegetated Area (%)[2]	*Arundo* Area (%)[3]
1	0.86	0.0007	506	178	35.2%	52.9%	11.4%
2	1.66	0.0015	582	52	9.0%	80.4%	47.1%
3	5.79	0.0023	509	44	8.7%	91.4%	20.4%
4	5.53	0.0021	834	48	5.7%	85.5%	29.9%
5	0.62	0.0030	544	38	7.0%	94.7%	22.3%
6	5.07	0.0029	1232	60	4.8%	92.4%	12.8%
7	3.73	0.0037	443	37	8.4%	89.6%	7.7%
8	3.73	0.0050	1186	29	2.4%	83.7%	0.1%
9	2.03	0.0110	797	24	3.0%	86.0%	0.2%
10	2.01	0.0148	424	31	7.3%	74.4%	0.3%
11	1.16	0.0048	1157	33	2.8%	68.1%	0.0%
Weighted Average		**0.0042**	**790**	**46**	**6.8%**	**85.7%**	**14.9%**
Total	**32.19**						

1 – Width Ratio = Average Floodplain Width / Average Low Flow Channel Width
2 – Vegetated Area = Percent area of the floodplain and channel surface with more than 50% vegetation cover
3 – *Arundo* Area = Percent area of the floodplain and channel surface occupied by *Arundo* (Cal-IPC 2010b)

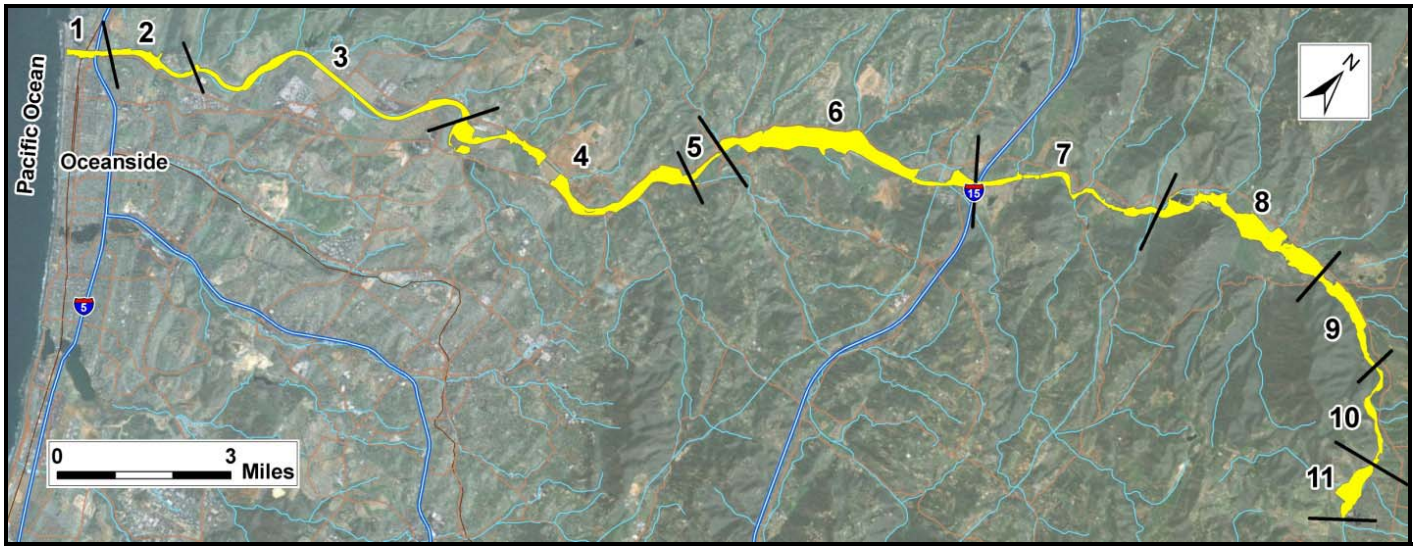


Figure 5-1.3 San Luis Rey River study reaches with extent of mapped floodplain denoted in yellow.

5.1.4. Santa Margarita River Case Study

5.1.4.1 Introduction

This chapter briefly describes the Santa Margarita River watershed, its climate and hydrology, and the morphology and historical behavior of the lower Santa Margarita River, before describing the effects of *Arundo* infestation on hydraulics, sedimentation and geomorphology. The effects of *Arundo* on these characteristics were determined from surveys, field observations, other consultant reports, and rerunning of hydraulic models developed in NHC (1997b) and NHC (2001). The NHC studies were completed during the period of maximum *Arundo* infestation, prior to the eradication programs that began in the late 1990s.

5.1.4.2 Santa Margarita Watershed

The Santa Margarita River watershed has an area of 740 square miles and drains into the Gulf of Santa Catalina (Pacific Ocean) near the city of Oceanside. Maximum elevations are about 6,825 ft at Thomas Mountain near the eastern end of the watershed. The upper watershed of the Santa Margarita River is mostly underlain by granitic rocks of pre-Cenozoic age; the central watershed, near Temecula and Murrieta, is mantled by Holocene and Pleistocene alluvial deposits (Jennings 1977). Occasional outcrops of Eocene and Jurassic marine rocks and metasedimentary and metavolcanic rocks are found in the central and lower watershed.

Three reservoirs regulate flows from the watershed. Vail Dam was completed in 1949 and regulates inflows from about 320 mi^2 of the upper Temecula watershed. Vail Lake storage capacity is about 40,000 acre-ft and it captures nearly all the winter runoff from its watershed, having overtopped only twice since the late 1940s (CDM 2003). Skinner Reservoir on Tucalota Creek, constructed in 1974 by the Metropolitan Water District (MWD), regulates a 51 mi^2 watershed and primarily stores imported water, releasing local inflows. Diamond Valley Lake Reservoir stores 800,000 acre-ft of imported water for the MWD; it reached full capacity in 2002. Skinner and Diamond Valley Lake Reservoirs have little effect on winter floods.

Lake O'Neill, operated by Camp Pendleton, provides off-stream storage for up to 1,200 acre-ft, which is diverted from the Santa Margarita River in spring and used for groundwater recharge in late fall. Releases for recharge are between 8 and 10 cfs (CDM 2003).

5.1.4.3 Climate and Hydrology

The Santa Margarita watershed has a Mediterranean climate, characterized by warm summers and cool, wet winters. Summers are dry and there are often several months without rain. About 90% of the annual precipitation falls as rain during large frontal storms that occur from November through April. Average annual precipitation is about 11 to 13 inches near the coast and over 25 inches at the highest watershed elevations, where it may include some snowfall.

The USGS has operated the Santa Margarita River at Ysidora (11046000) gage, near the mouth of the river, since 1923. Suspended sediment records were collected in the 1968-71, 1972-74 and 1977 water years. Inspection of the gage records shows an annual hydrograph where runoff primarily occurs during winter months, and is event-driven with most of the water discharge (and also most of the sediment discharge) occurring during a few, intense storms (Warrick and Rubin 2007). Annual maxima vary dramatically from year to year; annual instantaneous peaks at the Ysidora gage have ranged from zero to 44,000 cfs (Figure 5-1.4).

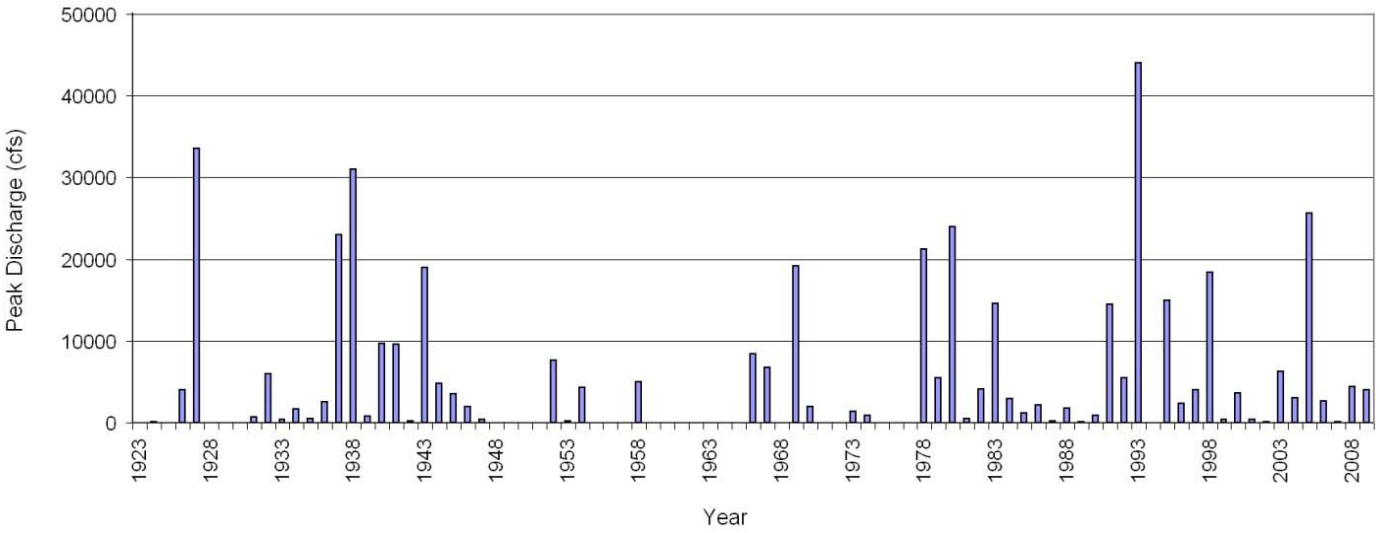


Figure 5-1.4. Annual peak discharges recorded at USGS stream gage 11046000 on Santa Margarita River near Ysidora.
Years with zero values or no data are shown as blank.

Large floods, those with return periods of more than 10 years and flows greater than 15 to 20,000 cfs, have been recorded at the gage in 1927, 1937, 1938, 1943, 1969, 1978, 1980, 1993, 1998, and 2005. Figure 5-1.4 shows a twenty-five year gap starting in the 1940s and lasting until 1969 that had no large floods. The 1993 flood was by far the largest on record; its peak discharge of 44,000 cfs is now about equivalent to the 50-year flood (USACE 1994a; Table 4.2=5-1.4). Before installation of the gage, large floods occurred in 1916 and 1884 (McGlashan and Ebert 1918). Stetson (2001) provides accounts of historical flooding and flood damages.

Most years include a long period of very low (<5 cfs) flows at the gage in the summer and fall, often extending for three or four months. Examination of decadal flow duration curves at the Ysidora gage shows a trend toward an increased duration of flows exceeding 10 cfs since the 1970s (Figure 5-1.5). This shift to a sustained, year-round, base flow is thought to be due to urbanization, water regulation since the construction of Vail Reservoir and groundwater recharge releases.

5.1.4.4 Lower Santa Margarita River

The Santa Margarita River begins at the confluence of Murrieta River and Temecula Creek near the City of Temecula. It is about 30 miles long; about 19 miles flow through Camp Pendleton near the mouth of the watershed. The lower Santa Margarita River begins at the mouth of DeLuz Canyon. Downstream, it flows through a 500 to 5,000 ft wide valley bordered by hilly terrain underlain by marine sedimentary rocks. The greatest widths are adjacent to the Marine Corps Air Station (MCAS) and at Ysidora Flats. The MCAS occupies a large part of the floodplain and is protected by a levee; otherwise the lower river valley is not developed, except for five bridges crossings and a few connecting roads.

The focus for this chapter is a 5.5 mile long project reach of the lower Santa Margarita River, which is adjacent to the MCAS and extends from De Luz Canyon to Ysidora Flats (Figure 5-1.6).

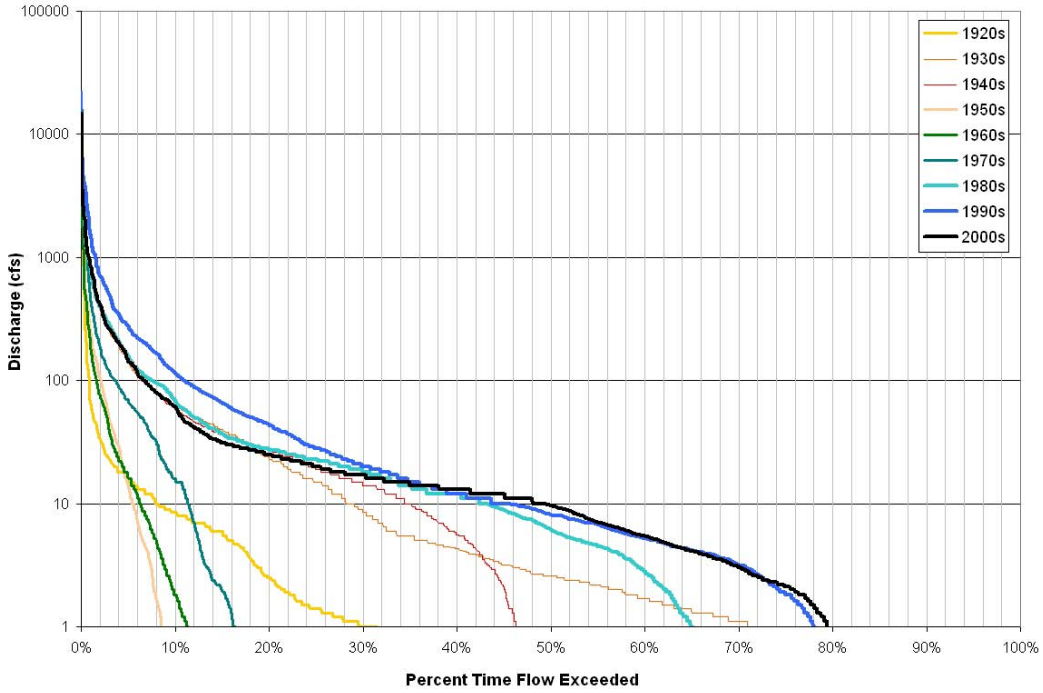


Figure 5-1.5. Flow duration curves plotted by decade at the Ysidora gage (11046000).

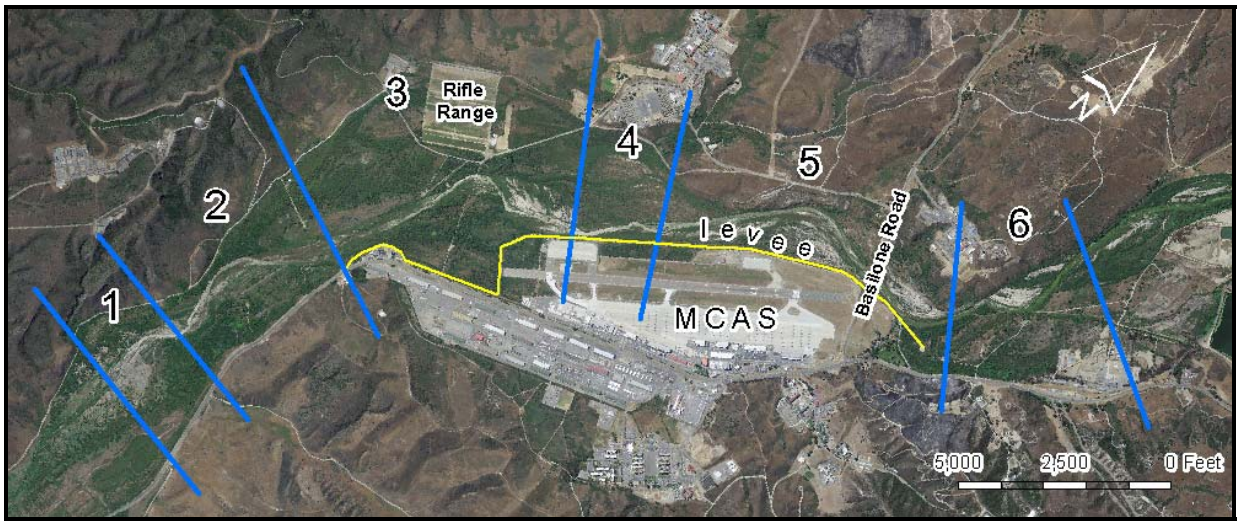


Figure 5-1.6. Sub-reaches (numbers 1 through 6) in the lower Santa Margarita River project reach.

This project reach is where NHC examined hydraulics and sediment transport capacity with mature stands of *Arundo* on the river bank and floodplain (NHC 1997a; 1997b; 2001) and covers about the same river mileage as Reaches 4 through 9 in Table 5-1.1 and Figure 5-1.1. The river floodplain is confined to varying degrees throughout the project reach, particularly upstream of the O'Neill Lake diversion and in the vicinity of Basilone Road Bridge (Table 5-1.4; Figure 5-1.6).

The sub-reach breaks on Figure 5-1.6 were set based on the degree of confinement, channel dimensions and longitudinal slope, using historical air photos, ground inspections and surveyed channel cross-

sections. Channel confinement resulted from geologic and anthropogenic features, including high bluffs, bridges, in-channel road or pipeline crossings, and levees along the MCAS. The sub-reaches are described on Table 5-1.4.

In the late 1990s, the main channel, as defined by channel banks, was typically 200 ft to 400 ft wide and bordered by moderate to abundant vegetation where the floodplain had not been developed. The main channel was generally four to eight times wider than the low flow channel defined in Table 5-1.1. The floodplain surface was generally 4 to 6 feet higher than the low flow channel invert, as indicated by field inspection and channel surveys. Small, concentrated flow paths (distributary or chute channels) were common on the floodplain and on vegetated bar surfaces throughout the project reach (Figure 5-1.7).

River banks generally consisted of loose or partially consolidated sand and were between four and six feet high. Stream bed materials consisted of coarse and medium sands with some fine gravel. Sands and silts were the common deposits observed on overbank floodplain areas.



Figure 5-1.7. View of the Santa Margarita River in Sub-Reaches 2 & 3 (view is upstream) taken on May 16, 1995.

Table 5-1.4. Description of the lower Santa Margarita project sub-reaches.

Sub-Reach	Reach Length (ft)	Slope (ft/ft)	Average Floodplain Width (ft)	Ave Channel Width (ft)	General Observations
Sub-Reach 1 (sta. 0 to sta. 18+61) *Downstream sub-reach*	1,900 ft	0.0011	3,200 ft	205 ft	Narrow active channel bed flowing in an undeveloped and well vegetated floodplain.
Sub-Reach 2 (sta. 18+61 to sta. 71+07)	5,250 ft	0.0023	1,900 ft	350 ft	Valley narrows due to adjacent hillslopes through this undeveloped sub-reach located just downstream of the MCAS airfield.
Sub-Reach 3 (sta. 71+07 to sta. 143+98)	7,300 ft	0.0023	3,500 ft	405 ft	Wide valley section with broad floodplain partly confined by MCAS levee and the Rifle Range and Rifle Range Road crossing.
Sub-Reach 4 (sta. 143+98 to sta. 162+66)	1,900 ft	0.0025	2,300 ft	310 ft	Short reach of intermediate width connecting the very wide sub-reach 3 with narrow sub-reach 5
Sub-Reach 5 (sta. 162+66 to sta. 241+58)	7,900 ft	0.0022	1,100 ft	325 ft	Narrow floodplain sub-reach due to the Basilone Road crossing and MCAS levee along the right bank.
Sub-Reach 6 (sta. 241+58 to sta. 274+55) *Upstream sub-reach*	3,300 ft	0.0030	1,500 ft	345 ft	Narrow floodplain sub-reach due to flow confinement and infrastructure on the south side of the valley.

5.1.4.5 Historical Changes in the Project Reach

Planform

NHC (1997a) examined the position of the lower Santa Margarita River on historical air photos and maps and found that it maintained the same overall course since 1938. Its course had been more or less straight, except where it followed the natural curvature of valley walls or was guided by levees along the MCAS. The channel mostly lay on the northwestern portion of the valley bottom, due to encroachment by the MCAS facilities.

Within this general alignment, the main or active channel has shifted several hundred feet at some locations and exhibited a general decrease in width since 1938, interrupted by dramatic increases in channel width following large floods, such as in 1969 (NHC 1997a; see also Figure 5-1.8). Large floods also restored multiple flow channels and braid bars in the project reach. Vegetation encroached on recently deposited bar and overbank sediments and a single channel re-established over time.



Figure 5-1.8. Comparison of 1970 (left) and 2008 (right) air photos of Sub-reach 3.

Bed Profiles

NHC (1997b) compared channel invert (thalweg) profiles from 1946 to 1994 and found no consistent trend in elevations. Rather, the sub-reaches showed bed elevations that varied around a mean value over time, suggesting a relatively stable profile that responded to large floods, bar development, scour and sediment deposition. No channel invert elevation surveys have been completed since 1994, and a profile that shows the potential effects of recent *Arundo* eradication on channel elevations has not been surveyed.

NHC (1997a) concluded that there was no clear evidence of recent aggradation or incision along the lower Santa Margarita River. However, numerical modeling of long-term sediment transport suggested aggradation rates of 1.5 ft per 100 years, as a result of the lower bed slopes in the downstream end of the project reach (Table 5-1.4).

Floodplain Vegetation

Figure 5-1.8 compares air photos of Sub-reach 3 from 1970 and 2008. The non-vegetated active channel bed is several times wider in 1970 than 2008, despite the recent *Arundo* eradication. Channel and floodplain conditions in the 1970 air photo resulted from the 1969 flood, which followed a twenty-five period with no significant floods. Stetson Engineers (2001) reported that large floods in 1927 and 1993 also scoured much of the valley bottom and dramatically enlarged the active channel in Deluz Canyon just upstream of the project reach.

Interestingly, the 2008 air photos were taken not long after the 2005 flood, whose peak was slightly greater than that in 1969. Despite this, the 2008 channel shows no evidence that it had recently enlarged to the width observed after the 1969 flood. This different behavior is assumed to result from changes in the riparian vegetation in the channel and on the floodplain, or changes in channel and floodplain geometry, that resulted in greater bank and floodplain resistance to erosion.

While intriguing, such behavior is not well documented or understood. However, it suggests that the large floods that once greatly altered the channel and floodplain vegetation on the lower Santa Margarita River conditions may not be as effective under current conditions.

***Arundo* Eradication Programs**

Efforts to control *Arundo* in the Santa Margarita River watershed began in 1997 (Lawson et al. 2005), and eradication has proceeded upstream to downstream, beginning at Interstate 15 in the middle watershed. *Arundo* removal continued for over a decade until 2009 when the river mouth was reached. The distribution of *Arundo* along the lower Santa Margarita River and the years when stands were removed are documented in a GIS database prepared by the California Invasive Plant Council (Cal-IPC 2010b).

The total area of *Arundo* stands in the project reach near Camp Pendleton was estimated to be about 400 acres in 1997 (Cal-IPC 2010b). Cal-IPC (J. Giessow, pers. comm.) provided a comparison of the 1997 and 2010 geomorphology in the project reach (See section 5.2.4), noting that the area of low flow channel and unvegetated bar or floodplain had increased from 120 acres in 1997 to 360 acres in 2010. Bed level changes or adjustments associated with the increased width for the main channel have not been documented.

5.1.4.6 Project Reach Hydraulics

HEC-RAS Model

In the late 1990s, NHC developed a calibrated, steady, one-dimensional HEC-RAS model (USACE 2010) of the Santa Margarita River project reach, as part of studies for a new levee (NHC 2001). The model was based on 62 cross-sections in the project reach, an average of one every 470 ft, developed either from July 1998 LiDAR, September 1996 air photos or June and July 1998 cross section surveys (Figure 5-1.9).



Figure 5-1.9. Location of HEC-RAS model cross-sections (in yellow) (NHC 2001).

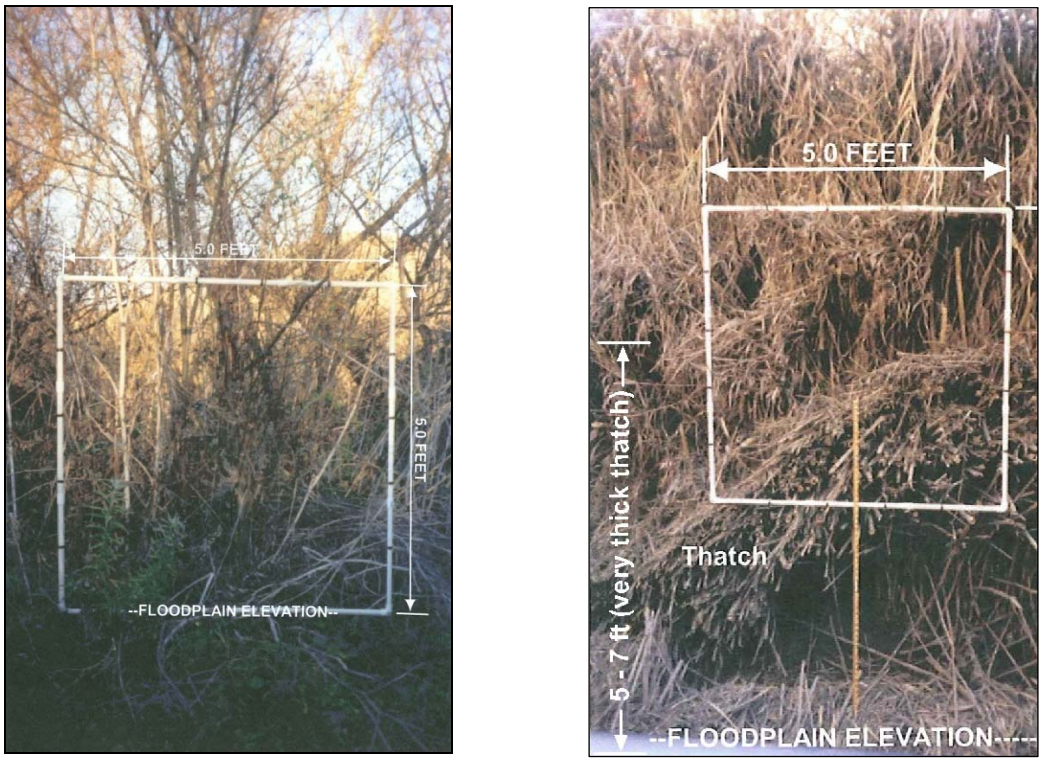
Model Calibration

The HEC-RAS model was calibrated to high water marks surveyed after the 1993 (44,000 cfs) and 1998 (18,400 cfs) floods. Calibration consisted of adjusting Manning's roughness and floodplain characteristics until calculated water surface profiles matched those observed during the floods. The initial calibration in *Arundo* infested areas resulted in Manning's n value on the floodplain that seemed unreasonably high, as much as 0.35 to 0.40, and were considerably higher than typical published values for roughness on vegetated floodplains.

Field observations of mature *Arundo* stands showed an extremely dense thatch of interlocking plant stems that extended 5 to 7 feet above the ground surface that effectively blocked conveyance on the floodplain (Figure 5-1.10). Above that elevation, the *Arundo* stems were not as interlocked or densely spaced and appeared to be able to bend in the flow, similar to native plant species such as willow. However, the *Arundo* exhibited a much higher density of stalks or stems than native willow species (Figure 5-1.10).

These observations led to a modified approach to hydraulic modeling in thick *Arundo* stands on the overbank or floodplain. The calibrated model eliminated flow conveyance in the first 5 feet in mature *Arundo* stands and used an average Manning's n value of 0.15 for water levels over 5 ft from the ground (NHC 2001). This range of roughness was in general agreement with the results of flume measurements of Manning's n for woody vegetation that included tamarisk (Freeman et al. 2000).

Additionally, a Manning's n of 0.10 was adopted for native vegetation on the floodplain and one of 0.05 for bare (un-vegetated) floodplain. A Manning's n of 0.04 to 0.06 was adopted for the low flow or main channel.



ti i i t ti b t t *Arundo*

Figure 5-1.10. Photographs of floodplain vegetation on the Santa Margarita River (1/4/1999).

Model Scenarios

The floodplain roughness in the calibrated HEC-RAS model described above was then adjusted to predict hydraulic characteristics over a range of flows for four different floodplain vegetation scenarios. These were:

- *Scenario 1 – Total Mature Arundo Infestation:* This scenario represents the ultimate extent of *Arundo* infestation, where the entire floodplain surface is covered by mature, monotypic stands.
- *Scenario 2 – Native Vegetation*: This scenario assumes that native vegetation covers the entire floodplain surface and that no *Arundo* is present.
- *Scenario 3 – Bare Floodplain:* This scenario assumes a floodplain surface where floodplain sediments are exposed as a result of fire, *Arundo* eradication, or a large flood event.
- *Scenario 4 – 1997 Floodplain:* This scenario represents the mix of *Arundo*, native vegetation, and bare surface on the floodplain observed in 1997, as interpreted from aerial photos onto the cross sections. Manning's n values vary across the floodplain in each cross section, based on the appropriate values adopted for the different vegetation types observed in the 1997 air photos.

In those scenarios where *Arundo* was present, floodplain elevations were raised 5 ft to simulate zero conveyance in mature *Arundo* stands (Scenarios 1 and 4). Otherwise, the low flow or main channel geometry and floodplain geometry were not altered and remain as described for the NHC (2001) model.

Peak Flows

Table 5-1.5 summarizes the peak flows adopted for the steady state HEC-RAS model runs that were performed as part this study.

Table 5-1.5. Peak flows adopted for the project reach (USACE 1994).

Return Period (years)	***Peak Discharge (cfs)***
2	3,000
5	9,400
10	17,000
25	31,500
50	46,000
100	64,000

Hydraulic Model Results for the 4 Scenarios

Table 5-1.6 provides a general summary of the variation in reach-averaged hydraulic variables for the various scenarios, compared to the native vegetation scenario (Scenario 2).

Table 5-1.6. Differences in hydraulic characteristics between scenarios.

Scenario	**Wetted Width[1]**	**Average Depth**	**Average Flow Velocity**	
			Channel	**Overbank**
1 – *Arundo* Infestation	Wider	Deeper	Faster	Slower
2 – Native Vegetation	*(baseline)*	*(baseline)*	*(baseline)*	*(baseline)*
3 – Bare Floodplain	Narrower	Shallower	Slower	Faster
4 – 1997 Floodplain	Variable	Variable	Variable	Variable

[1] Wetted Width – width of the wetted channel cross-section for a given flow discharge

The ratios of values for Scenarios 1 and 3 compared to Scenario 2 are generally consistent throughout the range of peak flows in Table 5-1.5. The ratios comparing Scenario 4 (1997 vegetation) to Scenario 2 vary. This occurs because the floodplain roughness varies from one cross section to another largely because the extent of the total floodplain area occupied by *Arundo* varies from one sub-reach to another (Table 5-1.7).

Table 5-1.7. Extent of *Arundo* by sub-reach as of 1997.

Sub-Reach [1]	***Floodplain Area (ac)***	***Arundo (ac)***	***Percentage***
1	128	24	19
2	210	93	44
3	396	112	28
4	113	62	55
5	203	90	45
6	59	11	18

[1] See Figure 5-1.6 for location of sub-reaches.

Design Water Surface Profiles

Figure 5-1.11 shows the project reach water surface profiles for the 100-year flood for each of the four scenarios. For the 1997 floodplain vegetation scenario (Scenario 4), 100-year water levels are typically close to that for native vegetation, but rise two to three feet in sub-reaches 4 and 5 where the infestation is dense (Table 5-1.7). Complete coverage by *Arundo* (Scenario 1) raises flood levels by 4 to 5 feet above those for native vegetation throughout the project reach; bare soil or no floodplain vegetation (Scenario 3) lowers them 2 to 3 feet throughout the project reach.

Water surface profiles for the 5-year flood show a similar pattern to that for the 100-year flood, but have smaller differences in stage. The full *Arundo* coverage scenario (Scenario 1) raises water levels up to 3 ft above those for native vegetation, whereas bare soil or no floodplain vegetation (Scenario 3) lowers them about 1 ft. The 5-year water levels for the 1997 vegetation scenario (Scenario 4) are close to those for complete native vegetation coverage, but rise one to two feet in sub-reaches where the infestation is particularly concentrated.

Comparison of results from Scenarios 1 and 4 to those from Scenario 2 suggests that there is a threshold for floodplain coverage by mature *Arundo*, below which impacts on average depths and water surface profiles are relatively insignificant. A rough idea of the threshold can be obtained by comparing *Arundo* densities in Sub-reaches 4 and 5 to those further downstream (Table 5-1.7). On this basis, percent *Arundo* coverage somewhere over 30% generally results in significant adjustments to the water surface profile.

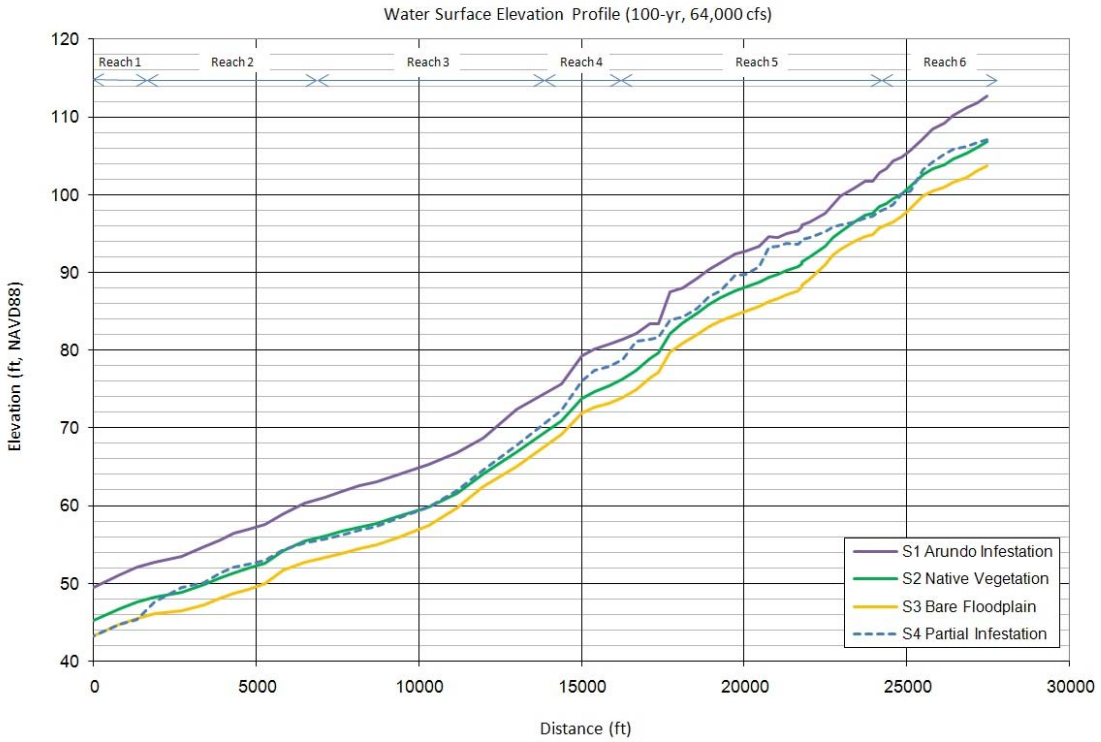


Figure 5-1.11. Project reach water surface profiles for scenarios 1 to 4: 100-year peak flow.

Channel and Floodplain Velocities

Table 5-1.6 indicated that complete coverage by *Arundo* results in the deepest flows and greatest velocities in the main channel and the slowest velocities on the floodplain. This illustrates a key characteristic of dense vegetation, such as *Arundo,* in the hydraulic model: flows are concentrated in the main channel by dense stands along the stream banks, resulting in deeper and faster flow through the main channel for a given discharge.

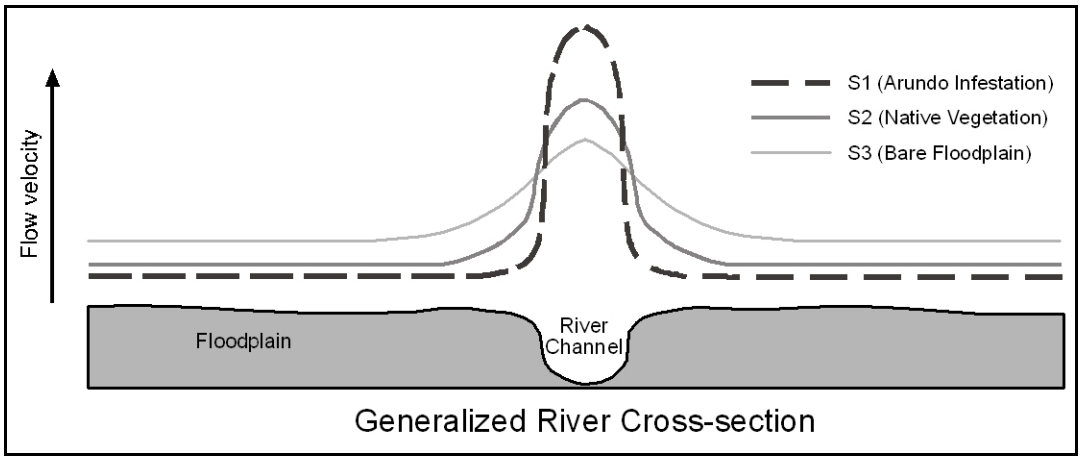


Figure 5-1.12. Generalized illustration of the effects of floodplain roughness (dense vegetation) on velocity across the section for Scenarios 1, 2, and 3.

In contrast, removal of floodplain vegetation results in the lowest average velocities in the main channel. Main channel velocities with floodplain vegetation removed would be lower still if channel widening due to the lower bank strength was incorporated in the RAS model. These observations are summarized in Figure 5-1.12.

Results by Sub-Reach

Table 5-1.8 compares hydraulic characteristics for the four scenarios for Sub-reaches 3 and 5. Sub-reach 5 has a 100-year floodplain width of about 1,100 feet; Sub-reach 3 is less confined and its floodplain width averages 3,500 feet (Table 5-1.4). As expected, the narrower Sub-reach 5 has greater average depths and velocities in the channel and on the floodplain than the wider Sub-reach 3 at the 100-year peak for all the scenarios. However, the percentage increases in average depths and velocities in Sub-reach 5, when comparing Scenario 1 to Scenario 2, are smaller than in Sub-reach 3. This is thought to occur because the main channel, whose roughness is not affected by differing vegetation types, occupies a larger portion of the total floodplain width and conveys a greater portion of the total flow. When Scenario 4 is compared to Scenario 2, the results are complicated by the different *Arundo* coverage percentages, but velocities increase in Sub-reach 3 and decrease in Sub-reach 5. In sub-reach 5, the increased floodplain roughness seems to be accommodated more by increased depths than velocities in the main channel, potentially as a result of backwater from Sub-reach 4.

Table 5-1.8. Depths and Velocities in Sub-reach 3 (wide floodplain) and Sub-reach 5 (narrow floodplain) for the 100-year peak flow.

Scenario	Sub-Reach 3 (wide floodplain)					Sub-Reach 5 (narrow floodplain)				
	Wetted Width (ft)[1]	Average Flow Depth (ft)		Average Flow Velocity (ft/s)		Wetted Width (ft)[1]	Average Flow Depth (ft)		Average Flow Velocity (ft/s)	
		CH	OB	CH	OB		CH	OB	CH	OB
1 – *Arundo* Infestation	3,530	17.5	7.5[2]	10.3	1.5	1,150	20.2	10.5[2]	13.4	2.3
2 – Native Vegetation	3,480	12.3	7.2	8.0	2.2	1,140	15.7	10.4	11.8	3.6
3 – Bare Floodplain	3,400	9.9	4.9	7.2	3.6	1,120	12.9	7.8	10.4	6.0
4 – 1997 Floodplain	3,280	12.2	6.6	8.4	2.5	1,140	17.5	10.0	10.9	3.7

[1] Wetted Width – width of the wetted channel cross-section for a given flow discharge
[2] Represents depth of active flow conveyance area only, and does not include 5 ft thickness of ineffective flow in *Arundo* areas.
Note: CH = Channel; OB = Overbank or floodplain

As noted earlier, the above results assume the same geometry for the main channel and floodplain for each scenario; only roughness changes from one scenario to another.

5.1.4.7 Project Reach Sediment Budget

Introduction and Context

Sediment transport in rivers is complex and this chapter considers only two of its components. This section discusses reach-based sediment budgets and addresses the question of whether *Arundo* infestation might reduce sediment delivery to downstream reaches and, ultimately, to the Pacific Ocean. This section also discusses the potential changes in sediment transport capacity that might result from the altered hydraulics discussed in the previous section and considers the likely channel response. The analyses are speculative for both of these components.

Sediment Budget Considerations

The sediment budget for a particular reach – such as the project reach on the Santa Margarita River – can be expressed as follows:

$$\text{Sediment}_{\text{Out}} = \text{Sediment}_{\text{In}} \pm \Delta\text{Storage} \qquad (1)$$

In (1), the change in sediment storage in the reach over time (ΔStorage) can be either negative (erosion from the reach) or positive (deposition in the reach), with erosion increasing the sediment output; deposition reducing it.

The budget can be constructed for various time periods or grain size classes. The analysis for the project reach focuses on long-term averages and the transport of sand. In the Santa Margarita River, sand makes up much of the bed material. It is transported both in suspension and as bed load (Slagel and Griggs 2006).

If we can assume that the sediment delivered to the project reach is reasonably constant over the long-term then the sediment that leaves the reach will differ from that arriving as a result of changes in sediment storage within the reach, including those that result from *Arundo* establishment. Changes in storage within the reach are best measured by comparing repeated surveys of channel and floodplain cross sections to define volumes and by sediment sampling to define the size distribution of the materials that have been eroded or deposited. Such information is not available on the Santa Margarita River and is seldom available for large rivers in Southern California. Instead, we rely on observations in other reports to roughly define the changes in sediment storage expected with *Arundo* infestation and sediment delivery studies to define the long-term sediment input to the stream reach.

Santa Margarita River Sediment Loads

Previous studies (Slagel and Griggs 2006, Inman and Jenkins 1999) have estimated annual sediment transport in the Santa Margarita River from sediment gaging at the Ysidora gage, which is downstream of the project reach. Average annual transport was between 50 and 70 acre-feet (65,000 and 80,000 m^3) in the two studies. Slagel and Griggs (2006) also concluded that average annual sand transport was about 20 acre-feet (25,000 m^3), or about 30 to 40% of the total transport.

Sediment Capture by *Arundo*

Previous studies (see Section 5.1.2) indicate that deposition occurs on the floodplain as *Arundo* stands establish and mature. Rates have not been measured on the Santa Margarita River but the average annual accretion rates discussed in Chapter 2 ranged from about 0.3 to 0.7 feet per year. Given these rates, the average annual storage in the *Arundo* stands on the floodplain might then be from 120 to 280 acre-feet over the 400 acres of *Arundo* growth that was present in 1997. Roughly one-third of the total is sand (see

Slagel and Griggs 2006), or about 40 to 90 acre-feet. This represents the average annual loss of sand in transport to storage in *Arundo* stands. Sediment deposition is also likely to occur on the remainder of the floodplain but this has been ignored in the simple budget constructed to evaluate *Arundo* impacts.

It is not known how long the above average rates of accretion or deposition might continue. Rates may be curtailed as the floodplain and braid channels fill with sediment, particularly because the channel thalweg does not seem to be aggrading on the Santa Margarita River.

Adding the above annual estimate of sand trapped on the floodplain to the transport observed at the Ysidora gage (the sediment leaving the reach) indicates that the annual sand inflow to the project reach might have been 60 to 110 acre-feet during the period of *Arundo* establishment and growth. On this basis, the sediment output from the reach was reduced to one-third or less of the sediment input by storage in the *Arundo* stands. This suggests that *Arundo* establishment and growth on the floodplain of the project reach has the potential to capture a substantial portion of the sediment delivery from the upper watershed. As discussed in the next section, losses to deposition on the floodplain may be partly compensated for by erosion from the channel bed.

Erosion in the Main Channel from *Arundo* Growth

Based on the literature review, at the same time as the *Arundo* stands on the floodplain are trapping sediment in transport, the main channel can be expected to narrow. We have no good measurements of the change in width that occurred as *Arundo* stands established and dominated the riparian and floodplain vegetation on the Santa Margarita River. However, measurements by Cal-IPC (Section 4.5) show that the main channel width about tripled in width following *Arundo* eradication. Assuming that the same results would occur in reverse during *Arundo* establishment and growth, the main channel with *Arundo* infestation might be about one-third to one-half as wide as it was prior to *Arundo* establishment.

As the channel narrows it would be expected to deepen to pass typical floods, as is commonly observed in regime studies. Such a response was not observed often in the literature review but that may be because the channel bed or thalweg rose as the floodplain filled but to a lesser extent, creating a deeper flow channel. It is not known how channel depths have changed on the Santa Margarita River following *Arundo* infestation.

A rough estimate of the increased depth required to pass typical floods as the channel narrows can be obtained by applying Blench's (1969) regime equation. It suggests that the increase in channel depth for the above reductions in width might be about 50 to 100%. The typical channel depth before *Arundo* establishment is not known, but the observed channel bank height in the project reach as of 1997 or so, with *Arundo* in place, was about 4 to 6 feet, consistent with calculated average depths at the 2-year flood. Based on the ratio above, it appears that the channel may now be 2 to 3 feet deeper than it was prior to *Arundo* establishment. The greater channel depth might result from bed erosion, increased floodplain height adjacent to the channel, or a combination of the two processes.

The area of the main channel in 1997 was 118 acres and the bed material was sand. Assuming that 2 to 3 feet of erosion occurred over twenty years, the average annual net loss of bed material from the reach could be as much as 12 to 18 acre-feet over the project reach. As noted above, the net erosion might be zero if the channel deepens by filling on the floodplain rather than by eroding its bed.

Project Reach Sediment Budget Summary

The above suggests that annual trapping of sand on the floodplain during *Arundo* establishment and growth in the project reach was about 40 to 90 acre-feet; the erosion from the channel bed as it adjusted

to narrower widths is expected to be less than 20 acre-feet. The above estimates are based on accretion and erosion rates from the literature rather than from measurements on the Santa Margarita River. However, they suggest that *Arundo* establishment and growth is likely to reduce the volume of sand transported through the project reach to the coast. As noted above, two-thirds of the sand transported from the upper Santa Margarita River watershed might be trapped in *Arundo* stands in the project reach during their establishment and growth.

After *Arundo* has established and reached its maximum coverage, we anticipate that accretion of sediment on the floodplain will slow, unless the channel fills rapidly so that flood waters continue to spill onto the higher floodplain. As the accretion on the floodplain slows or stops, the adjustment of channel depth to the narrower channel width will also slow or stop. At this point, sand transport out of the reach will be in equilibrium with sediment supply.

The observed difference between losses to sediment storage and gains from bed erosion in the Santa Margarita River may not be the same in other Southern California Rivers with different overall geomorphology. Where the floodplain is narrower than in the Santa Margarita River, bed erosion may be a large portion of storage and the reduction in sand transport towards the coast with *Arundo* establishment may be smaller. Where the floodplain is much wider, the opposite result may occur.

5.1.4.8 Project Reach Sediment Transport Capacity

Introduction and Context

Suspended sediment transport has been measured at the Ysidora gage on the Santa Margarita River; however, there are no measurements of bed load transport. Bed load and bed material load transport have been modeled by NHC (1997b) and West Consultants (2000) but only for the *Arundo* coverage that existed in the late 1990s. Consequently, an evaluation of the potential effects of varying *Arundo* coverage or *Arundo* eradication on sediment transport capacity must be calculated from the hydraulic output from the HEC-RAS model runs.

The RAS model runs have some limitations for calculating sediment transport capacity for different conditions. The actual channel and floodplain geometries under different vegetation scenarios are not known; nor do we know if the size of material on the channel bed differs for these scenarios. Instead, as described earlier, the RAS model adopted the channel and floodplain geometry from 1997 for all the scenarios, altering the floodplain roughness and conveyance to simulate different vegetation scenarios, and assumed the same bed material distribution.

Approach to Transport Capacity

We have adopted stream power as the best proxy for sediment transport capacity differences among the four floodplain vegetation scenarios (Bagnold 1966; Vanoni 1975). Stream power per unit length of channel, which is essentially a measure of the energy available to transport sediment once a critical threshold for mobility is passed, is defined as:

$$\Omega = \rho g Q S \qquad (2)$$

where Ω is stream power, ρ is the density of water, g is the acceleration due to gravity, Q is a discharge and S is energy slope, roughly parallel to the bed slope. For calculations from the model output, $Q = wdv$, where w is channel width, d is average channel depth and v is average sectional velocity, was substituted into Equation (2) and terms regrouped as:

$$\Omega = \tau v w \qquad (3)$$

In Equation (3), τ is the average bed shear stress. Stream power was calculated separately for the channel and floodplain for each of the four scenarios, for the 5-year through 100-year peak flows (see Table 4.2). Average annual stream powers were then calculated based on an expression reported in USACE (1995) that incorporates the stream power exerted by floods up to the 100-year return period and approximates the area under the annual probability-event yield curve.

Stream Power for Different Scenarios

Table 5-1.9 summarizes the stream power calculated for Scenarios 1, 3, and 4 as a ratio to that calculated for Scenario 2 (Native Vegetation), the adopted baseline or index condition. Numbers >1 indicate more power and greater sediment transport, and numbers <1 indicate less power and sediment transport. This table shows that the ratios of the stream power to that for Scenario 2 are not particularly sensitive to the magnitude of the flood, under the model assumption of fixed channel and floodplain geometry. In the Santa Margarita River we expect that the channel will respond rapidly to increased stream power, altering its depth, width (where geometry permits) or bed material size until thresholds for transport are increased or bed stresses are reduced. Thus, the observed differences may not persist for the frequent floods, but are likely to persist for the largest ones.

Table 5-1.9 is helpful when considering potential channel and floodplain responses to changes in floodplain vegetation. For example, it suggests that as vegetation changes from native to a mixture of *Arundo*, native vegetation and bare soil (Scenario 4) the stream power exerted in the main channel will increase and, hence, it will begin to deepen. Stream power exerted on the floodplain will decrease and filling of secondary channels and deposition on the floodplain might be anticipated. When floodplain changes from a vegetated state to bare soil (Scenario 3), as it would under the *Arundo* eradication program, the stream power exerted in the main channel reduces and deposition or channel filling might occur. On the floodplain, stream power is greatly increased and rapid development of channel braids would be expected, returning the channel form to a braided appearance, such as has been observed in the Santa Margarita River. This assumes that the *Arundo* root mass has been removed or that it does not affect stability of the sediments. Areas with rhizome mats still in place would be expected to be more erosion resistant than bare soil, and might reduce or prevent geomorphic change.

Table 5-1.9. Summary of relative differences in stream power by scenario for entire study area, (S2: native is baseline).
>1 = more power and sediment transport, <1 = less power and sediment transport

	Channel				Floodplain			
Flow Event	**S1 *Arundo***	**S2 Native**	**S3 Bare**	**S4 Mix-1997**	**S1 *Arundo***	**S2 Native**	**S3 Bare**	**S4 Mix-1997**
5-year	**1.41**	1.00	0.88	**1.02**	**0.23**	1.00	1.33	**0.95**
10-year	**1.59**	1.00	0.86	**1.06**	**0.38**	1.00	1.22	**0.92**
25-year	**1.51**	1.00	0.80	**1.10**	**0.50**	1.00	1.17	**0.89**
50-year	**1.50**	1.00	0.77	**1.13**	**0.59**	1.00	1.16	**0.92**
100-year	**1.50**	1.00	0.74	**1.14**	**0.66**	1.00	1.15	**0.95**
Average Annual	**1.50**	**1.00**	**0.83**	**1.07**	**0.49**	**1.00**	**1.20**	**0.93**

S1=all *Arundo*, S2=all native, S3=all bare, S4=1997 site conditions (mix of *Arundo*, native, bare).

Stream Power by Sub-Reach

In a similar fashion to the hydraulic characteristics, the relative changes in stream power also vary from sub-reach to sub-reach, depending on floodplain width. A narrow sub-reach (5) and a wider sub-reach (3) are presented in Table 5-1.10 to illustrate this.

Where the floodplain is wide relative to the channel there are potentially greater changes in stream power in the main channel with complete *Arundo* coverage (Scenario 1). Thus, a greater channel response (power and sediment transport) would be expected in wider floodplain reaches with complete *Arundo* coverage than in narrower ones, which is confirmed in Table 5-1.10. The lower power/sediment trapping effect on floodplains is more pronounced in narrower sub-reaches (S1 and S4 are lower). This may be off-set by the spatial extent of floodplains, however, as there is more invaded floodplain in sub-reach 3 to catch sediment, wider floodplain seems to balance in terms of sediment transport, narrower reaches may trap more.

Table 5-1.10. Differences in relative stream power for sub-reaches 3 and 5.

Sub-reach 3 (wider floodplain)

	Channel				Floodplain (overbank)				Total			
Flow Event	**S1** *Arundo*	**S2** Native	**S3** Bare	**S4** Mix'97	**S1** *Arundo*	**S2** Native	**S3** Bare	**S4** Mix'97	**S1** *Arundo*	**S2** Native	**S3** Bare	**S4** Mix'97
10-year	**1.75**	1.00	0.82	**1.09**	**0.42**	1.00	1.18	**1.02**	**0.99**	1.00	1.02	**1.05**
10o-year	**1.78**	1.00	0.82	**1.20**	**0.72**	1.00	1.18	**1.09**	**0.99**	1.00	1.09	**1.12**

Sub-reach 5 (narrower floodplain)

	Channel				Floodplain (overbank)				Total			
Flow Event	**S1** *Arundo*	**S2** Native	**S3** Bare	**S4** Mix'97	**S1** *Arundo*	**S2** Native	**S3** Bare	**S4** Mix'97	**S1** *Arundo*	**S2** Native	**S3** Bare	**S4** Mix'97
10-year	**1.30**	1.00	0.86	**0.89**	0.28	1.00	1.28	**0.68**	**0.90**	1.00	1.02	**0.81**
10o-year	**1.33**	1.00	0.73	**0.83**	0.57	1.00	1.22	**0.69**	**0.91**	1.00	1.00	**0.76**

S1=all *Arundo*, S2=all native, S3=all bare, S4=1997 site conditions (mix of *Arundo*, native, bare).

5.1.4.9 Case Study Summary

This section summarizes our understanding of the effects of *Arundo* establishment on hydraulics, sediment transport and geomorphology, based on the case study in the lower Santa Margarita River project reach.

Similar to other rivers in Southern California and throughout the American Southwest, the establishment and spread of *Arundo* on the lower Santa Margarita River has narrowed the active river channel and simplified its river cross-section. This has resulted in a shift from a wide, braided river planform to a single channel with defined banks and few bare active geomorphic surfaces. The narrowing trend has been interrupted by occasional large floods which remove floodplain vegetation and widen the channel, such as occurred in 1969 and 1993. It is not understood or known what the minimum channel width might be in the absence of large floods.

Inspection of historical air photos suggest that there has been much less channel widening from recent large floods than occurred in 1969, presumably because of different erosion resistance of the floodplain since the *Arundo* stands have been established. Little is known of the hydraulic forces that can be withstood by the *Arundo* stands in various types of floodplain deposits (soils) so there is no good understanding of how large a flood would be required to remove stems, erode the root mass, and reset the floodplain vegetation. In any event, it appears that *Arundo* will out-compete native vegetation on the disturbed floodplains and re-establish mature stands on much of the floodplain in the time interval between very large floods.

The mature *Arundo* stands essentially eliminated flow conveyance during low and moderate floods on the portions of the floodplain that they occupy, increasing the portion of the flow passing through the low flow or active channel. During large peak flows, when water levels are more than 5 feet or so over the floodplain surface, flow is conveyed over the mature *Arundo* stands but considerable roughness is

created by the stems and leaves. During very great flows, the *Arundo* stems may be broken off and carried downstream, substantially altering local resistance to flow.

Hydraulic modeling of four different floodplain vegetation scenarios (all *Arundo*, all native, all bare, 1997 field conditions) suggested that the conversion from native vegetation to complete coverage by mature *Arundo* stands would have three important implications. First, 100-year water levels are raised by 3 or 4 feet from the increased roughness. Second, the portion of the total discharge carried in the main channel increases and, thus, depths and velocities also increase for a particular return period flood. Third, the (modeled) conveyance on the floodplain is much less with *Arundo* infestation.

There are some interesting and significant subtleties suggested by the hydraulic modeling. First, there appears to be a threshold for *Arundo* coverage before there are significant effects on hydraulics. The exact portion of the floodplain that must be occupied for a significant effect is not fully understood. Second, the magnitude of the effect on hydraulics of *Arundo* infestation and the threshold for observing significant effects depends on the overall floodplain and channel width. Narrow total widths show less effect for a particular flood than wide ones, likely because there is less conveyance on the narrow floodplains for the native vegetation scenario, so there is a smaller increase in flows in the main channel when *Arundo* coverage is complete. Note that velocities are higher in the narrower reaches; the above differences refer only to the observed percentage increases with the *Arundo* scenario in the hydraulic model.

The results of the hydraulic model studies are limited because they do not account for channel adjustments that are expected to occur rapidly in response to the altered hydraulics on the floodplain and in the main channel. Stream power calculations, which were adopted as a proxy for sediment transport, show greatly increased stream power in the main channel and greatly reduced stream power exerted on the floodplain under complete *Arundo* coverage, when compared to native vegetation, and a smaller increase and smaller decrease for partial coverage (Scenario 4). The consequences of the changes in stream power (or any measure of forces exerted on the bed) when banks are less erodible because of *Arundo* establishment are expected to be increased depths of the main channel and sediment trapping and accretion on the floodplain and in overbank areas. Regime considerations suggest that average depths might increase by about 50% to 100% for frequent floods to compensate for the narrowed channel. However, this is only a rough estimate and has not been confirmed with field surveys or measurements.

Both of the channel responses described above change the sediment storage in the project reach on the Santa Margarita River and potentially affect the delivery of sediment from the upper watershed to downstream reaches and the Pacific Ocean. Considering only the sediment balance for sand, and relying on accretion rates observed in the literature, it appears that the annual loss of sand to trapping on the floodplain during *Arundo* establishment is much larger than the compensating erosion from the adjustments of the channel. In the Santa Margarita River project reach, the net deposition on the floodplain is a very large portion of the sand carried down from the upper watershed. As discussed, different conclusions might be drawn for rivers with much wider or much narrower floodplains.

Once *Arundo* reaches its maximum coverage, floodplain trapping and channel adjustments will eventually cease, and delivery from the upper watershed to the reach will equal that which passes through to downstream reaches and the Pacific Ocean.

5.1.5. Study Stream Arundo Responses

5.1.5.1 Introduction

This section applies the results of the literature review (section 5.1.3) and the case study analysis (section 5.1.4) to develop a method to qualitatively assess the potential impacts of *Arundo* infestation on river hydraulics, sediment transport capacity and geomorphology. Once developed, the method is applied to the Santa Margarita, Santa Ana and San Luis Rey Rivers, utilizing the river and riparian vegetation characteristics provided in Chapter 5.1.3. Stream responses to *Arundo* discussed in this chapter are based on the maximum extent of *Arundo* mapped in these study reaches by Cal-IPC, as presented in Chapter 5.1.3.

5.1.5.2 *Arundo* Impact Scoring System

The potential impacts of *Arundo* infestation on river characteristics and, to some extent, the potential impacts of reach characteristics on the maximum extent of *Arundo* coverage, were qualitatively assessed by totaling scores that were developed from the key findings and observations from the literature review, Santa Margarita River case study and GIS mapping effort (Chapter 5.1.3).

The Width Ratio and *Arundo* Coverage scores express the potential for modification of the river as a result of *Arundo* Infestation. The Changes in Floodplain Width and Bed Slope, and Other Features scores express the potential for *Arundo* to dominate the riparian vegetation on the floodplain in the reach. We have defined the *Arundo* Impact Score to be the sum of the individual scores, as defined below. As scores increase, significant changes in river characteristics become more likely and differences between the *Arundo* and native vegetation river characteristics become greater. The specific impacts of *Arundo* on river characteristics are likely to be different in each stream reach and river system; however, the general effects will be similar to those described in Sections 5.1.2.4 and 5.1.4.9.

Width Ratio Score

The Santa Margarita River case study demonstrated that wider floodplain reaches may have a greater hydraulic response to *Arundo* infestation than narrower ones. A score was developed based on this observation using the Width Ratio (see Chapter 5.1.3), which is the ratio of the low flow channel width to the floodplain width (Table 5-1.11).

Table 5-1.11. Width ratio score.

Width Ratio	Width Ratio Factor	Comment
Below 4%	2	Wide floodplain reach
4% - 8%	0	Average width floodplain reach
Above 8%	-1	Narrow floodplain reach, typically confined by either topography or levees

Width ratios of 4% and 8% were selected as the cut-offs between wide, average, and narrow floodplain categories, based on the differences observed between Sub-reach 3 (wide floodplain) and Sub-reach 5 (narrow floodplain) in the Santa Margarita case study. Note that Sub-reach 3 is Reach 6 (width ratio =

3.8%) and Sub-reach 5 is Reach 8 (width ratio = 7.0%) in Table 5-1.1. The scores assigned to the different width ratios is shown in Table 5-1.11.

Arundo Coverage Score

The Santa Margarita case study suggested that a threshold of floodplain coverage by mature *Arundo* exists, below which impacts on average depths and water surface profiles are relatively insignificant. This percent coverage seemed to be between 28% and 45% *Arundo* coverage for the case study river (see Section 5.1.4.6). Table 5-1.12 shows the scoring that was developed based on the percent *Arundo* Coverage mapped for each reach in section 5.1.3. Cut-off points of 25% and 40% were selected for scoring the impact of percent *Arundo* cover on river characteristics.

Table 5-1.12. *Arundo* coverage score.

% *Arundo* Coverage	*Arundo* Coverage Factor	Comment
Below 25%	0	The effects of *Arundo* on hydraulics may not be significant in this reach
25% - 40%	1	This range of *Arundo* coverage represents a transition zone within which significant impacts to the water surface profile and consequently river hydraulics and sediment transport and geomorphology may occur
Above 40%	3	High percent *Arundo* coverage suggests this reach provides optimal conditions for *Arundo* establishment and changes in hydraulic, sediment transport and geomorphic effects are likely to be significant

Changes in Floodplain Width and Bed Slope Scores

The GIS analysis in Section 5.1.3 showed a relationship between the maximum percent *Arundo* coverage observed in a reach by Cal-IPC and changes in floodplain width and bed slope relative to the reach upstream. As previously discussed, large increases in floodplain width and declines in bed slope contribute to decreased flow velocities and sediment transport capacity. This promotes deposition and increases the likelihood of *Arundo* dispersal in that reach. Conversely, abrupt declines in floodplain width or increases in bed slope may promote the opposite effect and limit *Arundo* propagules from depositing.

Chapter 5.1.3 also noted there may be an upper slope limit for significant *Arundo* coverage in the floodplain vegetation that may be a proxy for a number of other factors. Also, the above discussion does not apply to river estuary reaches where salt water intrusion restricts *Arundo* growth and coverage. This is a narrow range, however, as *Arundo* tolerates up to 90% salt water.

Large increases (>100%) in floodplain width relative to the reach upstream are observed in Reach 7 of the Santa Margarita River, Reach 6 of the San Luis Rey, and Reaches 2 and 4 of the Santa Ana River. Each reach exhibits either a large (>50%) increase in *Arundo* cover from the reach upstream and more than 40% total *Arundo* cover. Conversely, Reach 3 of the Santa Ana River exhibits a 100% decline in floodplain width and nearly 50% decline in percent *Arundo* cover relative to the reach upstream. The scores associated with changes in floodplain width are summarized in Table 5-1.13.

Large decreases (>33%) in bed slope relative to the reach upstream are observed in Reach 7 of the Santa Margarita River, Reaches 2, 4 and 8 of the San Luis Rey, and Reach 3 of the Santa Ana River. Reach 7 exhibits greater than 45% *Arundo* cover and Reaches 2 and 4 exhibit large (>33%) increases in percent *Arundo* cover relative to the reach upstream. Reach 3 shows a decline in percent *Arundo* cover, possibly because of a large decline in floodplain width, and Reach 8 has negligible *Arundo* cover as does the reach upstream. The effect of changes in channel bed slope on the *Arundo* impact score are summarized in Table 5-1.14.

Table 5-1.13. Floodplain width score.

% Change in Floodplain Width	Floodplain Width Factor	Comment
>100% Decrease	-1	Flow confinement promotes higher average flow velocity, limiting the potential for deposition of *Arundo* propagules in this reach
Less than 100% Change	0	Changes in floodplain width may be significant in affecting the deposition of *Arundo* propagules but do not show a clear impact.
>100% Increase	1	Floodplain widening promotes a decline in average flow velocity and promotes deposition of *Arundo* propagules in this reach.

Table 5-1.14. Bed slope score.

% Change in Bed Slope	Bed Slope Factor	Comment
>33% Decrease	1	Decreases in bed slope promote lower average flow velocity which favors the deposition of *Arundo* propagules in this reach.
Less than 33% Change	0	Changes in bed slope may be significant in affecting the deposition of *Arundo* propagules but do not show a clear impact.
>33% Increase	-1	Increases in bed slope promote higher average flow velocity, limiting the potential for deposition of *Arundo* propagules in this reach

Other Features

Other features not already incorporated into the *Arundo* impact score are also indentified and, if present, provide an additional factor of '1' or '-1' depending on the feature observed. These include salt water intrusion that limits *Arundo* growth at the river mouth, and anthropogenic features that could potentially influence *Arundo* impacts on a river reach. Features specific to each stream are discussed in the next section.

5.1.5.3 Santa Margarita River

Table 5.5 shows the *Arundo* impact scores for the Santa Margarita River study reaches (Figure 5-1.1 shows reaches). Note that the case study Sub-reaches 1 through 6 conform to Reaches 4 through 9 in the GIS mapping in Chapter 5.1.3.

Table 5-1.15. Santa Margarita River *Arundo* impact scores.

Reach	Reach length (mi)	Case Study Sub-Reach	*Total Score*	*Arundo* Impact Scores				
				Width Ratio	*Arundo* Coverage	Floodplain Width	Bed Slope	Other Features
1	1.52		***-1***	-1	0	0	1	-1
2	1.47		***-1***	-1	0	0	0	0
3	1.70		***0***	0	0	0	0	0
4	0.42	1	***2***	2	0	0	0	0
5	0.90	2	***6***	2	3	0	1	0
6	1.30	3	***2***	2	1	0	-1	0
7	0.42	4	***7***	2	3	1	1	0
8	1.60	5	***4***	0	3	0	0	1
9	0.77	6	***0***	-1	0	0	0	1
10	1.21		***0***	-1	0	0	0	1
11	1.89		***-1***	-1	0	0	0	0
12	4.11		***-1***	-1	0	n/a	n/a	0

Table 5-1.15 shows that Reaches 4 through 8 (Sub-reaches 1 through 5) are the most susceptible to changes in river form and process from *Arundo* infestation. For the most part, these reaches have low slopes, wide floodplains with abundant opportunity for *Arundo* establishment and propagation, and historically large areas of *Arundo* stands. Other features that affect *Arundo* distribution and potential impacts on river characteristics includes salt water that limits *Arundo* growth in Reach 1 and groundwater recharge from Lake O'Neill and infiltration ponds in Reaches 8, 9 and 10 that provides additional water.

Table 5-1.15 identifies sub-reaches 2 and 4 as those where *Arundo* is likely to exert the greatest impact on river characteristics. Such a result is reasonably consistent with the case study observations in section 5.1.4. Sub-reach 4 does show a rise in the water surface profile compared to the base case (Figure 5-1.11) and other modifications to the reach hydraulics occur. Sub-reach 2 shows no rise in the water surface profile (Figure 5-1.11); instead, the increased flow through the main channel is accommodated by increases in velocities. The highest scoring contiguous river sections (Reaches 4 to 8) is about 8 miles long. This is a significant portion of the river.

5.1.5.4 San Luis Rey River

Table 5-1.16 shows the *Arundo* impact scores for the San Luis Rey study reaches. Based on this table, the greatest modification to river characteristics from *Arundo* impacts are expected to be in Reaches 2 and 4. *Arundo* has also historically been well established in Reaches 3 and 5 but they do not score very high due to floodplain confinement by urban levees. Further upstream, in Reaches 8 through 11, a score of -3 was assigned in Other Features to reflect that these steeper reaches have little or no *Arundo* in their floodplain vegetations, suggesting that *Arundo* has not successfully colonized this area. This may be a

result of steep bed slopes in these upper reaches that reduce opportunities for *Arundo* establishment, or lack of source propagules or plants.

The overall scores for the San Luis Rey River reaches are considerable less than for the Santa Margarita River reaches suggesting that *Arundo* impacts on river forms and processes may be less significant. However, Reaches 2, 4 and 6 constitute most of the functional lower river (9 mi), and these areas are impacted. Reaches 3 and 5 only function to convey water, and they have limited geomorphic or biologic function.

Table 5-1.16. San Luis Rey *Arundo* impact scores.

Reach	Reach length (mi)	*Total Score*	*Arundo* Impact Scores				
			Width Ratio	*Arundo* Coverage	Floodplain Width	Bed Slope	Other Features
1	0.86	***-1***	-1	0	0	1	-1
2	1.66	***3***	-1	3	0	1	0
3	5.79	***-1***	-1	0	0	0	0
4	5.53	***2***	0	1	0	1	0
5	0.62	***-1***	0	0	-1	0	0
6	5.07	***1***	0	0	1	0	0
7	3.73	***-2***	-1	0	-1	0	0
8	3.73	***0***	2	0	0	1	-3
9	2.03	***-1***	2	0	0	0	-3
10	2.01	***-5***	0	0	-1	-1	-3
11	1.16	***-1***	2	0	n/a	n/a	-3

5.1.5.5 Santa Ana River

Table 5-1.17 summarizes the *Arundo* Impact scores for the Santa Ana River reaches (Figure 3-2 shows reaches). Based on these scores, the greatest modification to river processes and form are expected to occur in Reaches 1 and 2. Note that Reach 1 is in the Prado Flood Control Basin and *Arundo* establishment and spread will be different than in other reaches because of basin filling during large runoff events and long-term sediment deposition.

Reach 2 has a meandering channel that flows through a shallow valley. The wide floodplain provides substantial opportunity for *Arundo* establishment and the gradual reduction in slope down the reach and its location downstream of a steeper, more confined Reach 3 also contribute to the high score. Impacts of *Arundo* on river form and process are expected to similar to those observed in the Santa Margarita River here. It should be noted that Reach 2 is very long (8 mi), equaling the length of 3-5 reaches on the San Luis Rey or Santa Margarita. Impacts to reaches 1 and 2 total 10 miles, and this is most of the broad floodplain on the river.

Table 5-1.17. Santa Ana River *Arundo* impact scores.

Reach	Reach length (mi)	*Total Score*	*Arundo* Impact Scores				
			Width Ratio	*Arundo* Coverage	Floodplain Width	Bed Slope	Other Features
1	3.16	***5***	2	0	1	1	1
2	12.17	***4***	0	3	1	0	0
3	2.08	***-1***	-1	0	-1	1	0
4	2.35	***0***	-1	0	1	0	0
5	9.67	***0***	-1	0	0	1	0
6	3.98	***-2***	-1	0	-1	0	0
7	3.44	***-1***	-1	0	n/a	n/a	0

5.1.5.6 Application of Scoring System

The scoring system proposed above is preliminary and might be modified based on experience and further analyses of river response to *Arundo* infestation by adjusting scoring or weighting of the different scores. At this time, the scoring system can be used to identify and rank those river reaches where *Arundo* establishment is likely to have significant effects on river hydraulics, sediment transport and morphology. This could be used to prioritize areas for additional monitoring to look at: flood risk damage (bridges and overbank), sediment retention and loss, as well as setting control priorities and/or temporary reduction of vegetation to maintain flows.

5.1.6. Conclusions and Recommendations

The overall goal of this study was to describe the potential effects of *Arundo* establishment and growth on the hydraulics, sediment transport characteristics and morphology in Southern California Rivers. The study results are based on literature review, GIS analysis of river and floodplain vegetation characteristics, and hydraulic modeling of four floodplain vegetation scenarios on the Santa Margarita River.

Arundo is a highly aggressive, non-native plant species that has invaded riparian areas and floodplains of the sandy, braided Southern California Rivers, displacing native plants and degrading habitats. These historically braided and laterally unstable channels are transformed by *Arundo* into narrower, more laterally stable single thread channels with root-stabilized, steep banks. Inspection of historical air photos suggest that there has been much less channel widening from recent large floods than occurred earlier, presumably because of the replacement of native floodplain vegetation with much denser *Arundo* stands. In any event, it appears that if sufficient soil moisture is available *Arundo* will out-compete native vegetation on the disturbed floodplains and re-establish mature stands on much of the floodplain in the time interval between very large floods.

Plant colonization stabilizes bar and floodplain surfaces, increasing channel roughness and sediment trapping efficiency, thereby creating a mechanism for further sediment capture, deposition and vertical accretion. Long-term observed rates of vertical accretion on the floodplain vary widely in the reported literature but are as high as 0.8 ft/yr. Several feet may accumulate locally during a large flood.

Accretion rates likely vary with the volume of sediment in transport as well as the specific river conditions. There may be an upper limit on vertical accretion, which would about correspond to the elevations of typical floods. This may be reached fairly soon if the channel bed incises or does not accrete as rapidly as the floodplain. If the channel bed fills as the floodplain accretes, this limit may not be reached for a long time. Human modification to upstream and downstream reaches (such as levees or bridges) and to flood flows and sediment supply (such as by reservoir construction or groundwater recharge) may alter river and *Arundo* establishment processes and affect the above observations on river response to *Arundo* establishment and growth.

Hydraulic modeling and field inspection suggests that the mature *Arundo* stands essentially eliminate flow conveyance during low and moderate floods on the portions of the floodplain that they occupy, increasing the portion of the flow passing through the low flow or active channel. During large peak flows, when water levels are about 5 feet higher than the floodplain surface, flow that is conveyed over the mature *Arundo* stands also slows as considerable roughness is created by the stems and leaves. During very large flow events, the *Arundo* rhizomes and stems may be carried downstream, substantially altering local resistance to flow. Modeling of different floodplain vegetation scenarios suggested that the conversion from native vegetation to complete coverage by mature *Arundo* stands has three important implications. First, 100-year water levels are raised by the increased roughness. Second, the portion of the total discharge carried in the main channel increases and, thus, depths and velocities for a particular return period flood. Third the conveyance on the floodplain is much less. The hydraulic model does not include morphologic change that results from the altered depths and velocities and these may eventually mute the increases in water levels during floods.

There are some interesting subtleties suggested by the hydraulic modeling. First, there appears to be a threshold for *Arundo* coverage before there are significant effects on hydraulics. The exact portion of the floodplain that must be occupied for a significant effect is not fully understood. Second, the threshold for observing significant effects and the percentage increase in velocities and sediment transport capacity in the main channel seems to depend on the ratio of the main channel width and floodplain width. Where the channel is wide relative to the floodplain, there is less effect on velocities and sediment transport capacity for a particular flood than where the channel is narrow compared to the floodplain. This is thought to occur because there is less conveyance on the narrower floodplains compared to the main channel, so there is a smaller increase in flows in the main channel when *Arundo* coverage is complete and conveyance on the floodplain is reduced.

The results of the hydraulic model studies are limited because they do not account for the channel adjustments that are likely to occur rapidly in response to the altered hydraulics on the floodplain and in the main channel. Stream power calculations, which were adopted as a proxy for sediment transport, show greatly increased stream power in the main channel and greatly reduced stream power exerted on the floodplain under complete *Arundo* coverage, when compared to native vegetation, and a smaller increase and smaller decrease for partial coverage (Scenario 4). The consequences of the changes in stream power when banks are less erodible because of *Arundo* establishment are expected to be increased depths in the main channel and sediment trapping and accretion on the floodplain and in overbank areas. Regime considerations suggest that channel depths should increase to accommodate frequent floods, as compensation for the narrowed channel. Part of this increase may result from higher floodplain elevations rather than from channel incision or bed lowering.

Both channel responses described above change the sediment storage in the project reach on the Santa Margarita River and potentially affect the delivery of sediment from the upper watershed to downstream reaches and the Pacific Ocean. Considering the sediment balance for sand, and basing accretion rates on those observed in the literature, it appears that the trapping of sand on the floodplain in *Arundo* stands is large compared to the inflow from the upper watershed. The trapping on the floodplain may be partly

compensated by erosion of the stream bed to accommodate flood flows with the narrower channel but this gain to downstream reaches appears to be considerably smaller than the trapping on the floodplain. These conclusions are also appropriate for the Santa Ana and San Luis Rey Rivers but different ones might be drawn for rivers with much wider or much narrower floodplains, or those where channel filling or other conditions allows extensive floodplain accretion. In the long-term, as accretion on the floodplain slows, the sand transported out of the study reaches will return to being about equal to the supply from the upper watershed.

Based on the above results, the study developed a qualitative scoring system that can be applied to measured river and floodplain vegetation characteristics to identify those reaches where significant impacts on river processes may occur. Total scores that reflect potential *Arundo* impacts were developed by summing scores for the ratio of low flow channel width to floodplain width, the percentage of *Arundo* on the floodplain and the changes in floodplain width and channel slope from one reach to the next downstream one. The scoring system was reasonably consistent with the modeled hydraulic impacts on the Santa Margarita River and thus was thought to be appropriate for the Santa Ana and San Luis Rey Rivers.

Application of the scoring systems suggests that impacts on river form and process are less significant in the Santa Ana and San Luis Rey Rivers than in the Santa Margarita River project reaches, with the possible exception of Reach 2 of the Santa Ana River.

While the scoring system is preliminary it provides a simple procedure to identify those reaches where the riverine response to *Arundo* infestation may be most severe and also provides a useful tool to identify those reaches where monitoring may be concentrated.

5.2 Geomorphology and Hydrology: Spatial Analysis

5.2.1 Arundo's Distribution Within Geomorphic Forms

5.2.1.1 Methods

Geomorphology Attributes and Methods

Methods used to delineate floodplain geomorphic forms involved visual interpretation of imagery and topological data within a GIS. Due to time constraints and budget, groundtruthing and follow-up field *surveys were not possible at this time. Guidelines for defining geomorphic forms were based on the Riparian Ecosystem Restoration Plan for the Otay River Watershed (Army Corps of Engineers 2006) and consultations from staff at NHC.* Issues involving criteria for delineating terraces within the floodplain and the subjectivity of this classification was thoroughly discussed. Considering the subjectivity, several rounds of sample data and images were reviewed to determine the efficacy in characterizing geomorphic forms for each analysis. The most recently available imagery was used for each watershed.

San Luis Rey was used as a test case to work through the methodology. Other watersheds were completed after an approach was established. Using base imagery from ESRI, Google Earth, and Bing 3D pictometry (where available), areas of interest were reviewed to develop visual recognition of the potential terrace structures. Additionally, several sample locations and field photos taken by the analyst previously from the *Arundo* field mapping exercise were used to further visually train the analyst in the

separation of terrace forms. A significant number of images were gathered including several panoramas of the river valley that illustrate elevation changes.

The mapping delineation always started within the low flow channel and built out from this classification using the *Auto-Complete Polygon* tool in ArcGIS. The digitization was completed at a scale of 1:5,000. The following classifications (as described in Section 5.1.3.3) were selected:

- *Low Flow Channel* – The part of the main channel where water was flowing at the time of the aerial photos. In those cases where the riverbed is dry, the area appearing to have the most recent flows were delineated as low flow.
- *Bar / Channel / Floodplain - unvegetated* – Main channel or floodplain areas with less than 50% vegetation cover, usually consisting of bar surfaces, dry channel beds, or recent deposition or scour.
- *Floodplain - vegetated* – Areas on the river floodplain with more than 50% vegetation cover.
- *Floodplain / Low Terrace – vegetated* – Areas on either the river floodplain or an adjacent low terrace with more than 50% vegetation cover.
- *Upper Terrace - vegetated* – Areas on higher ground adjacent to the low terraces with more than 50% vegetation cover. This classification was rarely used in part because nearly all of the upper terrace areas on most rivers had been leveed or developed. The mapping did not go beyond levees or roads in most cases. In some specific areas where there were *Arundo* records, the levee sides were marked using this category. Hillslopes were typically not tagged unless they were surrounded by an apparent floodplain or if *Arundo* was present.

Terraces edges were extremely subjective because the field verification was not feasible and high-resolution elevation data was not available for all areas. One of several visual cues used to help delineate between terraces was based on the type and amount of vegetation present (USACE ref.).

There were instances where the imagery used to map geomorphology (usually 2006) did not match the same time period in which *Arundo* was mapped. These temporal mismatches caused alignment problems when *Arundo* stand mapping was compared to geomorphology mapping. Initial mapping/analysis placed large historical stands of *Arundo* in what are now the main low flow channel or sand bars. But in the time period when the *Arundo* stands were present, these areas were floodplain. The two rivers with the largest number of mismatched data were the San Luis Rey and Santa Margarita, which have had significant *Arundo* control. Both rivers had mapping data from the late 1990's and early 2000's reflecting areas that were controlled. Therefore, select geomorphic records were altered to match their historical form based on imagery that matched the mapping date of the *Arundo*. *Arundo* removal on the Santa Margarita has influenced the river channel geomorphology to change course and in many cases it allowed the river to revert back to having more open bars and seasonal channels.

5.2.1.2 Results

The area of interest (AOI) covers the six most *Arundo* invaded watersheds within the study area. This represents 77% of the gross *Arundo* acreage calculated for the entire study area (Figures 5-2.1 & 5-2.2). Since these are the most invaded areas, it is important to examine the distribution of *Arundo* within geomorphic forms found in the riparian zone.

The overall level of *Arundo* invasion for the AOI was 13% cover of the riparian zone (all geomorphic forms) (Figure 5-2.3, Table 5-2.1). Invasion levels of *Arundo* ranged from 8% to 16% cover for the AOI on the watersheds examined. There seem to be two levels of invasion on these large, broad watersheds: a higher level of 12-18%, and a lower level of 8-9%. Individual reaches within a riparian system can have much higher *Arundo* cover. Highly invaded reaches on Santa Ana and Santa Margarita had

invasion levels >40%. Establishing a 'peak level' of invasion over large areas is difficult to assess, but an upper range of 40-45% seems plausible (as the Santa Margarita River illustrates – Section 5.1).

An examination of *Arundo*'s distribution across geomorphic forms reveals that *Arundo* is relatively absent from the low flow channel (Figures 5-2.4 & 5-2.5, Tables 5-2.2 & 5-2.3). If *Arundo* was evenly distributed across geomorphic forms in proportion to a geomorphic class's acreage, it would have a distribution shown in Figures 5-2.6 to 5-2.11. There is less *Arundo* on all watersheds in the channel areas than would be predicted. This represents the high energy and dynamic riparian zone that has flows every year. Establishment and persistence of *Arundo* is difficult and little *Arundo* acreage (52 acres or 1.5%) of this form is invaded. Each watershed's geomorphic structure is shown in Figure 5-2.4 and Table 5-2.2 to allow examination of which forms dominate each system.

The bar/channel zone also has low cover of *Arundo* (102 acres of 6,575 acres, or 1.5 %). Much lower cover is present on each watershed than would be predicted if an even distribution of *Arundo* occurred (Figures 5-2.5 to 5-2.10). This is an active portion of the riparian floodplain with little vegetation, so it would be expected to have low cover of *Arundo*.

Most *Arundo* acreage is found in the floodplain and low terrace geomorphic forms (Figure 5-2.3, Tables 5-2.2 & 5-2.3). Floodplains have consistently high levels of invasion with an average of 19.7. As presented by watershed, *Arundo* cover exceeds predicted levels of distribution on all six watersheds (Figures 5-2.5 to 5-2.10). This is an important observation, as high *Arundo* cover in this geomorphic form tends to lock the low flow channel in a set location (Section 5.1).

Low terraces were also found to have high *Arundo* cover, averaging 15.4% (Table 5-2.3). Observed acreage was equivalent to, or higher than what would be predicted if an even distribution of *Arundo* occurred on most, but not all systems (Figures 5-2.5 to 5-2.10). Lower terraces, as a geomorphic form, vary significantly in acreage between watersheds (Figure 5-2.4, Table 5-2.2). Salinas and Santa Margarita have a significant proportion of this form, while Santa Ana has little. This is reflected in the *Arundo* acreages found on low terraces within these systems. Santa Clara is distinctly different due to a very low proportion of floodplain and terrace acreage. However, the floodplain and terrace acreage that does occur within a system is highly invaded with *Arundo*. Floodplain and low terrace geomorphic forms are a subjective distinction. These are essentially the more stable portions of the floodplain. They could be combined, but separating them helps characterize different watersheds.

Upper terraces comprise a small proportion of overall geomorphic composition for most watersheds (Figure 5-2.4, Table 5-2.3). Many of these areas have been developed or modified and are no longer part of the riparian system (examined in section 5.2.2). Where upper terraces do exist, they have a lower proportion of *Arundo* acreage than would be predicted if *Arundo* were evenly distributed. This is likely a result of the high elevation, which makes establishment and persistence of *Arundo* less common than the more hydrologically favorable floodplains and lower terraces

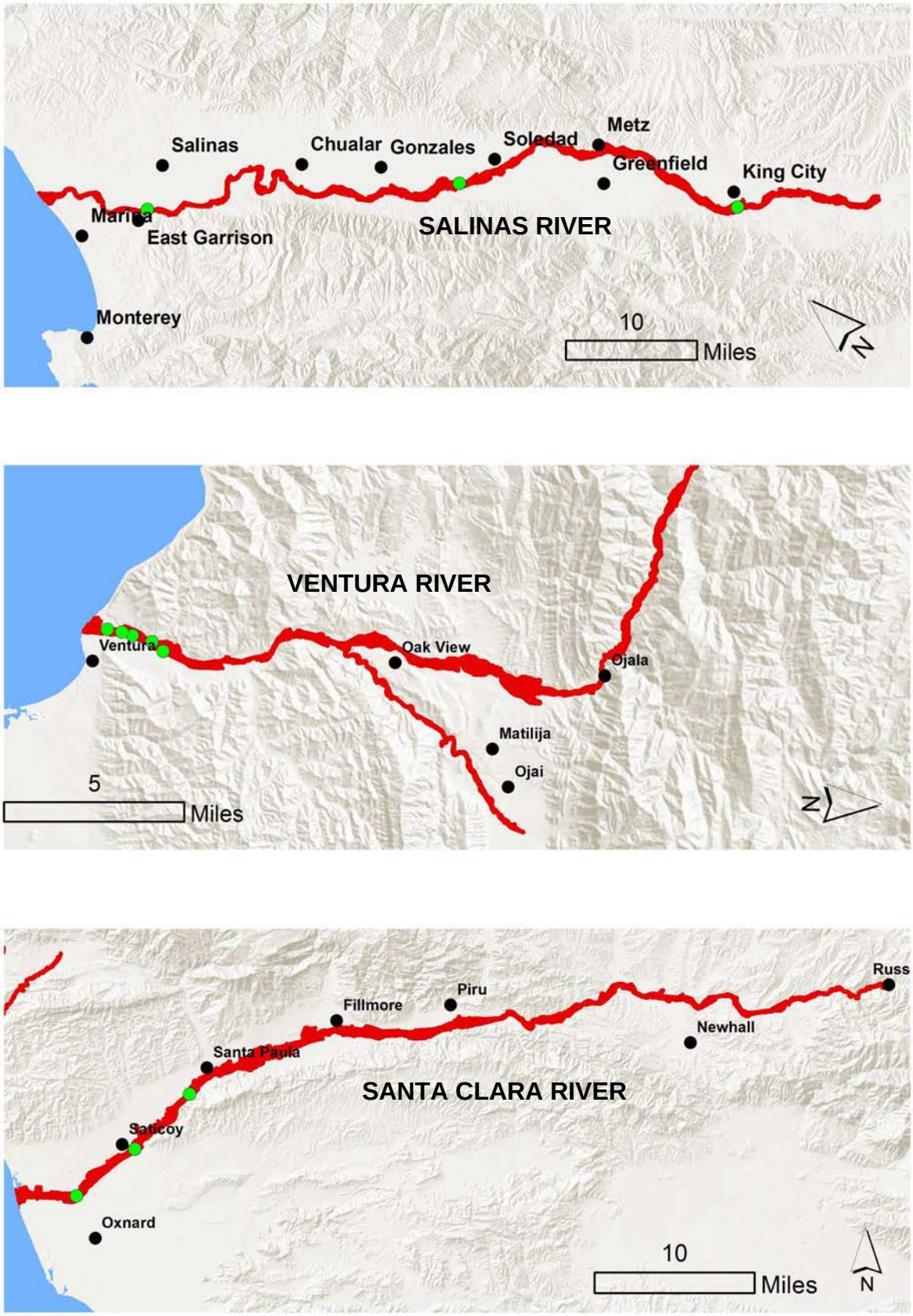


Figure 5-2.1. Location of the Area of Interest and cross-sections (northern watersheds).

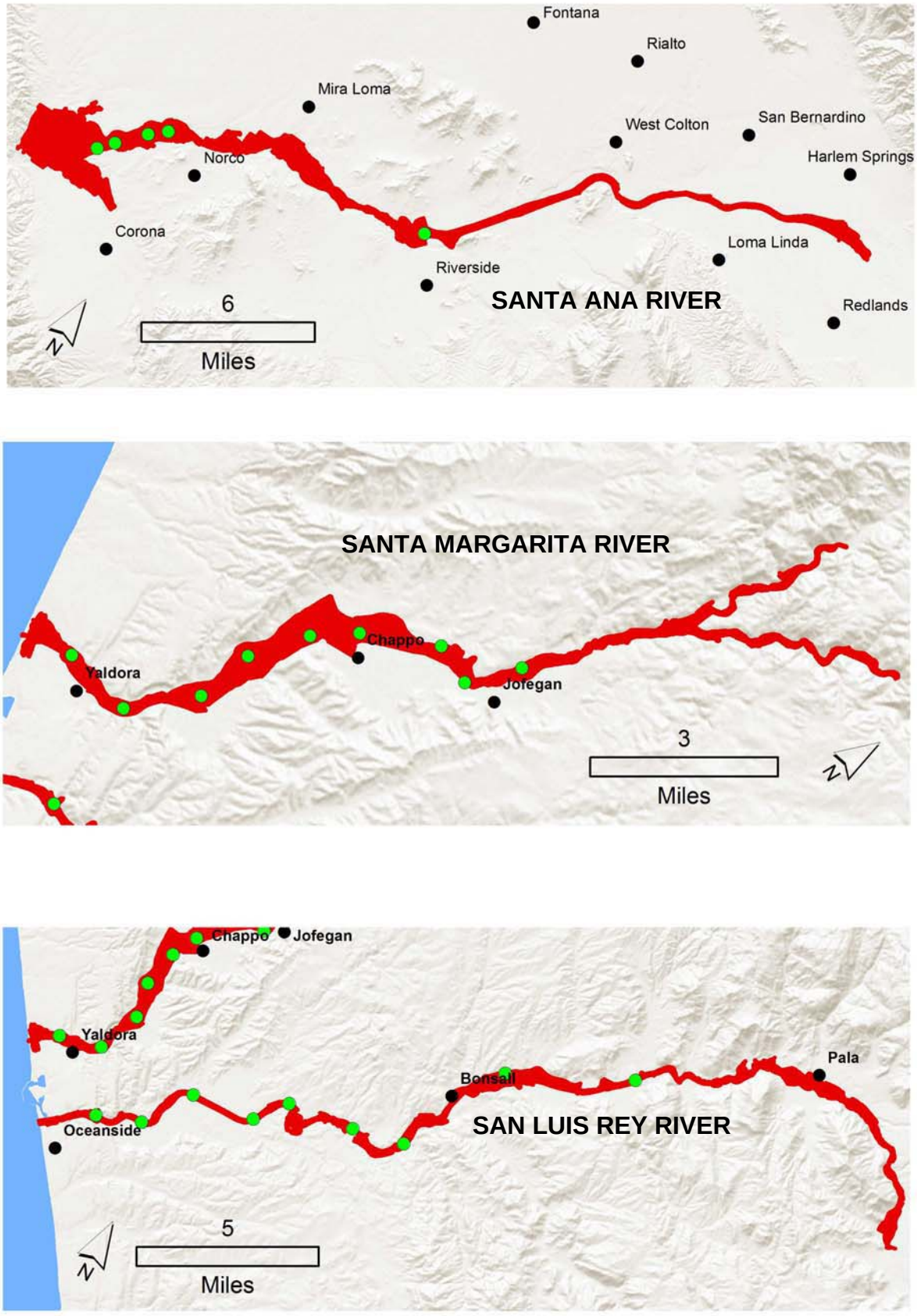


Figure 5-2.2. Location of the Area of Interest and cross-sections (southern watersheds).

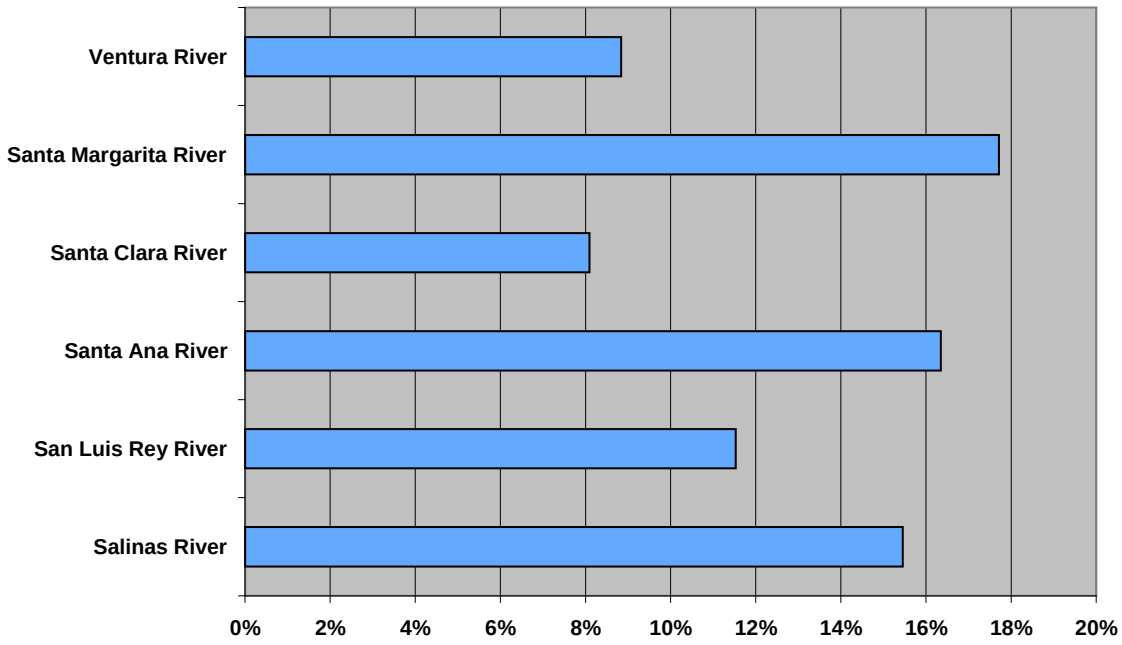


Figure 5-2.3. *Arundo* acreage as a percent of system acreage within the Area of Interest (AOI).

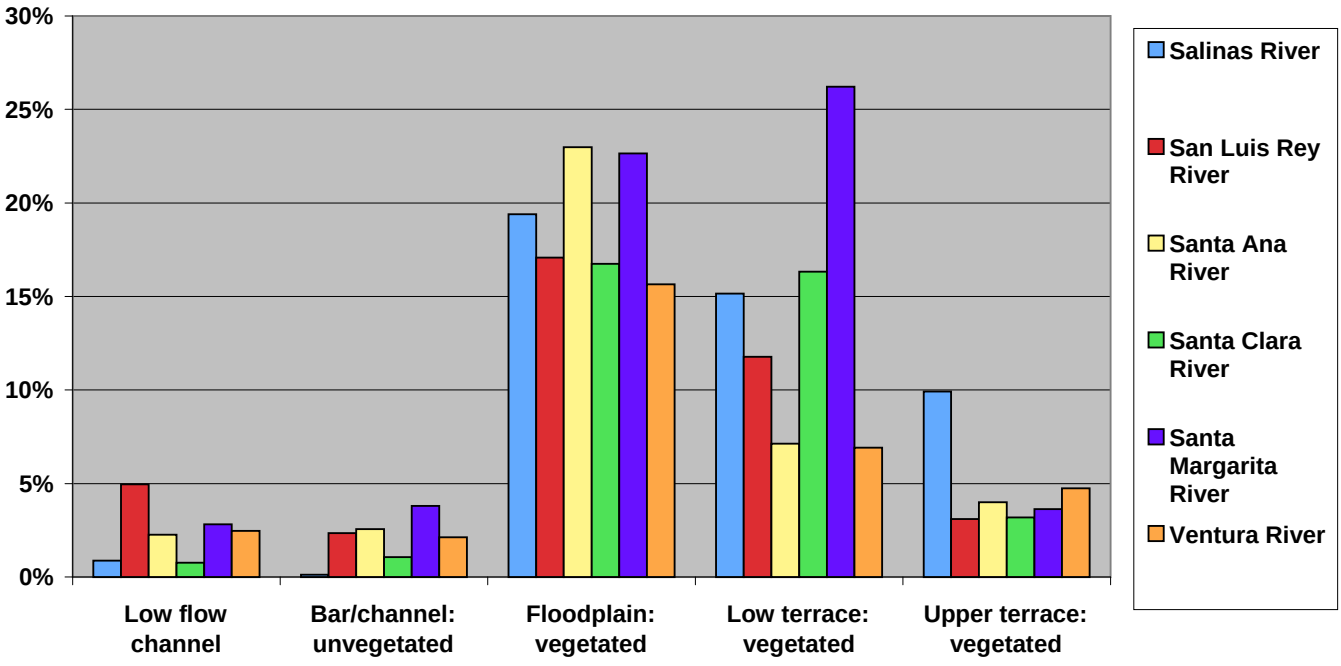


Figure 5-2.4. Percent of geomorphic form invaded by *Arundo* for the Area of Interest (AOI). This shows that the highest levels of invasion are in the floodplain and low-terrace geomorphic forms, regardless of the acreage of the geomorphic form itself.

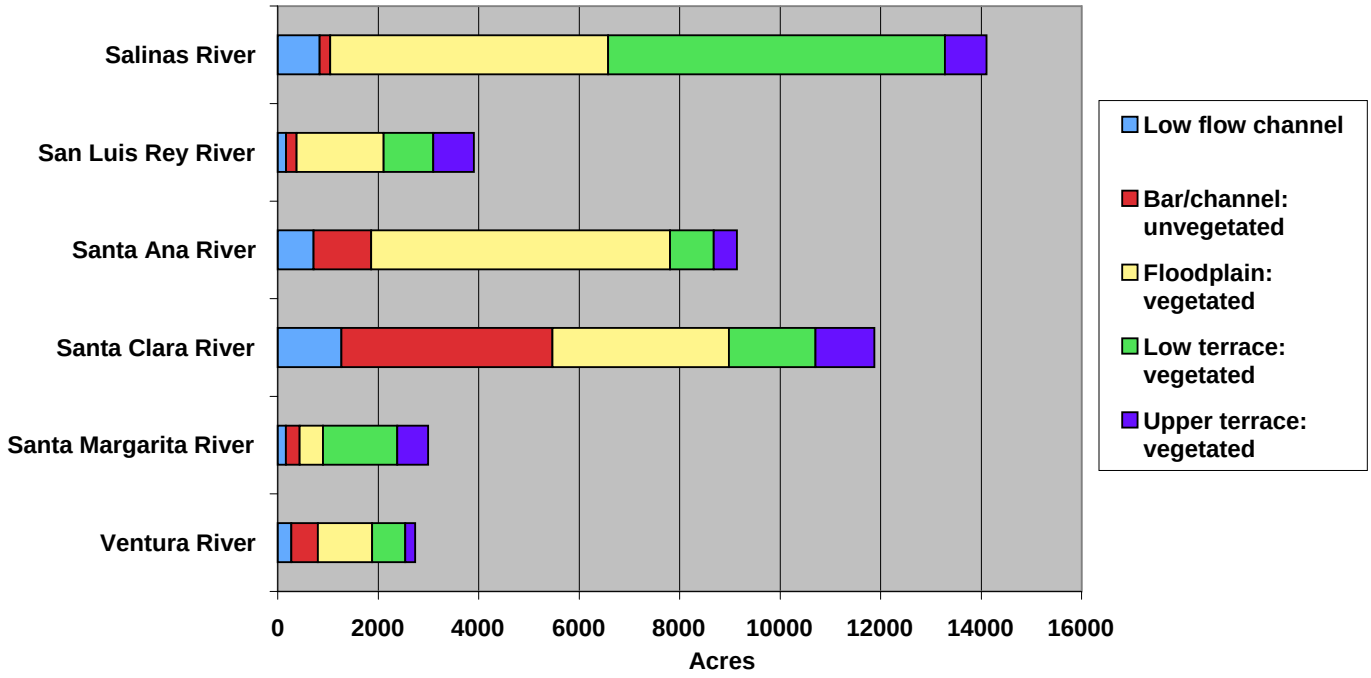


Figure 5-2.5. Acreage of geomorphic forms mapped within the Area of Interest (AOI). This shows that the floodplain and terrace forms dominate most systems (within the AOI).

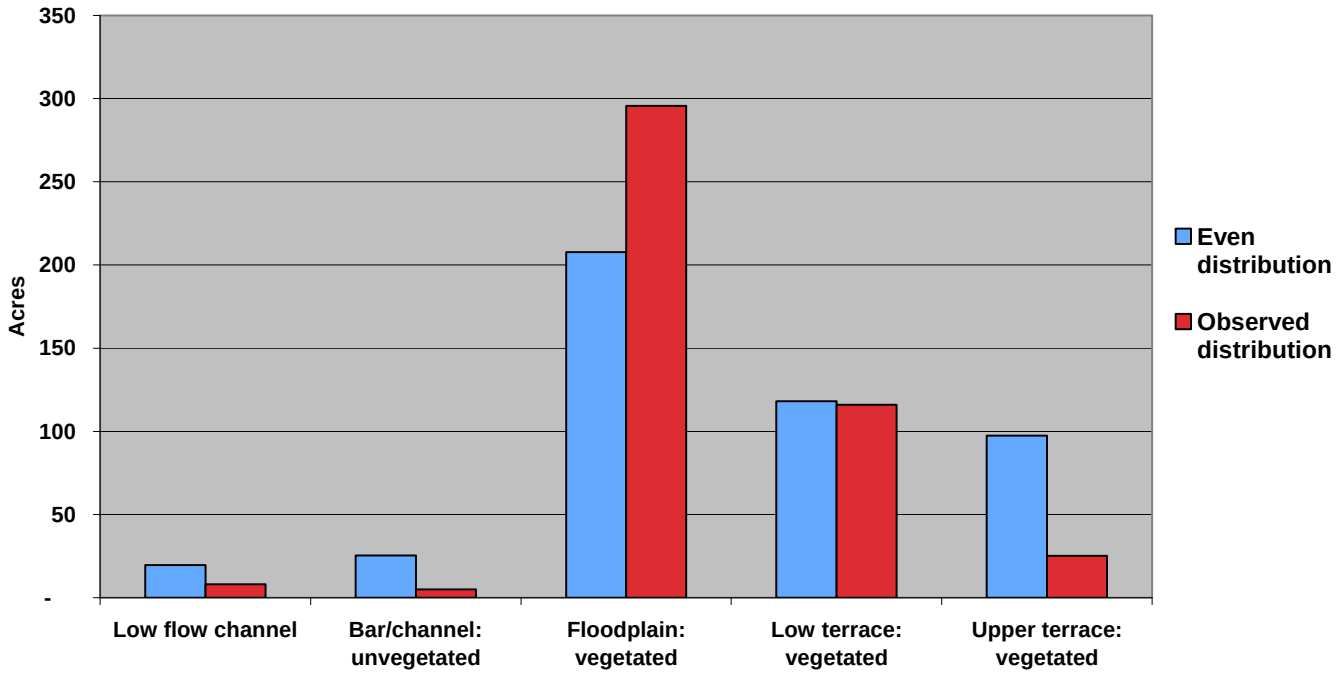


Figure 5-2.6. Observed and expected even distribution of *Arundo* acreage on the San Luis Rey watershed by geomorphic class.

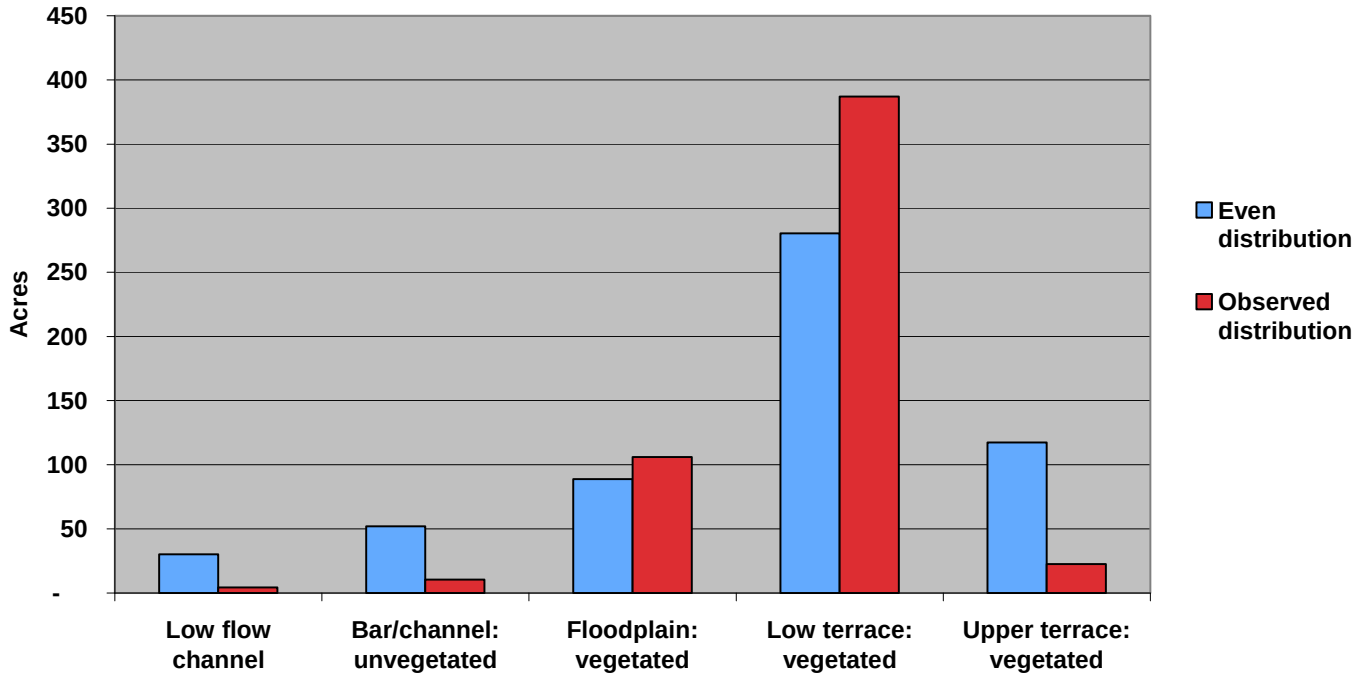


Figure 5-2.7. Observed and expected even distribution of *Arundo* acreage on the Santa Margarita watershed by geomorphic class.

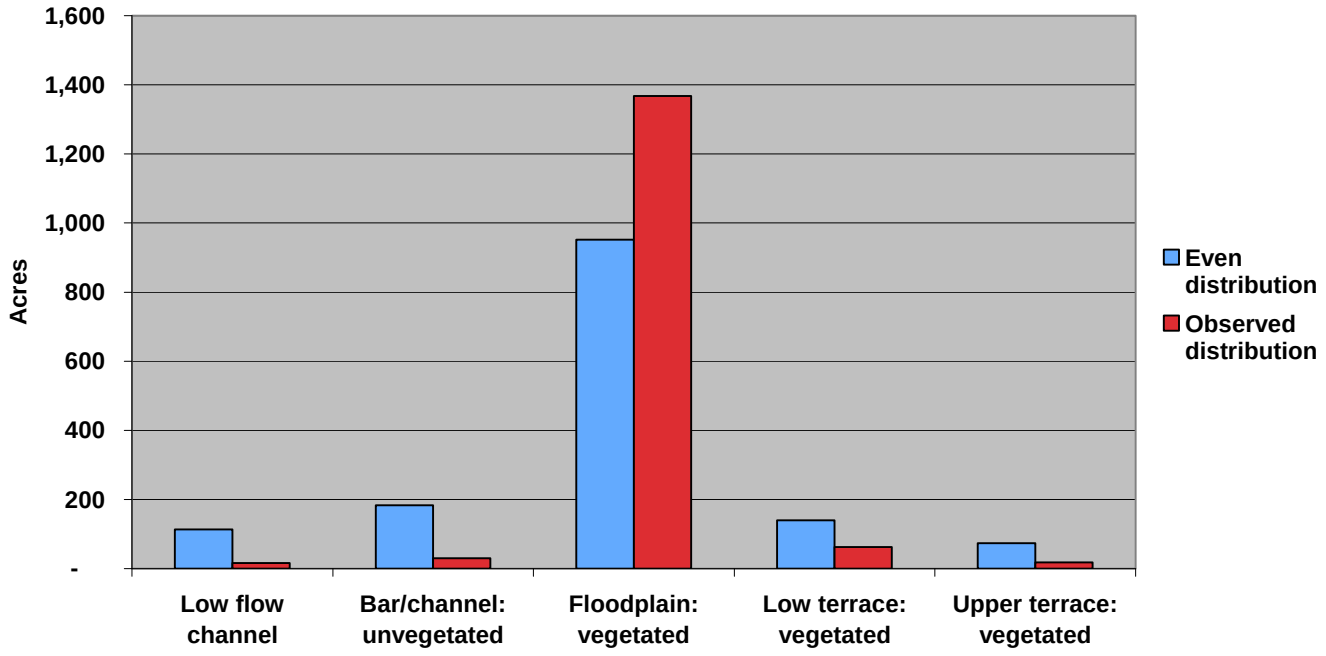


Figure 5-2.8. Observed and expected even distribution of *Arundo* acreage on the Santa Ana watershed by geomorphic class.

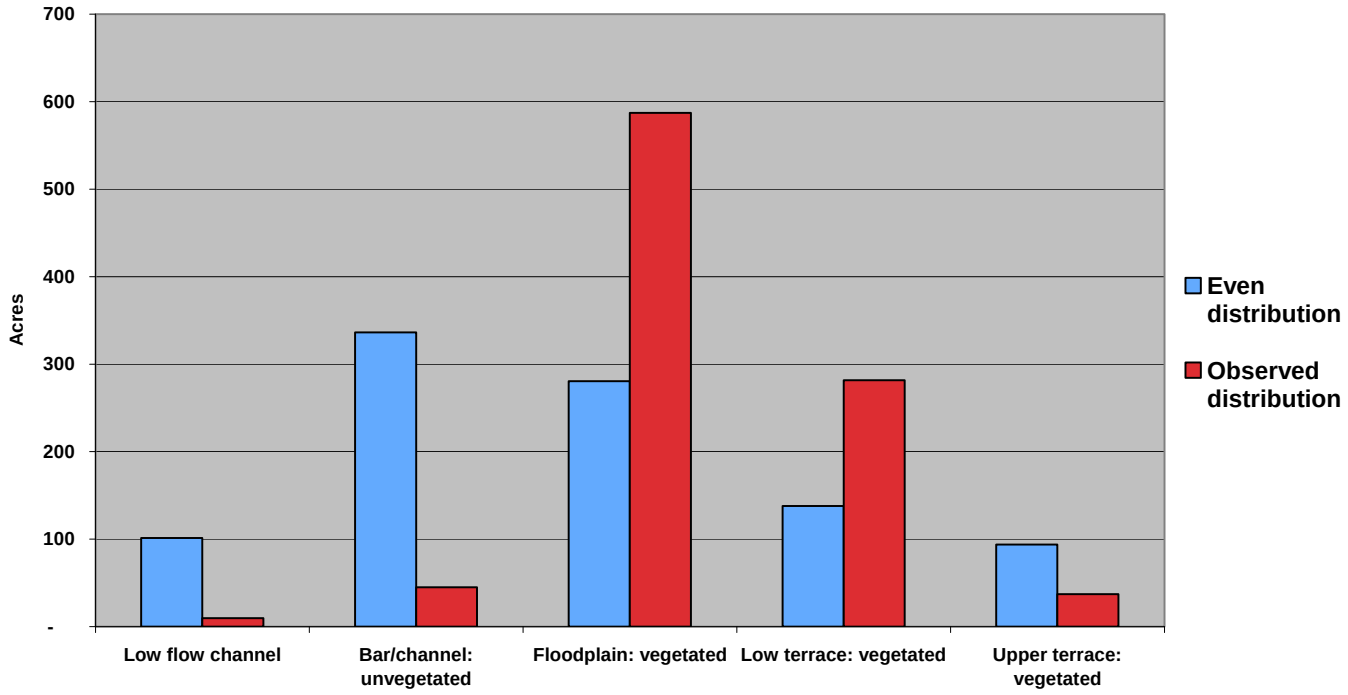


Figure 5-2.9. Observed and expected even distribution of *Arundo* acreage on the Santa Clara watershed by geomorphic class.
Santa Clara has much more low flow channel and bar/channel than the other systems.

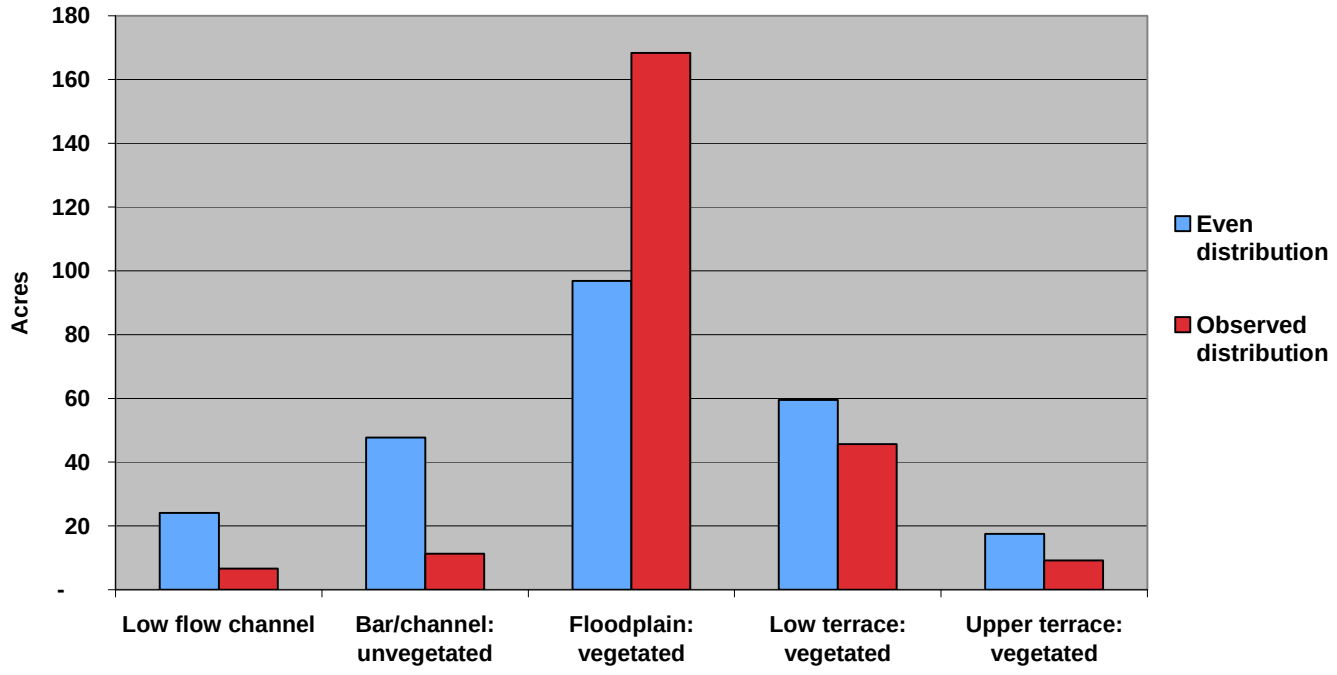


Figure 5-2.10. Observed and expected even distribution of *Arundo* acreage on the Ventura watershed by geomorphic class.

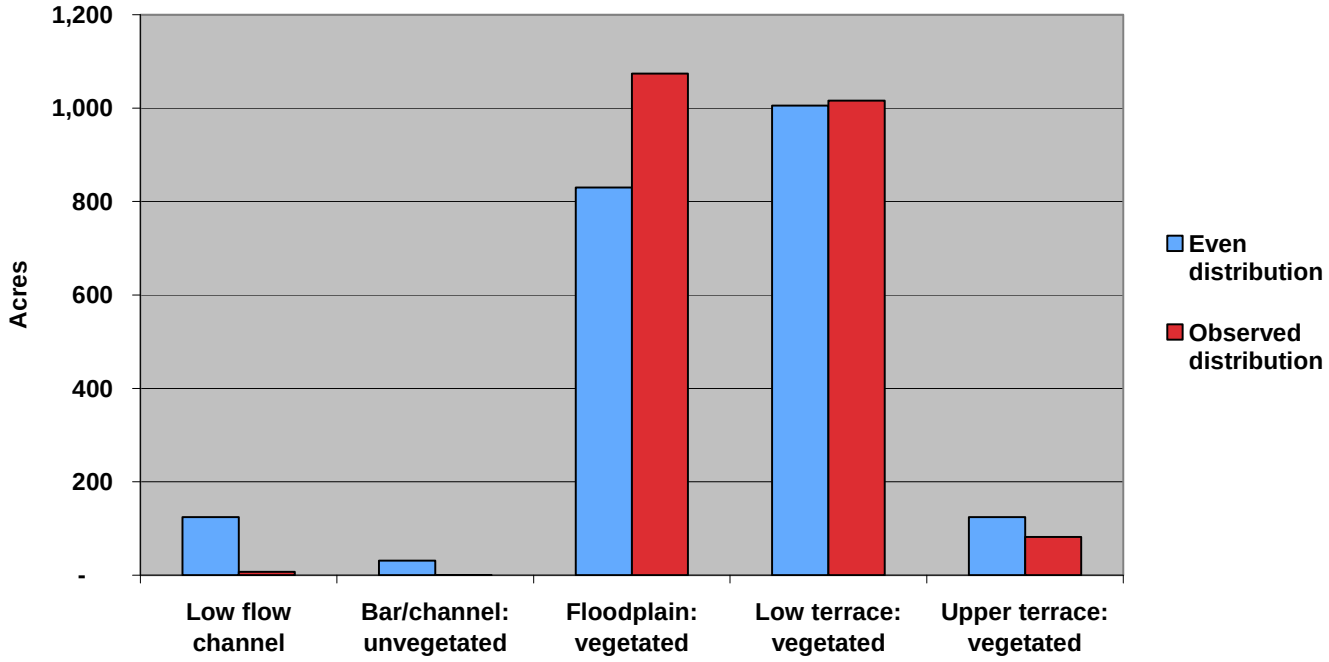


Figure 5-2.11. Observed and expected even distribution of *Arundo* acreage on the Salinas watershed by geomorphic class.

Table 5-2.1. *Arundo* and geomorphic acreage within the Area of Interest (AOI) for six selected watersheds.

Watershed (AOI area only)	*Arundo* Gross Acres	*Arundo* Net Acres	Geomorph Acres[1]	*Arundo* ac % system (net)
Salinas River	2,845	2,180	14,105	15%
San Luis Rey River	450	450	3,903	12%
Santa Ana River	1,674	1,493	9,136	16%
Santa Clara River	1,011	961	11,874	8%
Santa Margarita River	530	530	2,994	18%
Ventura River	321	241	2,730	9%
Total:	**6,831**	**5,855**	**44,741**	**13%**

[1]Geomorph areas: the acreage where geomorphic form was mapped within the AOI.

Table 5-2.2. *Arundo* and geomorphic class acreage within the AOI of six selected watersheds.

Watershed (AOI only)	Geomorphology Class	*Arundo* Gross Acres	*Arundo* Net Acres	Geomorph Gross Acres	% of geo class w/ *Arundo*
Salinas River	Low flow channel	8	7	829	1%
Salinas River	Bar/channel	0.4	0.3	209	0%
Salinas River	Floodplain	1,476	1,074	5,535	19%
Salinas River	Low terrace	1,269	1,016	6,704	15%
Salinas River	Upper terrace	92	82	828	10%
San Luis Rey River	Low flow channel	8	8	164	5%
San Luis Rey River	Bar/channel	5	5	211	2%
San Luis Rey River	Floodplain	296	296	1,731	17%
San Luis Rey River	Low terrace	116	116	984	12%
San Luis Rey River	Upper terrace	25	25	812	3%
Santa Ana River	Low flow channel	20	16	709	2%
Santa Ana River	Bar/channel	76	30	1,146	3%
Santa Ana River	Floodplain	1,492	1,367	5,948	23%
Santa Ana River	Low terrace	67	62	873	7%
Santa Ana River	Upper terrace	20	18	459	4%
Santa Clara River	Low flow channel	13	10	1,266	1%
Santa Clara River	Bar/channel	52	45	4,204	1%
Santa Clara River	Floodplain	624	587	3,506	17%
Santa Clara River	Low terrace	286	282	1,726	16%
Santa Clara River	Upper terrace	37	37	1,173	3%
S. Margarita River	Low flow channel	4	4	158	3%
S. Margarita River	Bar/channel	10	10	274	4%
S. Margarita River	Floodplain	106	106	468	23%
S. Margarita River	Low terrace	387	387	1476	26%
S. Margarita River	Upper terrace	22	22	618	4%
Ventura River	Low flow channel	10	7	267	2%
Ventura River	Bar/channel	21	11	530	2%
Ventura River	Floodplain	228	168	1,076	16%
Ventura River	Low terrace	52	46	661	7%
Ventura River	Upper terrace	9	9	194	5%
	Total:	**6,831**	**5,855**	**44,741**	**13%**

Table 5-2.3. *Arundo* and geomorphic class acreage for the entire AOI (all seven watersheds).

Geomorphologic Class	*Arundo* Present: Gross Acres	*Arundo* Present: Net Acres	Geomorphology Mapped (Current Day): Gross Acres	% *Arundo* (Net)
Low flow channel	63	52	3,393	1.5%
Bar/channel	165	102	6,575	1.5%
Floodplain	4,221	3,598	18,263	19.7%
Low terrace	2,176	1,909	12,424	15.4%
Upper terrace	206	195	4,085	4.8%
Total:	**6,831**	**5,855**	**44,741**	**13.1%**

5.2.1.3 Discussion

The most important observation is that *Arundo* has high cover in the floodplain and low terrace geomorphic forms, and low cover in the low flow and bar/channel forms, within each of the six systems examined. Given that *Arundo* has a similar distribution across geomorphic forms on all systems, it is likely that similar mechanisms are at play in the systems. It is also likely that *Arundo* is having the same impacts associated with its presence in floodplains. This is important in that it makes observations from the specific case study of the Santa Margarita River (section 5.1) applicable to other systems in the study area.

Arundo's ability to form dense monotypic stands on floodplains in all of the major systems within the study area is likely having significant impacts to channel form, channel depth, flow conveyance, and sediment transport, as well as putting infrastructure at risk. *Arundo*'s impacts on these abiotic processes has biotic impacts as well by affecting habitat for flora and fauna. The documented abundance of *Arundo* within systems, and its higher growth within specific geomorphic forms, helps to demonstrate that impacts to organisms are also transferable from system to system.

Reproductive strategies used by *Arundo* are strongly reflected in distribution data by geomorphic form. Channel and bar areas are too dynamic to sustain plant survival, growth and establishment. Floodplain and low terrace are optimal, with favorable hydrology and less frequent flow events that would remove newly established plants. Upper terraces only periodically receive reproductive material (rhizome fragments), and hydrology is not optimal for their establishment and survival.

Understanding geomorphic composition and *Arundo* distribution would be aided by a historical evaluation of geomorphic forms over time, as well as an examination of vegetation cover. It would be useful to know if current geomorphic form and vegetation condition are comparable to past conditions.

5.2.2 Geomorphology Historic Analysis

In the previous section, the distribution of *Arundo* within geomorphic forms was examined using recent or current conditions within the AOI. The current acreage of geomorphic forms within each river system was also given. But acreage and proportion of geomorphic forms is not set as they respond to flood events and human activities. This chapter section will examine how each watershed's

geomorphology has changed over time, using historic air photos and cross-section based-data. In addition to change in geomorphic class, we will also examine the abundance of woody vegetation (open versus dense) within the floodplain and lower terrace areas. This will help characterize the hydrology of the system over time.

5.2.2.1 Methods

To quantify the changes in the river systems over time, a historical cross-section analysis was undertaken. Historic photography was aggregated from the UCSB Library, HistoricAerials.com, Google Earth, CaSIL (California Spatial Information Library) and the USGS. For each river system, the availability of imagery was evaluated on the range of years and reaches of the river where imagery timeframes overlapped. The number of photos was narrowed down to have optimal time differences of 10-15 years between samples, and equal distribution across as much of the river's extent as possible (where *Arundo* occurred). The San Luis Rey River had the widest array of images available by both area and year. Image availability dictated the extent of areas available for analysis on each river. Cross-section locations were at times determined by limited imagery coverage overlap on rivers, other than the San Luis Rey and Santa Margarita. Within each area of imagery coverage, a cross-section was digitized into the GIS (Figures 5-2.1&2). These areas were selected based on: a) the earliest available imagery showing a floodplain that was not naturally constrained by a narrows or other impediment, and b) when possible, level distribution across the full extent of the available imagery time sequence. Each cross-section was drawn perpendicular to the current channel. The length of each cross section was determined by where the upper terrace of the floodplain ended on both the oldest and most recent imagery (Figures 5-2.12&13). This takes into account flood events that eroded bluffs or hillslope in the intervening years. Cross-sections were opportunistically placed at locations along the river where: a) *Arundo* was abundantly present, b) the area was representational of changes over time, and c) cross-sections being perpendicular to the current channel line would not create a diagonal in the historic floodplains, as this would amplify any constriction or expansion of the river. Random or equidistant placement may have put cross-sections in areas that had little change due to geomorphic landform constraints like a narrows.

With the cross-section lines in place, the historical imagery was then georeferenced. Spatial inaccuracies may occur where ground control was not easily identifiable. It should also be noted that imagery varied in scale, which may affect the spatial and attribute accuracy of the interpretation. Each digitized cross-section was duplicated for each year of imagery. Using a scale of 1:3,000, the length of the line was split into pieces as it crossed each geomorphic form in the photo. Because linear cross-sections were used in place of generalized polygons[2], a higher level of detail was captured in the fluvial landforms. For instance, the polygon interpretation methodology (used to delineate current-day geomorphology) may broadly group a mixture of bare sand and scrub as one class *(Bar/Channel:Unvegetated),* while the cross-section method broke those same strips of bare sand and scrub into separate classes (*Bar/Channel:Unvegetated* and *Floodplain:Vegetated*). This level of detail was captured in an attempt to keep the mapping consistent over time and limit the amount of subjectivity in the interpretation across the variety of historical imagery.

Additional classes were added to this analysis so that cross-sections were the same length for each time period and all situations of floodplain changes could be described. These added classes include:

- Floodplain Modified: sand mining, grading /channelizing of the floodplain, and agriculture fields in the floodplain that are not protected by levees.

[2] Polygon interpretation was not feasible with the time constraints and budget available for the historical analysis.

- Levee Protected Agriculture[3]: levees may be dirt or armored with rock.
- Levee Protected Developed[3]: usually a rock-armored levee with housing, industry or airport development. On two occasions, this class includes water treatment or storage ponds.

[3] The "Levee protected" classes do not appear in the charts because they, like the hillslope, are no longer part of the floodplain.

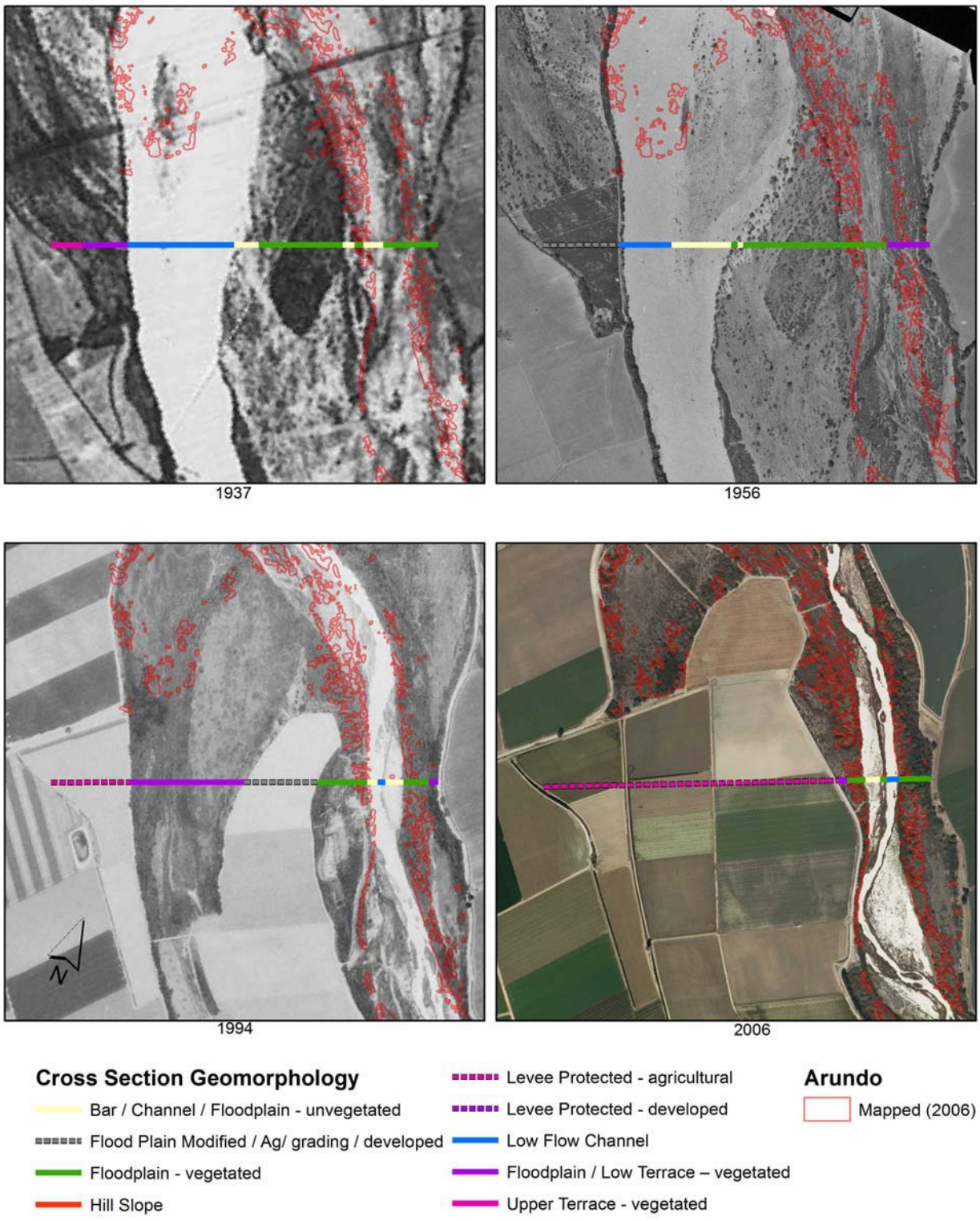


Figure 5-2.12. Cross-section geomorphology using historic aerial imagery on the Salinas watershed from 1937 to 2006.

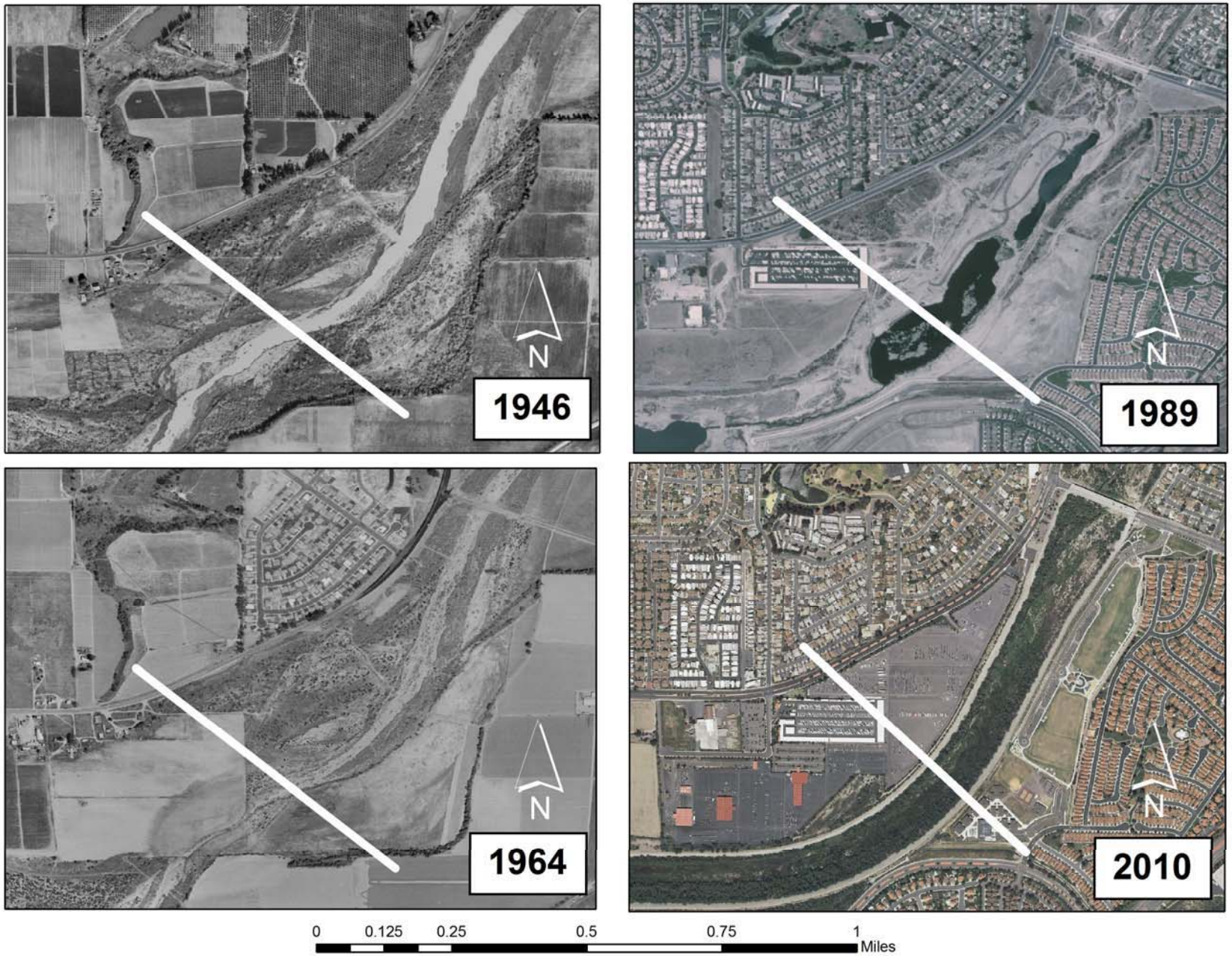


Figure 5-2.13. Historic photo analysis of geomorphic and hydrologic cross-sections on the San Luis Rey River from 1946 to 2010.

5.2.2.2 Results

There have been many changes to river systems over the past 100 years. These changes will be aggregated into two basic categories: 1) drastic increases of water in the system (from urbanization and agriculture) and 2) removal/modification of riverine areas (from development, agriculture, levees, water/flood management). High levels of water importation have transformed ephemeral riverine systems into perennial systems in southern California. This transformation occurred over time, but for the study area, this study suggests the 1960s-70s as a tipping point for most watersheds. At the same time that more water was imported and released into coastal watersheds, the functional riparian zone was reduced and modified. Use of floodplains for farming and sand mining has occurred for over 100 years. Historically these uses were not physically protected from river flows by levees and berms, so the area of activity was still functionally connected to the river. When floods occurred, these areas were inundated. However, in the 1950s and 60s permanent levees and berms were constructed in many systems. This resulted in the removal of geomorphic structure and habitat, as well as a significantly narrowing of the floodplain/riparian zone. Increased importation of water and development of riverine areas (urban or agriculture) are correlated, with both forms of development tied to increased water use.

San Luis Rey: Nine cross-sections were used. The San Luis Rey Watershed exhibited significant loss of over two-thirds of its riverine habitat from 1938 to 2010 (Figure 5-2.14). Lower and upper terraces are now nearly absent. Historic use and modification of floodplains occurred throughout the early portion of the time frame, but much of the use (agriculture and sand mining) has stopped or been permanently removed from the system. Urbanization is a significant pressure. Specifically note that open bar/channel area has drastically reduced over time (2,161m in 1938 to 175m in 2010, a 92.5% reduction; Figure 5-2.14), while floodplains are of equal, or greater, extent.

Santa Margarita: Nine cross-sections were used. The Santa Margarita Watershed has had very little riparian habitat development or permanent habitat removal. The Department of Defense manages all of the area examined in this review. This makes the Santa Margarita interesting in that is separates the two factors: loss of habitat and increased water input. As seen on the San Luis Rey, channel and bar was a large proportion of the system in 1938 (50%, 3,500m; Figure 5-2.15). A steady decline has occurred over time, and by 1997 channel/bar was 8% (of 700m) of the system. Removal of many *Arundo* stands from 1998 to 2006 may have resulted in the modest increase of channel/bar in 2010. Floodplain and terrace areas expanded from 1938 to 2010.

Santa Ana: Five cross-sections were used. The Santa Ana Watershed also had low levels of permanent development and land use change within the riverine areas of the AOI between 1938 and 2010. This is in part due to high bluffs that separate the river from upland areas. Upland areas have become highly developed, but the river bottom has not. The cessation of agriculture and sand mining activities, which was significant from the 1940's to the 1960's, has allowed most of the river to function as natural riverine areas. Trends are less clear on Santa Ana (Figure 5-2.16). Low flow channel and channel/bar areas were greatest in 1938. Ten years later they were significantly less, in part due to modification. Current and recent low flow channel and channel/bar areas are still a low proportion of the total riverine area, but it is not low as was observed on the San Luis Rey and Santa Margarita Rivers. The proportion of floodplain and terrace has been consistently high since 1980.

Ventura: Five cross-sections used. The Ventura River shows a similar pattern of permanent conversion of habitat to development and agricultural use (separated by levee) as seen on the San Luis Rey, with a 50% loss of riverine areas. Unlike San Luis Rey and Santa Margarita, Ventura has retained a large proportion of channel and bar areas (Figure 5-2.17). However, terrace areas as a class was effectively removed from the system through development and agriculture.

Santa Clara: Three cross-sections were used. The Santa Clara River has had significant development protected behind levees. The permanent land use change started as agriculture, but since 1970, it has become increasingly urbanized. Santa Clara appears to be a higher energy system than the other watersheds. A larger proportion of the system is maintained as low flow channel and bar/channel in all years (Figure 5-2.18). A slight decrease in this class has occurred, but it has been stable over the last 30 years and it is still well represented. Floodplain and terrace forms appear to be less abundant. The river has maintained open channel/bar areas, but lost floodplain and terraces, especially in comparison to 1927 and 1938.

Salinas: Three cross-sections were used. Aerial photography was difficult to obtain for the system. 1971 data is presented even though the data set was incomplete (2 of 3 cross-sections). Land use change has significantly reduced the riverine portion of the system. Protection of agriculture with levees started prior to 1971 and accelerated between 1994 and 2006. Low flow channel and channel/bar areas have decreased substantially, and the decline is linear (Figure 5-2.19). Dams have significantly reduced the riverine portion of the system. Floodplain areas are less abundant, while terrace areas have remained relatively constant.

5.2.2.3 Conclusions

Overall patterns of historical change in geomorphic forms on the six watersheds (Table 5-2.4) indicate the following:

- Significant reduction of riverine habitat (levee-protected permanent land use change) - systems are smaller (4 of 6 systems).
- A large decline of low flow channel and channel/bar (active low elevation areas) was seen on three systems.
- The retention/expansion of floodplains as a proportion of the system was observed on four of the six systems.

The long-term geomorphic changes observed on other larger river systems in the Southwest are evident on southern California coastal watersheds.

Table 5-2.4. Summary of geomorphic changes by watersheds.

Trend	San Luis Rey	Santa Margarita	Santa Ana	Santa Clara	Ventura	Salinas
Reduction in functional riverine areas	Yes >50%	No <10%	No <5%	Yes >50%	Yes >50%	Yes >50%
Reduction of low flow channel and channel/bar (in length & proportion)	Yes >70%	Yes >60%	No	Minor	No	Yes >60%
Proportion of riverine habitat that is floodplain & low terrace is stable or larger	Yes	Yes	Yes	No	No	Yes

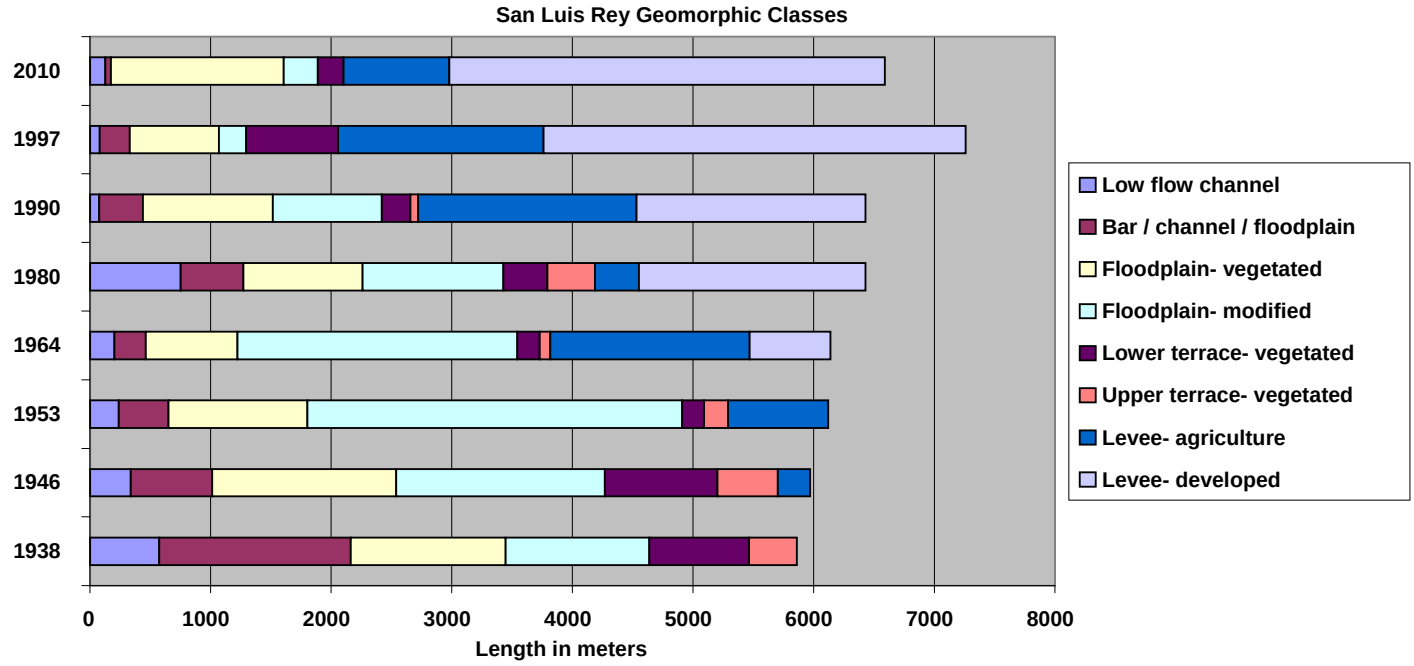


Figure 5-2.14. San Luis Rey geomorphic forms from 1938 to 2010.

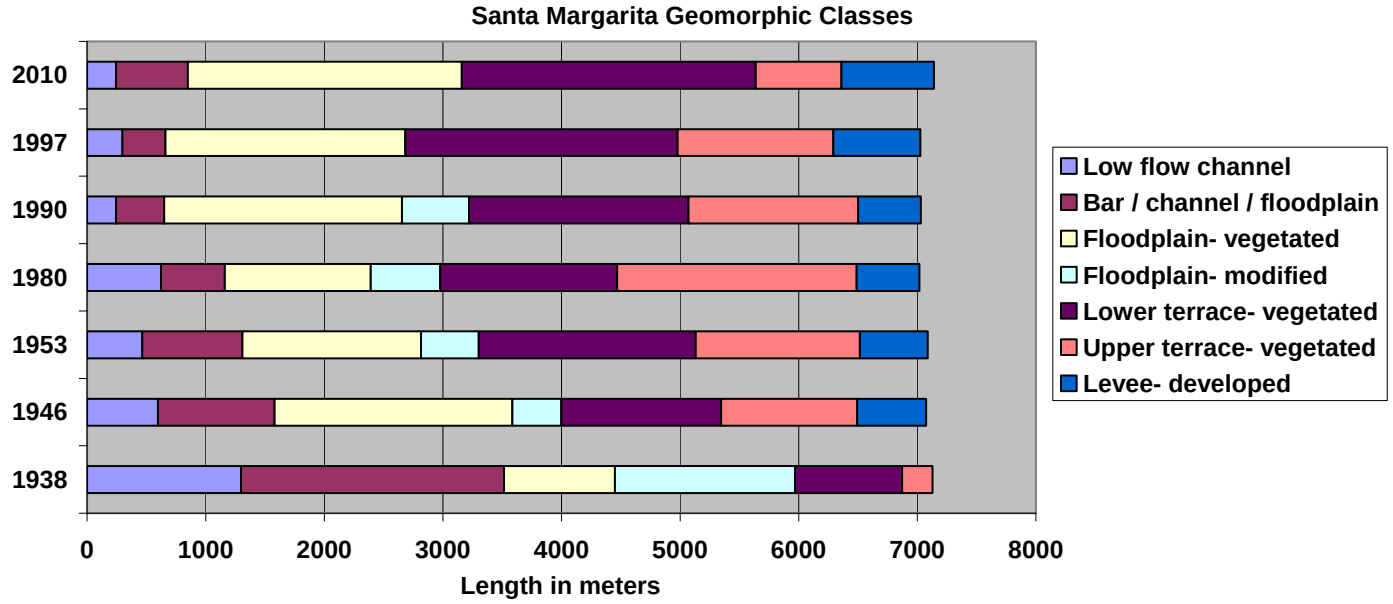


Figure 5-2.15. Santa Margarita geomorphic forms from 1938 to 2010.

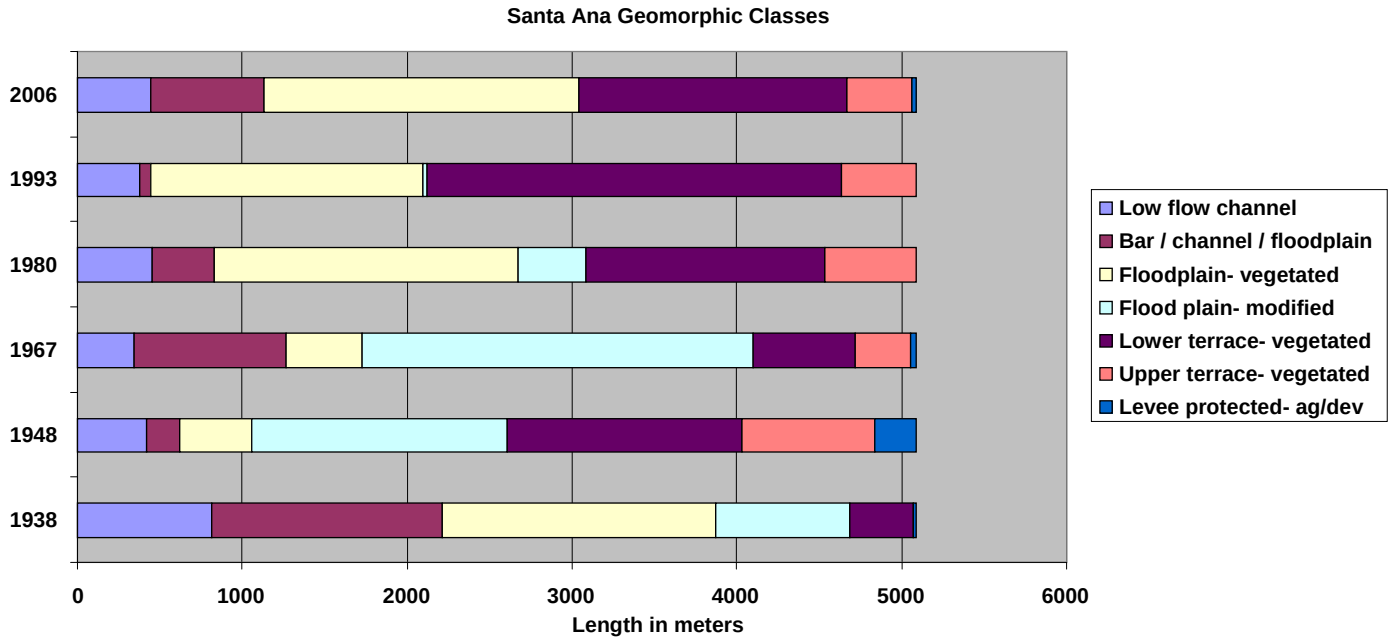


Figure 5-2.16. Santa Ana geomorphic forms from 1938 to 2006.

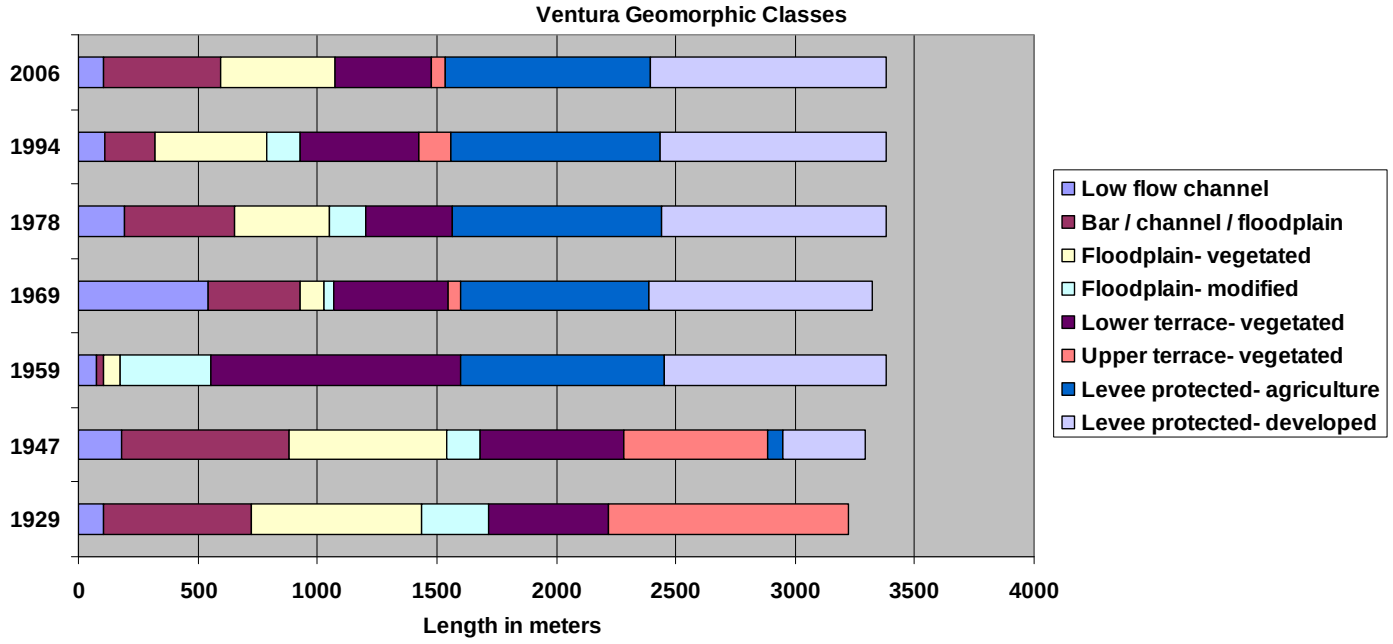


Figure 5-2.17. Ventura geomorphic forms from 1929 to 2006.

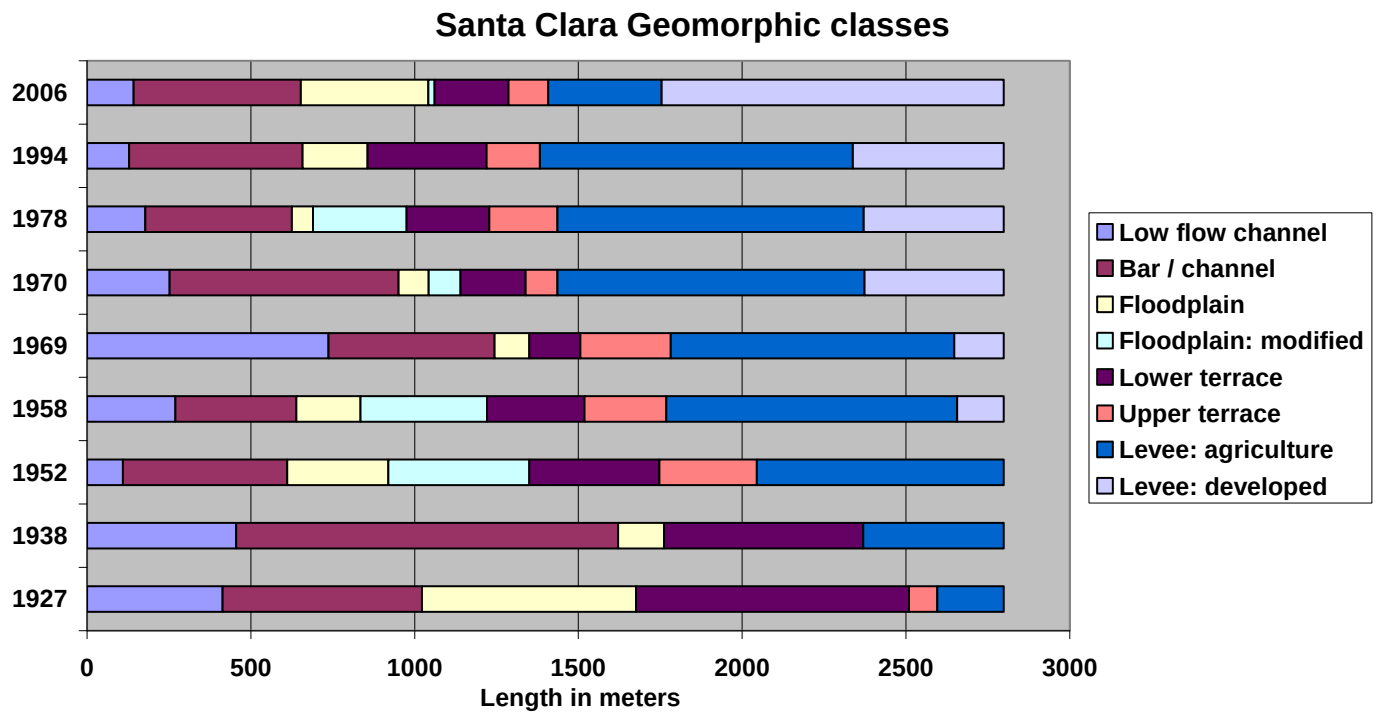


Figure 5-2.18. Santa Clara geomorphic forms from 1927 to 2006.

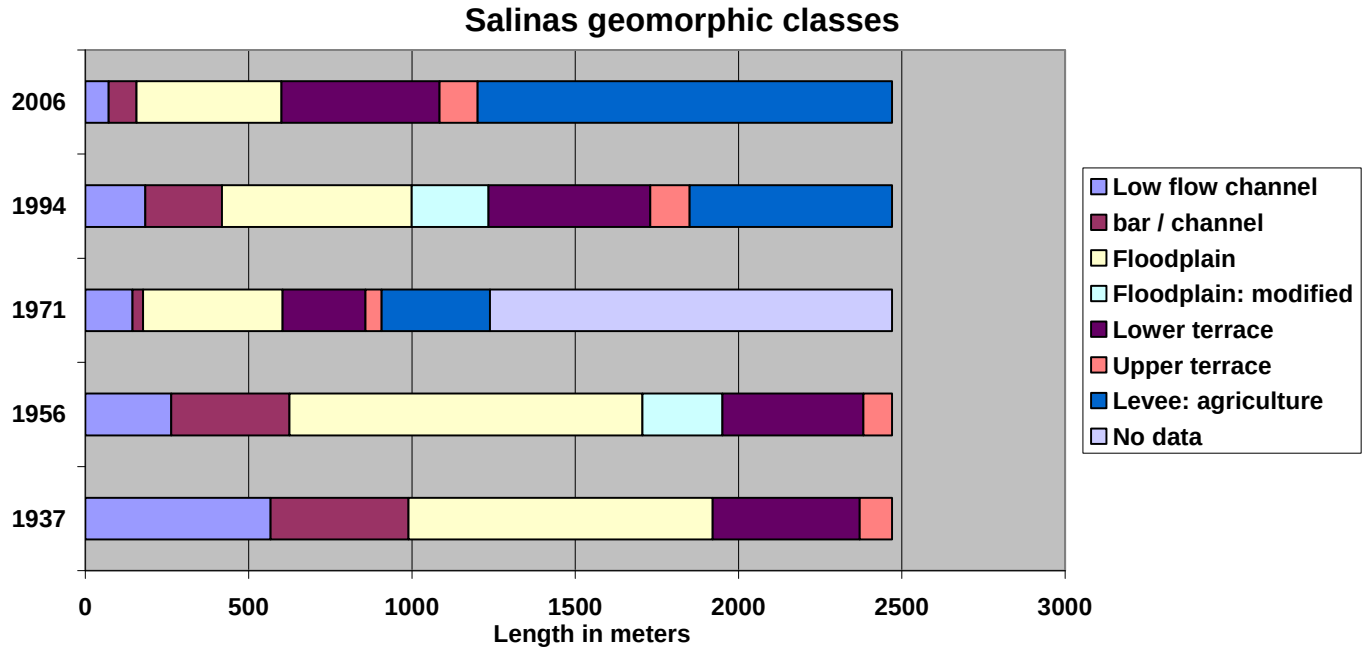


Figure 5-2.19. Salinas geomorphic forms from 1937 to 2006.

5.2.3 Vegetation Cover Historic Analysis

5.2.3.1 Methods

Preparing historic imagery for analysis reinforced a theory that many of the river systems have converted to a more heavily vegetated state over time. Supporting data was captured during the historical cross-section analysis. An attribute was added to the *Floodplain-Vegetated* and *Floodplain/ Low Terrace–Vegetated* geomorphic forms. The attribute values "dense" and "open" were used to describe the conditions and types of vegetation within these forms (see definitions below). Based on observations from the *Arundo* field mapping, the "dense" classification is the most likely place for *Arundo* to thrive, and thus, it was classified as such. An example of aerial imagery showing floodplain and terrace areas with dense and open vegetation classes marked is shown in Figure 5-2.20.

Definitions:

Dense – High woody/*Arundo* vegetation cover (>50%, typically >80%) of large, well-developed vegetation including plants like cottonwoods, sycamores, willows, mulefat and *Arundo*.

Open – Low woody/*Arundo* vegetation cover. Typically these are bare open areas, or areas with annual herbaceous cover. Areas with scattered woody vegetation and clumps of *Arundo* are also included in this category.

5.2.3.2 Results

The characterization of vegetation on the floodplains reveals a strong pattern of increasing cover of dense *Arundo* and woody vegetation. Dense woody/*Arundo* vegetation is taken to be an indicator of high water availability that allows dense vegetation to develop. Individual watersheds are illustrated over 80-90 year periods (Figures 5-2.21 to 5-2.26, Table 5-2.5). Most systems initially show low cover of dense vegetation on floodplains and terraces, except for Santa Margarita and Salinas. Over time dense vegetation cover increases, particularly on the San Luis Rey, Santa Ana, Ventura and Santa Clara from 1980 forward. The increase in proportion (percentage) of "dense" vegetation to "open" is shown in Figures 5-2.27 and 5-2.28 for all watersheds studied. A clear shift in vegetation cover is occurring. Dense cover was typically 10-30% in the 1920s and 1930s, but by the 1990s/2010 most systems were >75%. High R^2 and steep trendlines are apparent for most systems. All data aggregated show a clear upward trend, but systems apparently have different equilibrium points.

5.2.3.3 Conclusions

The strong historic trend toward greater vegetation cover on floodplain and terrace portions of river systems indicates that a major hydrologic shift has occurred within the study area. *Arundo* comprises a significant proportion of this dense vegetation. This overly vegetated condition, compared to 1928-50, seems to be moving these systems toward a more fixed geomorphic and vegetative state, with both fewer smaller size fluvial re-setting events and a faster return to a heavily vegetated state after major events. The dense growth of *Arundo* is likely compounding this effect by holding the low flow channel in a set position which converts systems from a braided unstable form to a narrow single thread that is laterally stable. The availability of water all year within riverine systems has allowed *Arundo* to drastically expand in cover. Although difficult to detect in pre-1990 aerial imagery, *Arundo* is clearly not a dominant vegetation form on systems prior to 1980. By 2000 *Arundo* has become abundant with over 40% cover on reaches of selected systems (section 5.1) and an average cover of 13% on the lower gradient floodplain areas as a whole (Table 5-2.1).

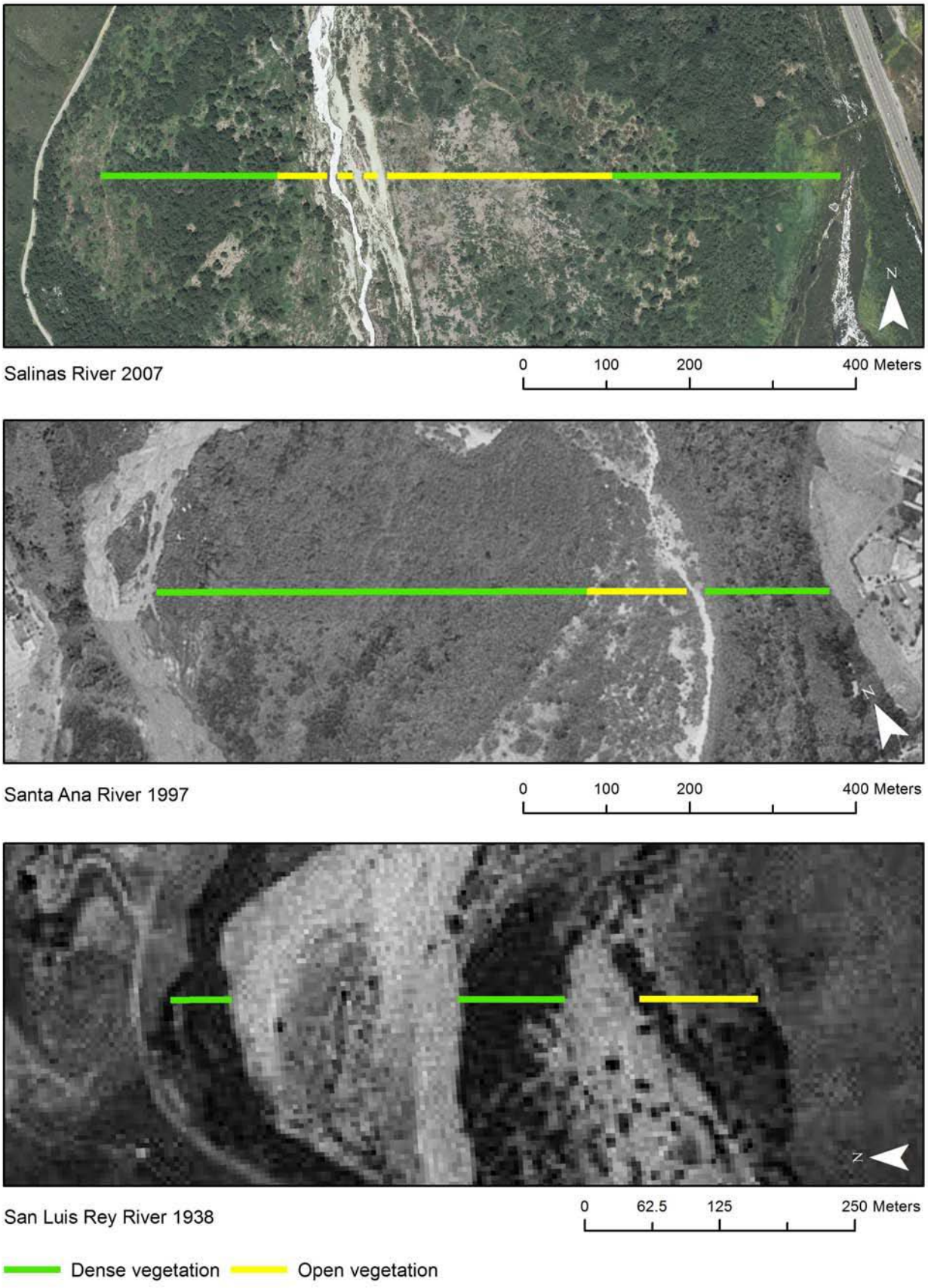


Figure 5-2.20. Aerial imagery showing floodplain and terrace areas with dense and open vegetation classes marked.

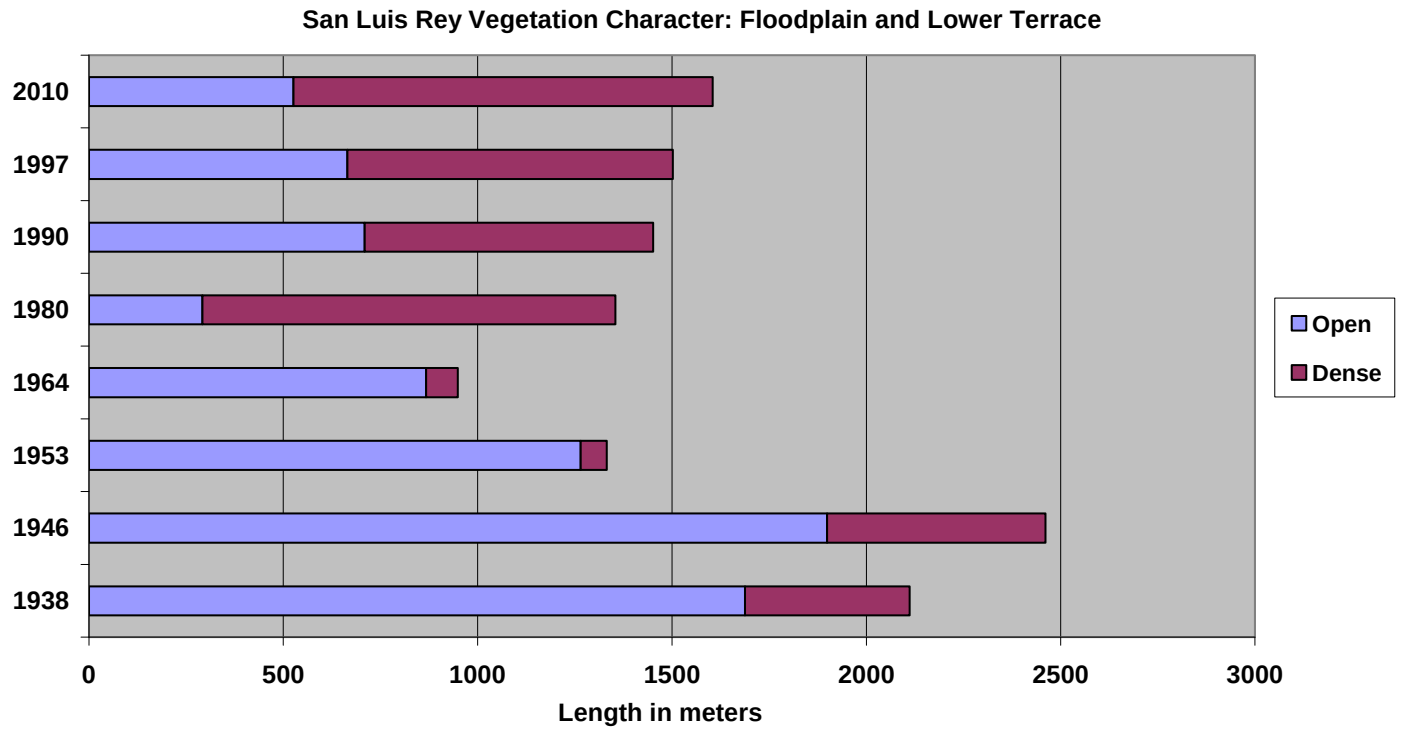


Figure 5-2.21. San Luis Rey open and dense vegetation classification on floodplain and lower terrace areas from 1938 to 2010.

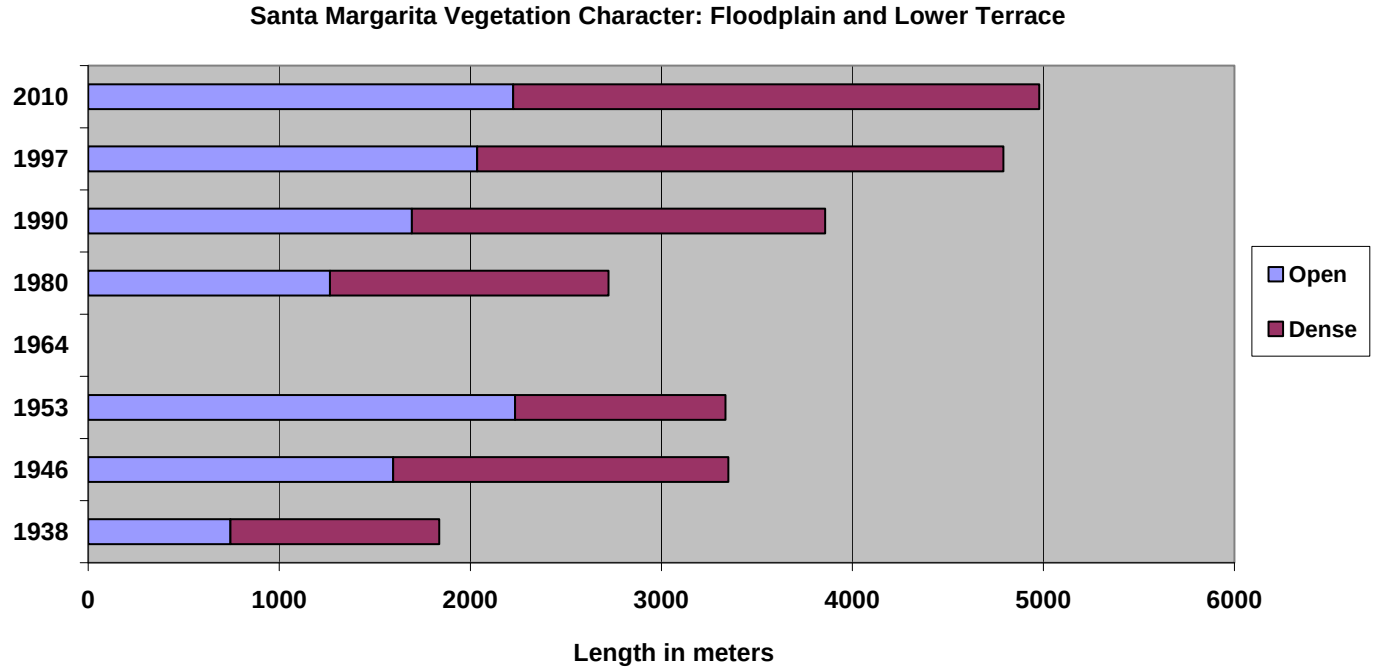


Figure 5-2.22. Santa Margarita open and dense vegetation classification on floodplain and lower terrace areas from 1938 to 2010.

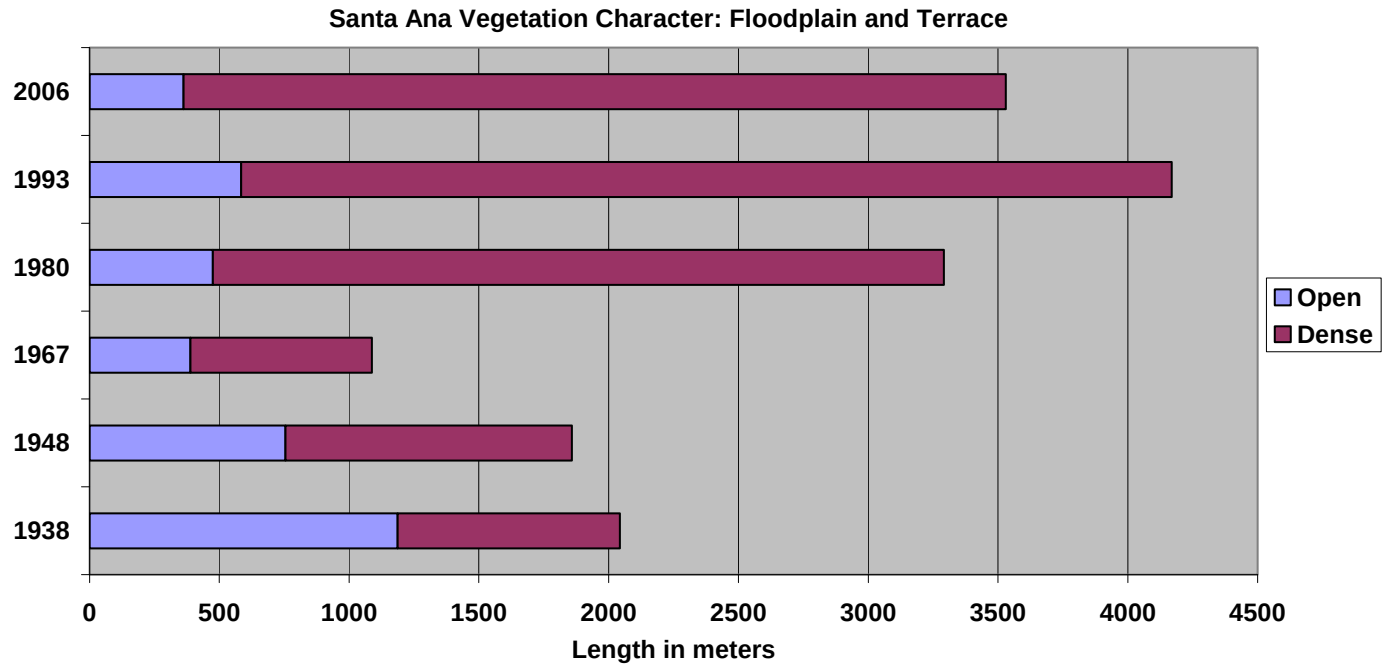


Figure 5-2.23. Santa Ana open and dense vegetation classification on floodplain and lower terrace areas from 1938 to 2006.

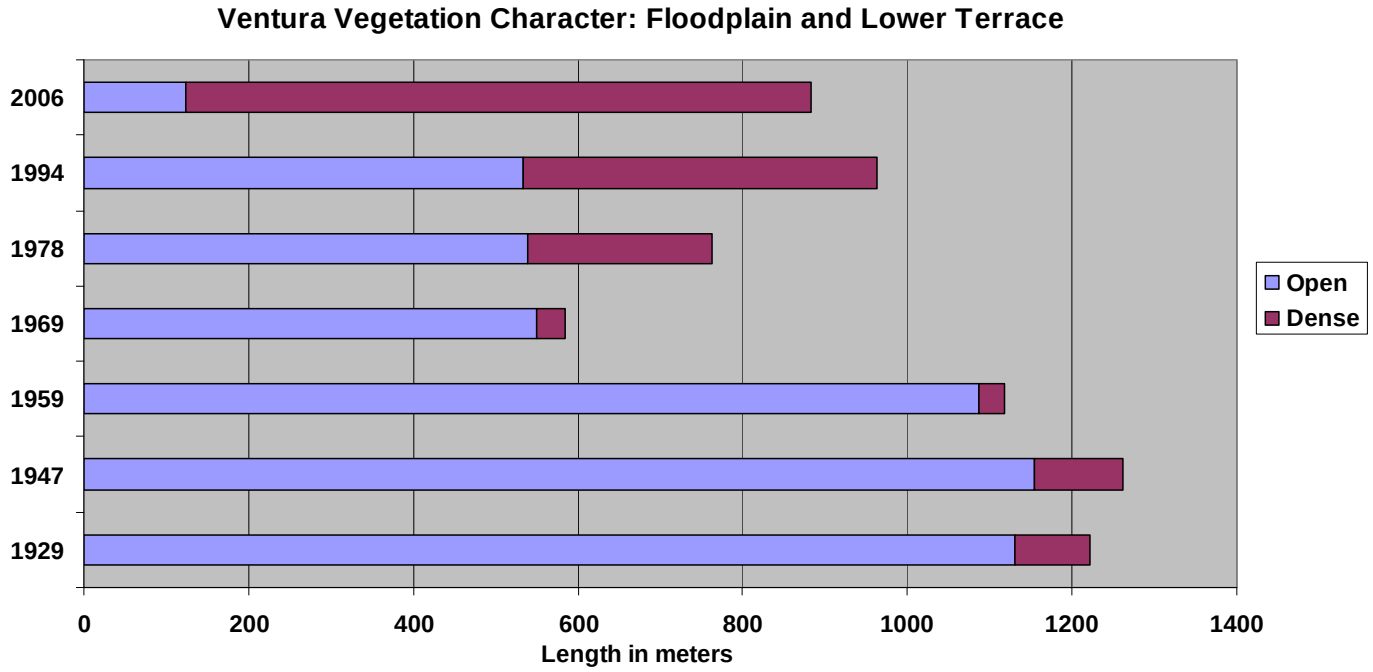


Figure 5-2.24. Ventura open and dense vegetation classification on floodplain and lower terrace areas from 1929 to 2006.

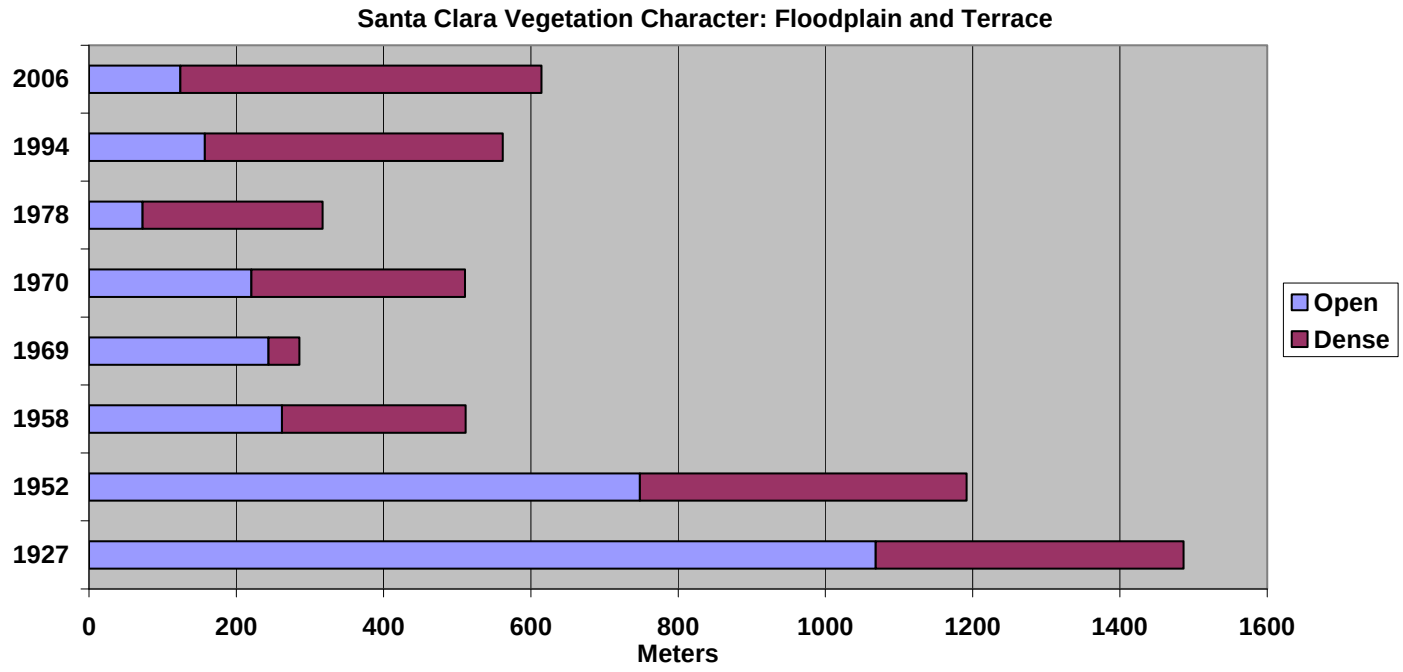


Figure 5-2.25. Santa Clara open and dense vegetation classification on floodplain and lower terrace areas from 1927 to 2006.

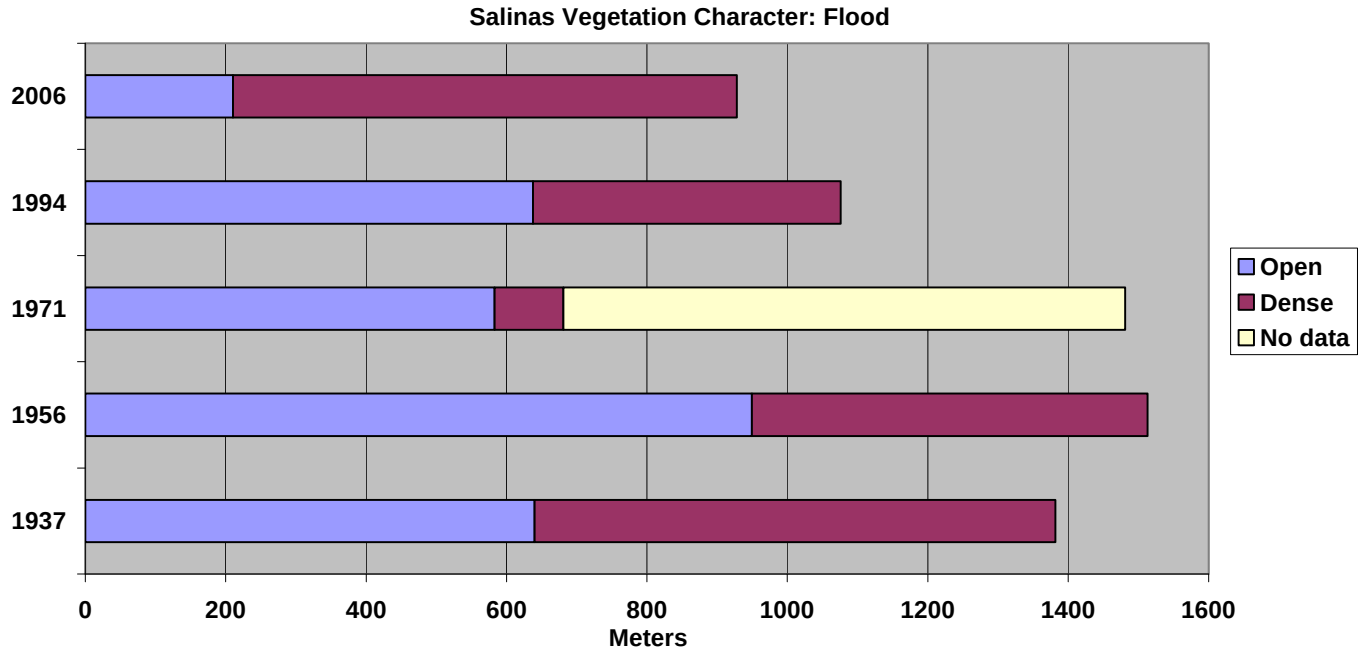


Figure 5-2.26. Salinas open and dense vegetation classification on floodplain and lower terrace areas from 1937 to 2006.

Table 5-2.5. Open and dense vegetation by year for four watersheds.

Watershed	Year	Total length (m)	Open length (m)	Dense Length (m)	% Open	% Dense
San Luis Rey	1938	2112	1688	424	80%	20%
San Luis Rey	1946	2461	1899	561	77%	23%
San Luis Rey	1953	1332	1265	67	95%	5%
San Luis Rey	1964	949	867	81	91%	9%
San Luis Rey	1980	1354	292	1062	22%	78%
San Luis Rey	1990	1451	709	742	49%	51%
San Luis Rey	1997	1502	665	837	44%	56%
San Luis Rey	2010	1605	526	1079	33%	67%
Santa Margarita	1938	1838	745	1093	41%	59%
Santa Margarita	1946	3351	1597	1754	48%	52%
Santa Margarita	1953	3336	2235	1101	67%	33%
Santa Margarita	1980	2724	1266	1458	46%	54%
Santa Margarita	1990	3857	1694	2163	44%	56%
Santa Margarita	1997	4790	2036	2753	43%	57%
Santa Margarita	2010	4978	2225	2753	45%	55%
Santa Ana	1938	2043	1187	856	58%	42%
Santa Ana	1948	1858	755	1103	41%	59%
Santa Ana	1967	1088	389	699	36%	64%
Santa Ana	1980	3292	475	2817	14%	86%
Santa Ana	1993	4169	584	3585	14%	86%
Santa Ana	2006	3530	362	3168	10%	90%
Ventura	1929	1222	1131	91	93%	7%
Ventura	1947	1262	1153	108	91%	9%
Ventura	1959	1117	1087	30	97%	3%
Ventura	1969	584	550	34	94%	6%
Ventura	1978	762	538	224	71%	29%
Ventura	1994	963	534	429	55%	45%
Ventura	2006	883	125	758	14%	86%

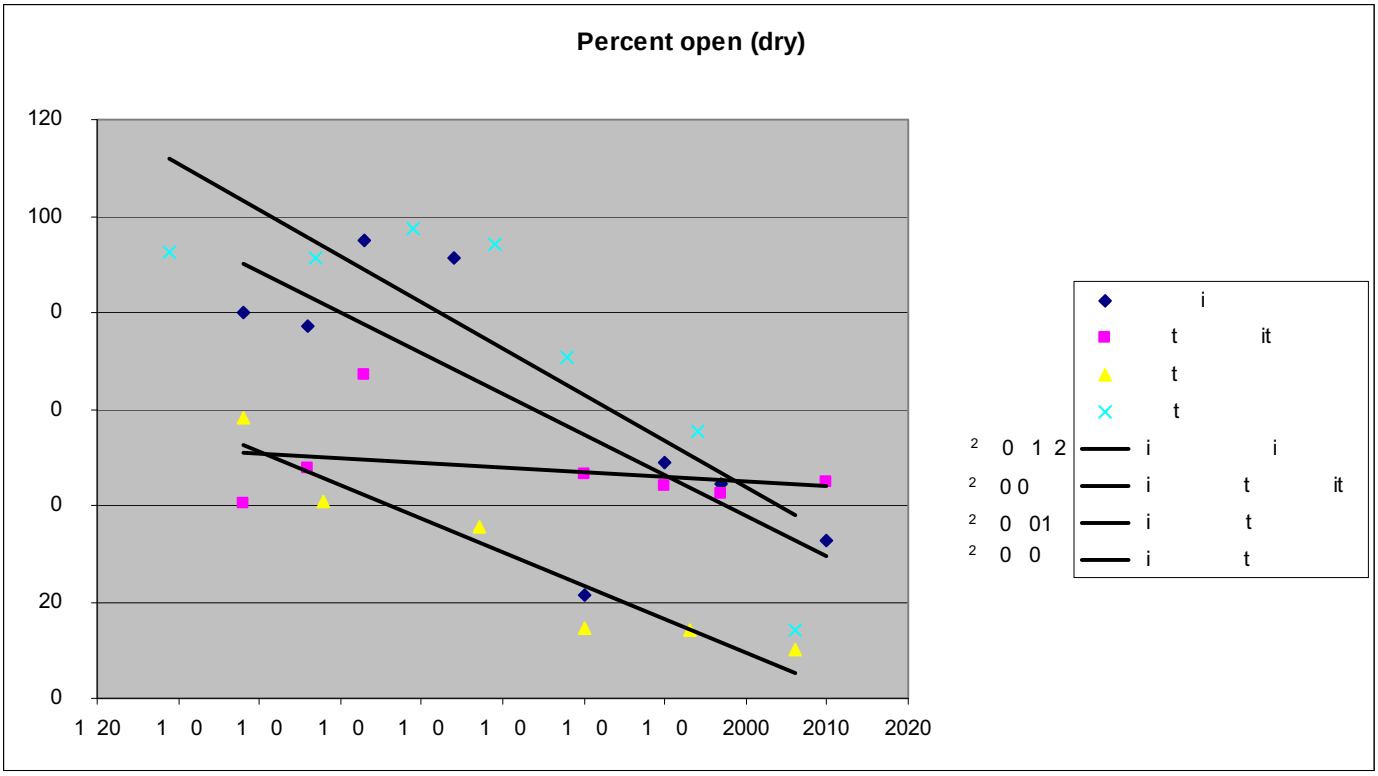


Figure 5-2.27. Trend graph of percent of the open vegetation category from 1927 to 2010 for four watersheds with the AOI.

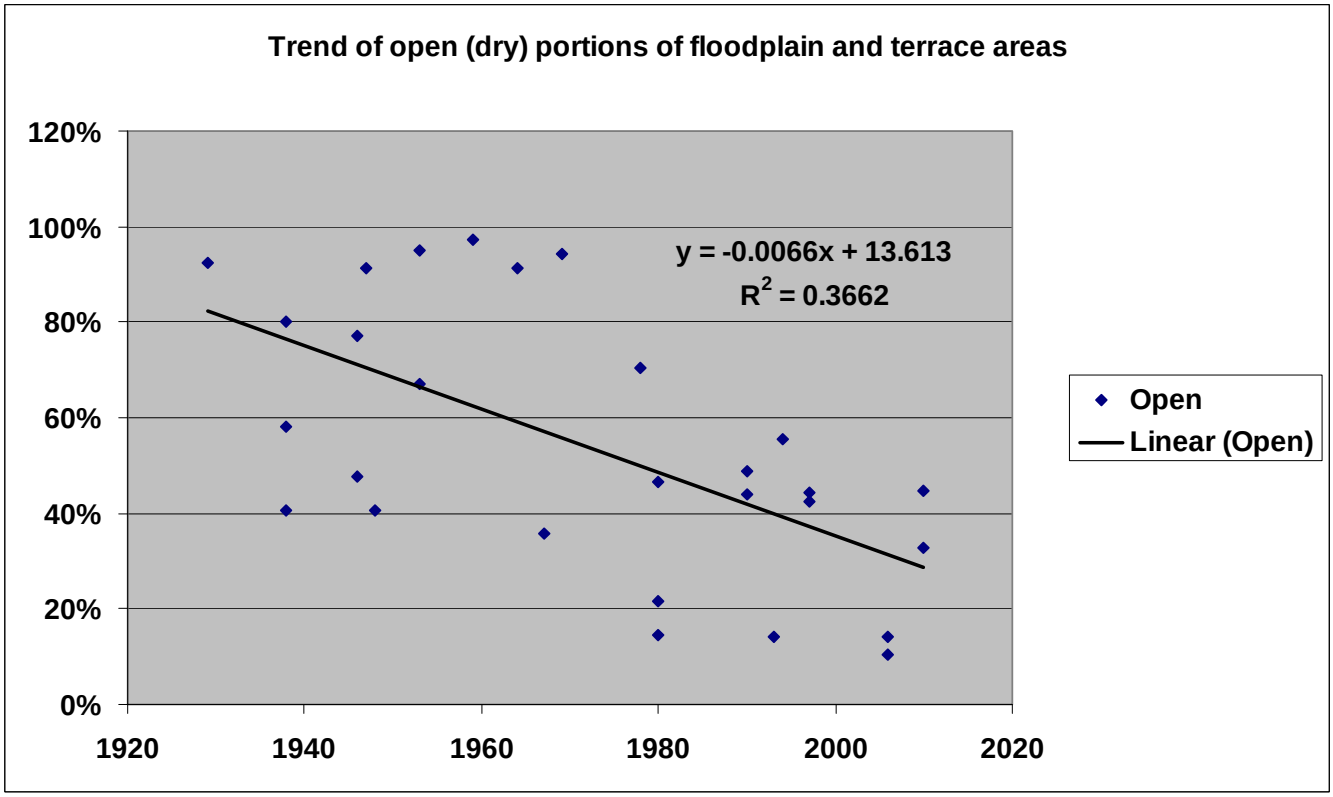


Figure 5-2.28. Trend graph of percent of the open vegetation category from 1927 to 2010 for all watersheds with the AOI.

5.2.4 Geomorphology and Hydrologic Modification by Arundo

What role does *Arundo* play in modifying geomorphic processes? This topic was examined in Sections 5.1 and 5.2 in the context of mapping geomorphic forms and investigating how *Arundo* interacts with river flows and sediment movement. What happens when *Arundo* is removed from a river system? *Arundo* was controlled over a large portion of the Santa Margarita watershed by 2000, so this provides an opportunity to look at one system after *Arundo* has been effectively removed. Large flood events have occurred in the ten years since then, so has the acreage of geomorphic forms changed? Mapping of geomorphic forms at peak *Arundo* cover (1997) and 10-year post *Arundo* removal (2010) show some interesting changes (Figure 5-2.15, Table 5-2.6). Low flow channel area decreased, but bar/channel area increased. Combined together they increased 38% from 118 acres to 163 acres. This is a sizeable change, especially given the linear decline of that class that had been occurring (Figure 5-2.15). A major shift in classification from floodplain to low terrace also occurred. These two classes are close in elevation, and the shift shows a movement to more stable native vegetation on terraces and more active zone area (but vegetated) on floodplains. The floodplain is no longer a dense wall of vegetation (*Arundo* with natives) that restricts flows, rather water now passes through the area. This change in functional flow area has broadened the active flow zone to 362 acres in 2010, a 307% increase over the highly invaded *Arundo* state in 1997 (118 acres). This is a major functional change with implications for groundwater recharge, flood risk, sediment transport and habitat function.

The lower elevation areas in the 2010 classification will likely be more 'dynamic' over time as the vegetation is not able to hold the low flow channel in place. Movement of the low flow channel, braiding, and changing bar/channel structure in the 362.5-acre zone is a significant re-establishment of fluvial forms that was in decline within the study area.

Table 5-2.6. Acreage of geomorphic forms within a portion of the Santa Margarita River in 1997 and 2010.

Geomorphic form	**1997 Acreage:** *Arundo* present	**Flows in a 15 Year event?**	**2010 Acreage:** *Arundo* removed	**Flows in a 15 Year event?**	**Percent change**
Low flow channel	74	Yes	49	Yes	-34%
Bar/channel	44	Yes	114	Yes	159%
Floodplain	536	No	199	Yes	-63%
Floodplain/low terrace	557	No	900	No	62%
Upper terrace	297	No	253	No	-15%

5.2.5 Infrastructure Impacts: Roads, Bridges, Levees, Sewer/Water Transfer, Beaches

5.2.5.1 Bridges & Levees

Reduced flow capacity (elevation of 5'), outlined in Section 5.1, is of great consequence for both bridges and levees. Bridges, particularly older structures, may not have been designed to account for this altered flow capacity during large flow events. The loss of 5 feet of profile over the width of a structure is a significant flow conveyance loss. Many older bridges have multiple, tightly spaced buttresses that tend to collect biomass during flows. *Arundo* mixed with large-sized tree trunks is a particularly problematic combination as it forms a block that catches what might otherwise have flowed through the structure. *Arundo* lodged against a Santa Ana River bridge that failed in 2004 (Figure 5-2.29). A bridge on the Santa Margarita River on Stuart Mesa Road was nearly lost in 1998, but crews pulled *Arundo* off pylons during the flow event, likely saving the structure. In 1993 the Basilone Bridge on the same river was lost and a levee protecting the Air Station was breached with severe flooding of the Air Station occurring. Although these losses cannot be fully ascribed to *Arundo* stands that were dense in the area, it was clearly a factor in these structural failures due to flow conveyance loss. An additional levee failure in the same area in 1998, resulting in damage to Air Station fuel pad, led to the baseline work of documenting *Arundo* impacts on flows (see Section 5.1). It was this study that demonstrated the 5' flow conveyance loss over *Arundo* stands. These higher flows overtopped the levee in 1998, an event size that should not have achieved this outcome. *Arundo* was specifically pinpointed as the reason why flows were higher than expected. Given *Arundo*'s demonstrated effect in 1998, it is certain that levee breaches and flooding in 1992 was of greater magnitude due to the presence of extensive *Arundo* stands. This realization was one of the impetuses for *Arundo* eradication on the Santa Margarita River.

A similar series of events has occurred on the San Luis Rey River. Two bridges were lost following 1992 flooding events at College Avenue and at Camino del Ray Ave. The College Bridge was located below large *Arundo* stands, but the Camino del Ray Bridge was not. An extensive levee system was constructed in the early 1990s on the lower San Luis Rey River. By 2005 significant flow capacity had been lost due to vegetation growth (*Arundo* and natives combined). This led to vegetation reduction and *Arundo* control activities initiated in 2008.

These events on three heavily invaded *Arundo* invaded river systems suggest there will likely be future impacts from *Arundo* on other watersheds in the study area. Impacts and cost valuation for bridge damage or loss is included in the Cost Benefit study in Chapter 8.



Figure 5-2.29. Floods stacked *Arundo* biomass against the River Road Bridge on the Santa Ana River, resulting in the bridge being pushed off its foundation in 2004.
Photo by Richard Zembal.

5.2.5.2 Biomass on Beaches

Arundo biomass on beaches following flow events is a recurring impact (Figure 5-2.30 & 5-2.31). In many areas, particularly from Santa Monica to San Diego, biomass is cleared by Municipal, County and State workers using tractors, loaders and sweepers. Estimating the magnitude and cost of these efforts is complicated due to their periodic nature, in addition to a large range in the amount of material. *Arundo* biomass is not the only material discharged by river flow events. There are also other non-native plants, native plants and refuse. It is not unusual for more than 80% of the material to be *Arundo* biomass near heavily invaded watersheds (San Luis Rey, Santa Margarita, Santa Clara, Ventura). Two of these systems will have lower *Arundo* biomass yields in the future as most *Arundo* has been removed (San Luis Rey, Santa Margarita). Santa Ana has lower *Arundo* discharge than other systems because most *Arundo* is present above the Prado Dam. Small and mid-sized watersheds may discharge large amounts of *Arundo* material, particularly watersheds in the Los Angeles basin (Douce 1993).



Figure 5-2.30. In Santa Barbara County, *Arundo* washes down the Santa Clara River and accumulates on Rincon Beach, blocking access for beachgoers and increasing the cost of beach maintenance.
Photo by David Chang.



Figure 5-2.31. *Arundo* and other biomass washed onto the beach in Long Beach after a large flow event on the Los Angeles/San Gabriel River.
Photo by Drew Ready.

Many beach areas are not maintained for public use. Some of these areas are of significant value to wildlife, particularly areas near estuaries and river mouths. These are also where *Arundo* biomass load is highest. Impact to fauna and threatened and endangered species are outlined in Chapter 7.

Approximately 21 miles of beach are likely to have routine removal of *Arundo* biomass. These areas are north San Diego, Los Angeles/Long Beach, and Ventura/Ojai. Estimates for *Arundo* biomass are based on data from Long Beach following large flood events in 2004/05 (Lopez, pers. comm. 2009, Douce 1993). The city estimates *Arundo* at 40% of total biomass/debris on their beaches. Note that the Los Angeles and San Gabriel Rivers (source of *Arundo* for Long Beach) have significantly less *Arundo*

acreage compared to many other systems. Tons of *Arundo* cleared and the cost of collection are presented in Table 5-2.7. Additional flood event sizes are added to reflect a ten-year period. This data is then extrapolated to the two other regions that have higher levels of *Arundo* biomass on their beaches. Discharge of *Arundo* biomass for a single region is estimated at 875 tons/year or 8,750 tons over ten years. For the region, it would be 2,625 tons of *Arundo* biomass annually or 26,250 tons over ten years (Table 5-2.8).

5.2.5.3 Conclusions: Impacts to Infrastructure

Arundo appears to be having significant impacts to structures that cross rivers as well as structures that contain flows (levees). *Arundo* biomass combined with the loss of flow capacity are the two primary factors contributing to these impacts.

- Loss of flow capacity and presence of *Arundo* biomass is likely contributing to overbank flows and bridge loss and damage. (Section 5.2.5.1)
- Flow events mobilize large amounts of *Arundo* biomass. Part of this biomass load ends up on coastal beaches where it is frequently removed by public agencies that required an estimated annual cost of $197,000. This does not include impacts on habitat quality. (Section 5.2.5.2)

Table 5-2.7. Amount of *Arundo* biomass on beaches of Long Beach and clean-up costs for a ten-year period.

Flood Events in 10 Year Period for Long Beach (LA & San Gabriel Rivers)	Percent cost	Tons *Arundo* biomass	Cost of disposal	Cost of collection	Total cost
Large event (1 in 10)	100	5,000	$175,000	$200,000	$375,000
Medium event (2 in 10)	50	2,500	$87,500	$100,000	$187,500
Small events (2 in 10)	25	1,250	$43,750	$50,000	$93,750
No event (5 in 10)	0	0	0	0	-
10 year Total:		**8,750**	**$306,250**	**$350,000**	**$656,250**

Table 5-2.8. Estimate of the amount of *Arundo* biomass on beaches in North San Diego County, Long Beach and Ventura, and the clean-up costs for a ten-year period.

Major regions	10 yr cost	*Arundo* 10 yr biomass (tons)
Long Beach: L.A. and San Gabriel Rivers	$656,250	8,750
North San Diego: San Luis Rey, Santa Margarita	$656,250	8,750
Ventura: Ventura and Santa Clara	$656,250	8,750
10 years:	**$1,968,750**	**26,250**
Annual cost:	**$196,875**	**2,625**

6.0 IMPACTS OF *ARUNDO: Fire*

Fire is one of the most discussed impacts related to *Arundo* invasion, yet there is little documentation of its occurrence in the literature. A few studies have looked at post-fire recovery of vegetation, but no studies have examined fuel loads, fuel characteristics and ignition sources, explicitly attempted to quantify fire events that start in *Arundo*, or quantified wildfire events that burn riparian areas with *Arundo* in them. All of these subjects will be explored in this chapter.

6.1 Fuel Load

Arundo stands have greatly increased the fuel load of riparian habitat. As outlined in section 2.3, *Arundo* stands in the study area had an average dry biomass of 69 tons/acre or 155 tons/hectare (Table 2-5). This is within the range of other studies on *Arundo* biomass. Studies have shown that *Arundo* produces biomass containing large amounts of energy per unit (17 to 19.8 MJ/Kg; Table 6-1). The high productivity of *Arundo* is why biofuel generation has focused on *Arundo* as a potential fuel source. It is significantly more productive than other species used for fuel generation. One study specifically growing willows for biofuel in riparian strips with high planted density of 15,300 trees/ha (6,200 trees/ac) generated 16.8GJ/ha (for 36.8t/ha biomass, Turhollow 1999). Compare this to *Arundo*: 810 GJ/ha (for 45 t/ha annual biomass, Williams et al. 2008) or 2,790GJ/ha for a mature *Arundo* stand (for 155t/ha biomass, this study). Based on annual yield, *Arundo*'s productivity is 400% higher than riparian vegetation (Turhollow 1999). This is in excess of estimates made by Scott (1993) who proposed that *Arundo* has doubled or tripled the fuel available for fires in the Santa Ana River Basin. Examination of mature stands during collection of *Arundo* biomass for this study also indicated that *Arundo* stands retain a significantly higher amount of dry, dead biomass compared to native woody and herbaceous vegetation, and it is held higher in the canopy. The *Arundo* stand has optimal, well-ventilated structure with both wet and dry fuel present throughout the stand profile. This introduction of a unique stand structure of *Arundo*, a clonal tall grass, into an ecosystem naturally dominated by woody trees and shrubs, herbaceous vegetation and open spaces, has altered fuel types, layers, and loads (Scott 1993, DiTomaso 1998, Brooks et al. 2004). The documentation of biomass loads in Spencer et al. (2006) and this study demonstrate the high levels of *Arundo* fuel. Later portions of this chapter focus on documentation of ignition sources and fire events in *Arundo*, which demonstrates how *Arundo* can be a direct or indirect factor contributing to an increase of fire occurrences.

Table 6-1. *Arundo* energy levels per unit of dry biomass.

Energy MJ/kg	Source
19.0	Williams et al. 2008
18.3	FAIR 2000
17.0	Angelini 2004
19.8	Dahl & Obernberger 2004
18.5	**Average**

Decreased moisture content and increased surface to volume ratio of *Arundo* versus native vegetation may lead to an altered or increased length of fire susceptibility and probability of ignition in these systems, although no data currently exists to document this assertion. Addition of this novel fuel

characteristic to the riparian ecosystem has increased vertical continuity (structure of fuel allows fire to spread from surface to crowns of shrubs and trees), which can in turn increase the frequency and extent of fires (Brooks et al. 2004).

Research still needs to investigate comparative moisture and surface to volume ratios, but current studies definitely indicate that *Arundo* has exceptionally high biomass levels. This directly translates into higher energy per acre.

6.2 Fire Intensity

Arundo stands contain a significant amount of energy and aboveground plant biomass, in addition to a well-ventilated, tall structure. *Arundo* stands always have large amounts of dry leaves, primary and secondary leaves that drop off canes as they grow. As it was discussed in sections 2.2 and 2.3, when a cane matures from the first year of growth to the second year, with the emergence of secondary branches, more than half of the leaves on the cane senesce (Figures 2-18 &6-1). Senescence of leaves on secondary branches also occurs periodically as the canes age. In addition to leaf senescence, both primary and secondary leaves frequently have portions of the leaf that are dry and non-photosynthetic (Figures 2-3 & 4). There is also a highly variable amount of dead cane material, in addition to the large amount of dry leaf material found both at the base of the stand and throughout the canopy. Within a stand, 0 -30% of the biomass is dead cane and leaf material (Spencer et al. 2006, Figure 6-1). This study did not directly measure dead cane biomass, but we observed a low density of dead canes within the plots sampled, averaging less than one cane per m^2 (n = 16, Table 2-4). However, sites can certainly be found with high amounts of dead cane biomass. Often these are areas where material has collected within the stand during flow events (photos in Chapter 5). Stands growing in dry areas will also have significant dead biomass, but these stands also have shorter stature and lower cane density (i.e. lower overall biomass). *Arundo* stand structure (tall height and high cane density per square meter) is an important factor in conveying fires high into the riparian canopy.

Movement and intensity of the fire are also related to weather, but conditions do not need to be favorable for a fire to occur in *Arundo*. *Arundo* can burn any time of the year under varying conditions. *Arundo* stands contain enough dead dry fuel that they can be ignited and carry a fire even under poor fire conditions, such as low wind speed, cool weather, and even when humidity is high or during light rains. This was demonstrated by the fire event on October 2006, which started at night during a light rain and low temperatures (Figure 6-2). Fires have also been observed during light rains and cool temperatures on the San Luis Rey River. Successive heavy rains will reduce *Arundo* stand flammability, but for many areas in the study region heavy rainfall only occurs for 6-10 weeks of the year. High fire threat weather conditions (low humidity and high winds) are not required to start or carry *Arundo* fires. The greatest risk of fire is still in the late summer/fall when stand moisture is low and Santa Ana conditions can exacerbate fire events.

The large amount of biomass per unit area along with a favorable structure for burning generates fires that burn intensively. This is illustrated by fire behavior and an examination of post-fire site conditions. Low intensity fires leave unburned material. Ash levels and color can also be used to gauge fire intensity. *Arundo* fires usually leave little unburned biomass and ash is usually white (Figures 6-3 & 4, also section 6.4 photos).

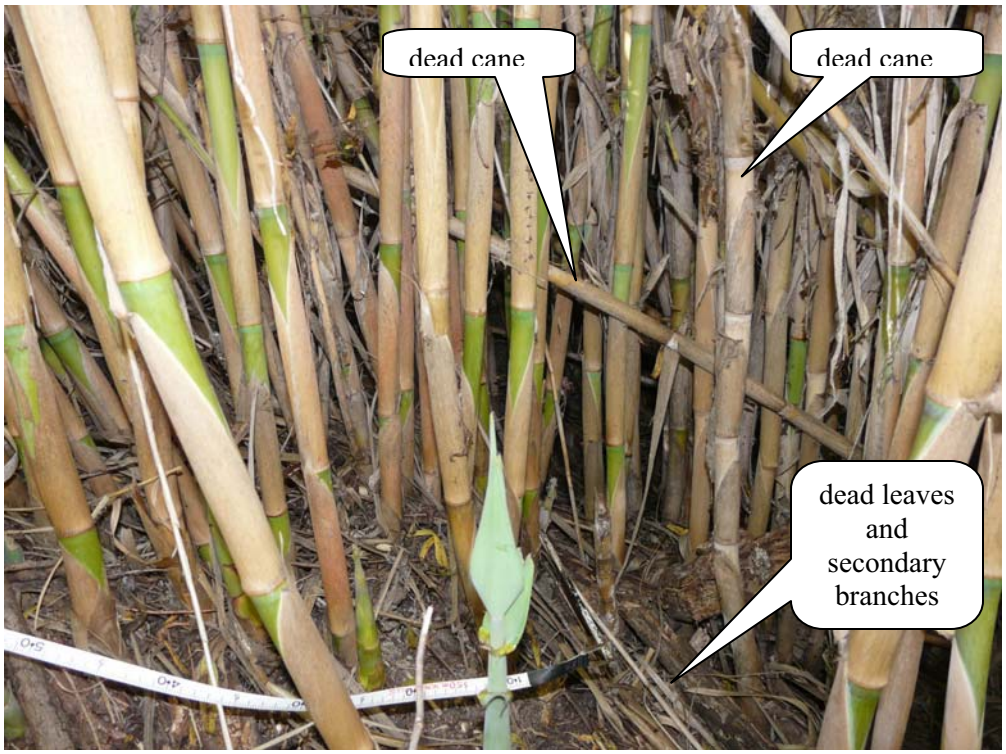


Figure 6-1. Large amount of dead/dry *Arundo* fuel.
While only a small percent of the overall stand biomass is dead and dry, it is enough to start and maintain fires.



Figure 6-2. This fire started in *Arundo* at night during a light rain in October 2006.
Photos from San Diego News outlets (Fires SLR#1-3).



Figure 6-3. Burned *Arundo* stands on the San Luis Rey River (Fire SLR #6).



Figure 6-4. Burned *Arundo* stands on the San Luis Rey River (Fire SLR #6).

6.3 Ignition Sources

Fires must have an ignition source in order to burn. Two main groups of ignition sources have been observed for fires that burn *Arundo* stands: local ignition sources (people in or around *Arundo* stands) and wildland fires. Wildland fires may be started by humans, or may start from lightning, although this is an increasingly infrequent occurrence (Keeley & Fotheringham 2005). Most wildfires start from arson, campfires, vehicle fires, power lines, and other human activities (CalFire and Ventura incident reports, Keeley & Fotheringham 2001).

6.3.1 Human Ignition Sources:

This report documents that *Arundo* directly increases the probability of fire ignition due to *Arundo* stands supporting human activities that lead to fires. *Arundo* stands offer concealment and shelter, which results in encampments and use by transients (Figure 6-5). Activities by transients within *Arundo* stands directly start fires. The following examples are from the San Luis Rey watershed, which has had documented camps and fires within *Arundo* stands for the past 10 years. Camps often have open fires for cooking and heat (Figures 6-6 & 7). Some camps even have portable heaters and ovens (Figure 6-8). Humans frequently smoke and use substances that must be ignited or heated for use, or may process these materials in camps (Figure 6-9). Humans have also intentionally set fires to *Arundo* stands (NLF 2006/7). Fireworks and firearm discharge may also lead to fires. Concealment, availability of water, and remoteness in some areas has also led to the cultivating of cannabis on several watersheds (documented on the San Luis Rey and Santa Ana). These operations have resulted in at least one fire event from an area where the workers had an open campfire (Figure 6-10). Transient activities and encampments are the primary ignition source for fires that start in *Arundo* stands. Direct evidence of the ignition source is usually present at the fire site.



Figure 6-5. Camp on San Luis Rey River with *Arundo* folded over to make an enclosure.



Figure 6-6. Camp on San Luis Rey River in *Arundo* stands showing tent, tarp and fire ring. *Arundo* surrounds the camp.



Figure 6-7. Camp on San Luis Rey River within *Arundo*, showing multiple lighters, cooking area and burned *Arundo* canes.



Figure 6-8. Camp on San Luis Rey River in *Arundo* showing tent and cooking area with a portable oven connected to propane.



Figure 6-9. Small methamphetamine lab on the San Luis Rey River within *Arundo* stands.



Figure 6-10. Open fire associated with workers of a cannabis plantation.
This was the ignition source of a wildfire that started within *Arundo* on the San Luis Rey River (Fire SLR #6).

An excerpt from the North County Times on January 23, 2007, referred to the fires on the San Luis Rey River:

> "The fires all started in areas widely known as hideouts for transients that set up camps among the brush and 'bamboo' that clogs the riverbed," authorities said. "We've always had fires occur in the river bottom due to the homeless population," Lawrence said. "But transients normally go through great effort to keep fires from spreading, so we're surprised to find uncontained vegetation fires when we arrive. Normally they're small cooking fires." Patricia Clutter, who lives near the river, said that she has witnessed five fires in the last four years and many neighbors are concerned.

Between 2000 and 2009, 34 encampments in *Arundo* stands were documented on the San Luis Rey River (Figure 6-11, Table 6-2). San Luis Rey data indicate that approximately one camp occurs for every 2 miles of invaded river. Encampments in *Arundo* on other rivers were recorded as encountered through reports or during the mapping phase of this project. While this is an incomplete data set, it indicates that encampment use of *Arundo* stands occurs on all large watersheds (Figure 6-11): San Diego (6 recorded), Santa Ana (3), Los Angeles (3), and Ventura (5 recorded with very high density). More focused surveying over a longer time period would likely reveal similar levels of encampment use as seen on the San Luis Rey River. This study's data, coupled with the San Luis Rey long-term monitoring data, clearly show a fairly high density of encampments in *Arundo* stands occurring in urbanized areas (homeless transients) as well as agricultural areas (agricultural workers).

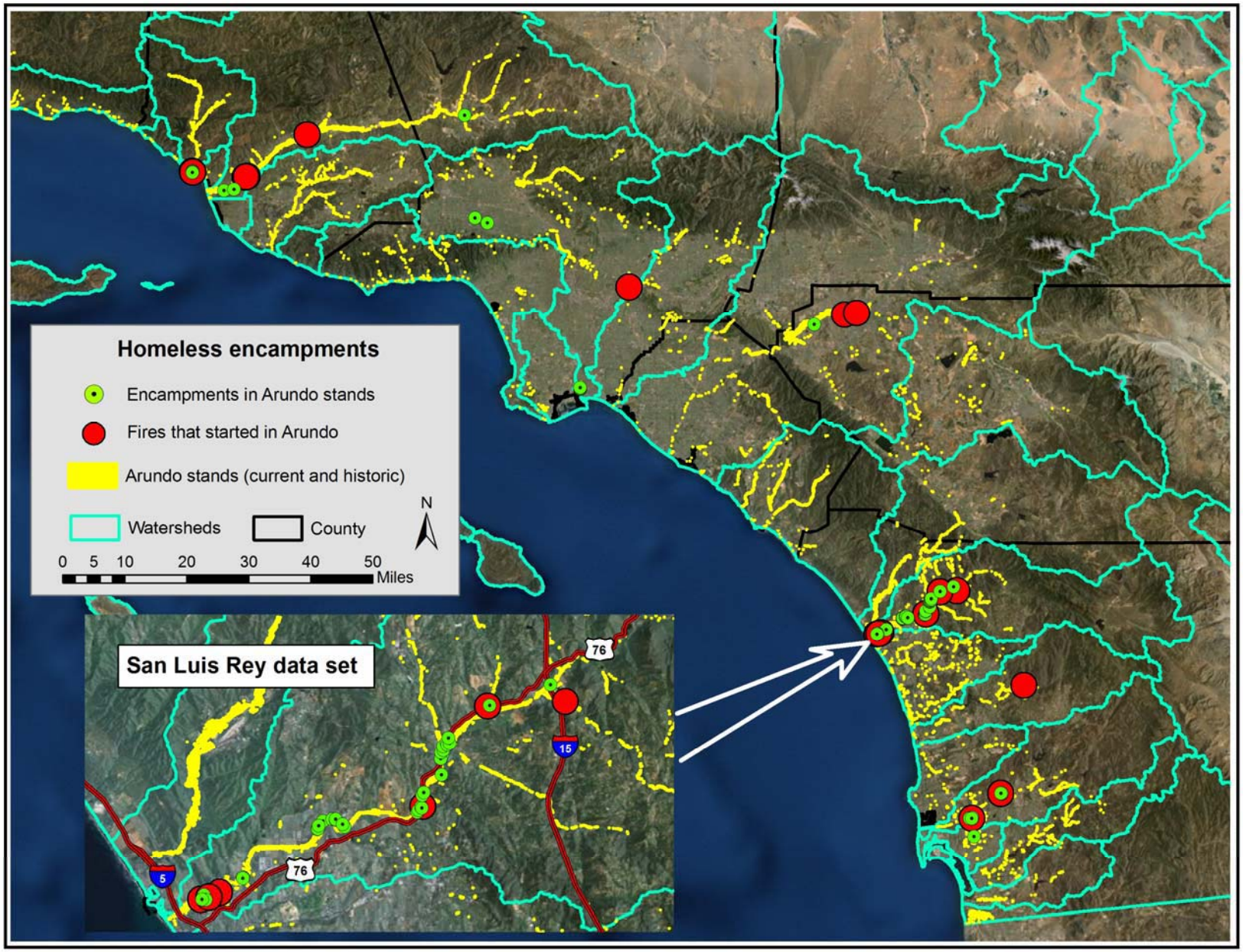


Figure 6-11. Location of *Arundo* fires for some southern California watersheds.

Table 6-2. Encampments found within *Arundo* stands on the San Luis Rey River.

Camps	People	Time Frame	Completeness
34	84	2000-2009	Very complete, but likely an underestimate

The second most common ignition source is likely from cigarettes being thrown out of vehicles on bridges above *Arundo* stands. This has resulted in frequent fires in the San Diego, San Luis Rey, and Santa Ana Rivers. Areas under bridges and overpasses are also high use areas for transients, so differentiating ignition sources can be difficult, but some fire events occurred in areas that have little use by transients.

Arundo fires started by human activities are usually suppressed quickly. The fires can occur at any time during the year. They frequently occur during conditions that are not optimal for fire events, helping fire suppression/response teams. These fires usually have smaller footprints than wildland fires. There is no recorded example of a fire that started in *Arundo* developing into a large wildland fire, but the number of *Arundo* fires that have already been documented increases the potential for this to occur.

6.3.2 Wildland Fire As An Ignition Source:

Wildfires that pass through an area where *Arundo* is present will ignite and burn *Arundo* stands. The presence of *Arundo* changes how the fire behaves within the riparian zone. *Arundo* can have three important impacts on wildfires: 1) *Arundo* causes the fire to burn hotter and more completely within the riparian area, 2) *Arundo* causes the wildfire to burn larger areas within the riparian zone, and 3) *Arundo* conveys the wildfire through the riparian area into adjacent landscapes, causing more area to burn (urban, rural, or wildland areas). These impacts will be explained in the next section.

6.4 Spatial Distribution and Frequency of *Arundo* Fires

Two types of fire events that burn *Arundo* were mentioned in the previous section: 1) fires that start in *Arundo* and 2) wildland fires that burn *Arundo* stands. The frequency and spatial distribution of these events within the study area will be discussed in this section.

6.4.1 Fires Starting in Arundo

Due to the difficulty of detecting fires on aerial imagery (unless they happen to be taken right after a fire event), only the San Luis Rey River watershed can be used as a comprehensive estimate of *Arundo* fire events over time. Boundaries of fires were captured by examining aerial imagery and ground-based photography, and digitizing the footprint of the fire. In some instances the fire line had been walked with a GPS immediately after the fire events to document the extent of the fire. The San Luis Rey River watershed is a good system to examine as it had abundant *Arundo* acreage and is fairly characteristic of coastal watersheds with various land uses (urban, rural, and open space). Additionally, as outlined in the previous section, data on ignition and encampments has been collected for the San Luis Rey. The number of fires, acreage of fires, and impacts associated with fire suppression were recorded.

6.4.1.1 San Luis Rey Watershed Case Study

A total of six separate fire events initiated in *Arundo* stands were recorded between 2000 and 2007 (Figure 6-12, Table 6-3). Fire events occurred within all reaches of the watershed where *Arundo* was abundant, from the coast to inland areas.

Three fires (SLR #1 to 3) occurred near the river mouth between October 2006 and March 2007 (Figures 6-2, 6-12 to14). These fires were reported in local newspapers and observed by Jason Giessow (this study). Fire suppression clear zones as well as fuel break strips were created to contain the fire (Figures 6-13&14). The ignition source for at least one fire was believed to be an arsonist. Transient use of the area was also high. The fires burned a total of 27.7 acres, and 5.6 acres of habitat were cleared during fire suppression activities (Table 6-3).

Proceeding upstream, the next fire (SLR #4) occurred at the Highway 76 bridge over the San Luis Rey River near East Vista Way in June 2005. This fire burned 1.40 acres (Figures 6-12 & 15). No specific ignition source was identified, but it was likely either a discarded cigarette from the highway overpass or a transient camp. Both uses occur in that specific area. No fire lines were cut around the fire because the river channel and a road surrounded it.

A large fire occurred on June 17, 2007 near Gird Road and Highway 76 (SLR #5; Figures 6-3 & 4, 6-12 & 16). This struck during high fire season and burned a larger area than the other fires on the river. The fire was 64.31 acres in size and fire suppression activities disturbed an additional 0.90 acres. This fire had active suppression, but would likely have been much larger were it not for a vertical 30-foot river bank that served as a natural fuel break on the southern edge of the fire line. The ignition source was likely a campfire related to cannabis cultivation within the central portion of the *Arundo* stand (Figure 6-10). Irrigation tubing was observed leading into the stand area from the river.

The most upstream fire within the study area occurred on a tributary near the confluence of the San Luis Rey River and Keys Creek (SLR #6; Figures 6-12 & 17). This fire occurred in 2001 and was 10.37 acres in size. Local residents speculated that it was kids playing with fire/fireworks/guns. The area has no use by transients and it is not close enough to the highway for cigarettes to have caused the fire. No fire suppression disturbance was recorded, but impacts could have occurred.

Table 6-3. San Luis Rey Watershed: Data on fire events fires that started in *Arundo* between 2000 and 2007.

Fire Name	Date	Fire acreage	Acreage of Impacts from suppression	Total
SLR Fire #1-3	Oct 2006-Mar 2007	27.7	5.6	33.3
SLR Fire #4	June 2005	1.4	0	1.4
SLR Fire #5	June 17, 2007	64.3	0.9	65.2
SLR Fire #6	May 2004	10.4	?	10.4
	Total:	**103.8**	**6.5**	**110.3**

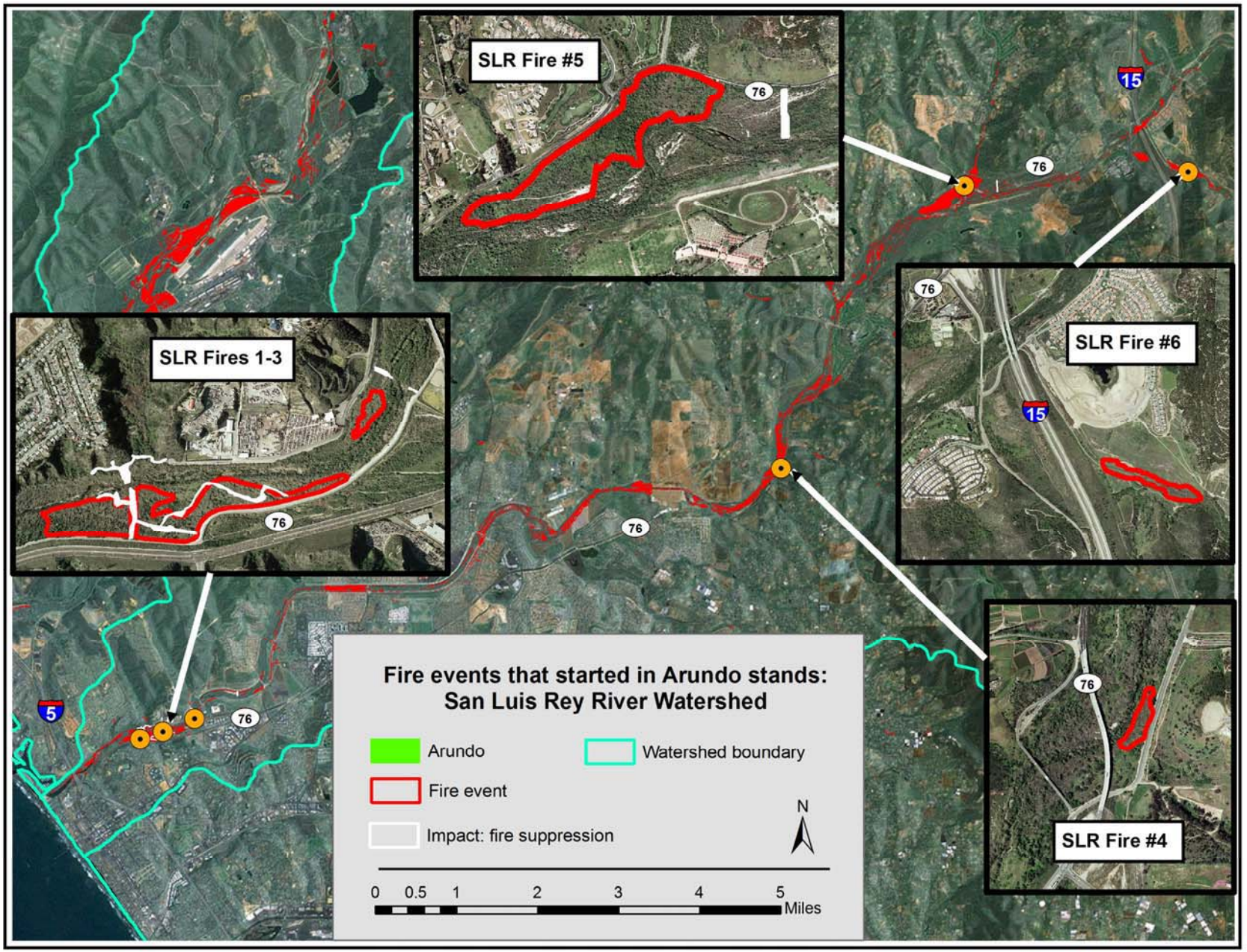


Figure 6-12. Fire events that started in *Arundo* stands on the San Luis Rey River from 2000 to 2007.

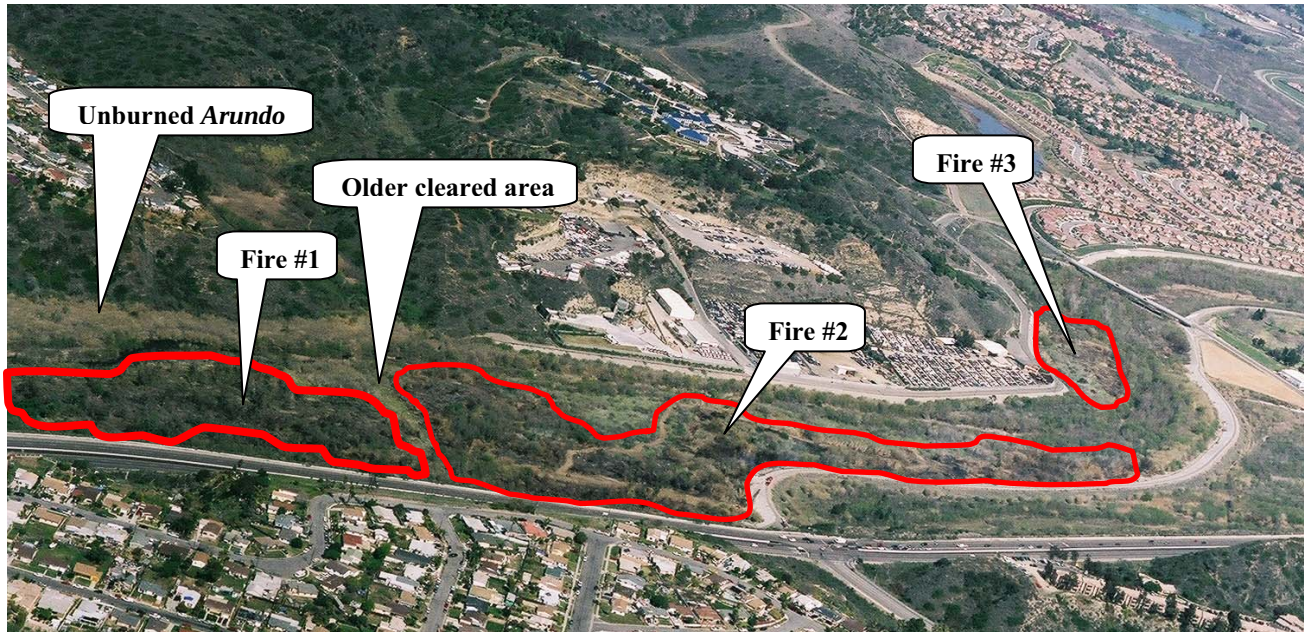


Figure 6-13. Footprint of fires # SLR 1-3 on the San Luis Rey River.

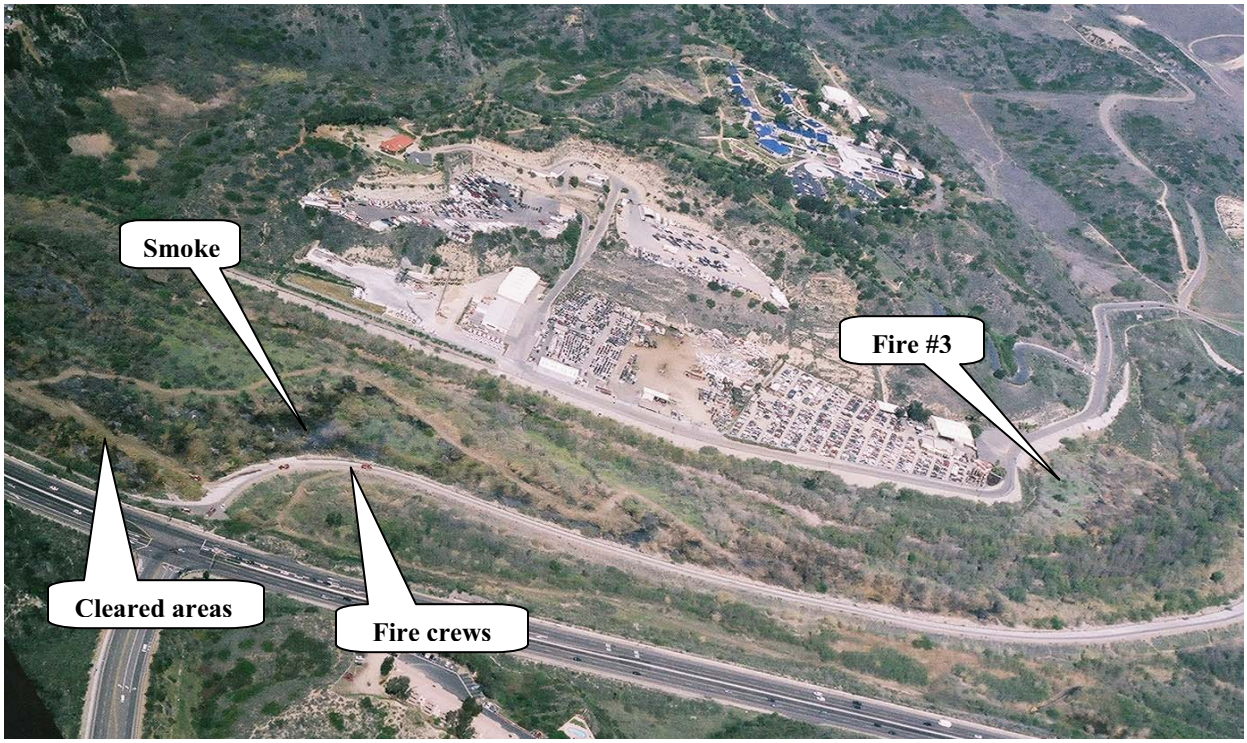


Figure 6-14. Location of fires # SLR 1-3 and fire containment cleared areas on the San Luis Rey River.



Figure 6-15. *Arundo* resprouting after a fire on the San Luis Rey River. Native trees are either dead, or still dormant (Fire SLR #5).



Figure 6-16. Immediately after a fire that burned an *Arundo* stand on the San Luis Rey River, leaving only ash and very little unburned material (Fire SLR #6).



Figure 6-17. Shortly after a fire through *Arundo*-infested riparian habitat on the San Luis Rey River. This demonstrates the quick and dense resprouting of *Arundo* before any native vegetation (Fire SLR #7).

6.4.1.2 Summary of Fire Impacts: Fires Initiated in *Arundo* Stands

For the eight-year period between 2000 and 2007, a total of 103.8 acres of riparian habitat burned during six recorded events (Table 6-4). *Arundo* dominated stands were 43.28 acres of the burned area and native dominated vegetation was 60.54 acres. *Arundo* stands on the San Luis Rey totaled 684.2 acres. During the eight-year period, 6.3% of the *Arundo* stands burned in fires that started in *Arundo* (Table 6-5). A total of 6.9% of *Arundo* stands either burned or were impacted during fire suppression for these events. The average acreage burned each year was 13.0 acres with an additional 0.8 acres impacted during fire suppression. These relationships will be used to extrapolate the fire and fire suppression impacts to other watersheds.

Table 6-4. San Luis Rey Watershed: Acreage summary of impacted vegetation for fires started within *Arundo* stands over an eight-year period (2000 to 2007).

Interval	**Acreage Burned: Fires Started in *Arundo***			**Acreage impacted during fire suppression**			**Total riparian acreage**
	Arundo	*Native*	*Riparian*	*Arundo*	*Native*	*Riparian*	*Total*
8 yr	43.3	60.5	103.8	3.7	2.8	6.5	110.3
Annual	5.4	7.6	13.0	0.5	0.4	0.8	13.9

Table 6-5. San Luis Rey Watershed: Acreage of *Arundo* that burned in fires started within *Arundo* stands over an eight-year period (2000-2007).

Fires started in *Arundo* (documented)	Gross *Arundo* Acres	*Arundo* burned acres over 8yrs	% *Arundo* burned in 8 yrs	Annual % *Arundo* burned in 8 yrs
San Luis Rey	683.9	43.28	6.3%	0.8%

A key finding in this San Luis Rey River fire history is that *all recorded fires that started in the river were initiated in Arundo.* This does not mean that riparian habitat lacking *Arundo* cannot burn. The fires that started in *Arundo* burned large sections of riparian habitat (60.54 acres) that had little or no *Arundo*. What this shows is that un-invaded riparian habitat is not typically ignitable and usually only burns if a hot, well-developed fire is actively burning. This happens when *Arundo*-initiated fires start or when wildland fires occur.

6.4.1.3 Fires That Started Within *Arundo* Stands: Other Watersheds

A second data set was also prepared on behalf of the San Diego River Watershed for known fires that began within *Arundo* stands. The data set is most likely incomplete as less background information was found for the system. Two fires were mapped: 1) a 1990 8.4-acre fire that occurred on the lower watershed and 2) a January 2008 0.9-acre fire on the upper watershed. Over this 19 year time there were 9.3 acres of *Arundo* fires. This represents 6.2% of the *Arundo* stands on the San Diego River (150.5 acres), but over a longer time frame then the San Luis Rey fire documentation. There are more reports of fire events on the lower and upper San Diego River, but it was not possible to quantify them. Operators of a golf course along 1.5 miles of the heavily invaded upper river report frequent fire events over the past 15 years. Ignition source was likely a mix of transient use (which is high in that area) and discarded cigarettes from the highway that runs over the river. The lower San Diego River also has had additional fire events that are tied to homeless activity, but these could not be tied to specific locations and/or *Arundo* stands. The San Diego River *Arundo* fires show the same general pattern of ignition and fire pattern as the San Luis Rey River.

To help illustrate those fires that originate in *Arundo* stands are not isolated occurrences, we prepared a data set of all fires reported/encountered within *Arundo* for the project area (Figure 6-11). We mapped 12 fires that started in *Arundo* stands on other watersheds. This data set grossly underestimates the number of fires starting in *Arundo*, as it is limited to citations in reports, media coverage, fire response reporting, and discussion with program proponents on other watersheds. Even as a conservative representation of *Arundo* fire events, it shows that fires initiated within *Arundo* are indeed common events that have been observed on most watersheds with dense stands of *Arundo*. A brief qualitative overview demonstrates that each affected watershed has similar fire patterns - fires tend to occur where there are dense *Arundo* stands and ignition sources (encampments, bridges). Level of urbanization and transient use is highest along the coast for select watersheds (Ventura, San Luis Rey, San Diego), although interior cities and towns are found along rivers on others (Santa Ana, Santa Clara, Salinas). Agricultural use and migrant worker camps are found in the centralized portions of the watersheds (San Luis Rey, Santa Clara, Salinas). Remoteness, allowing cannabis cultivation and its associated fire impacts, has been observed in San Luis Rey and Santa Ana. These operations usually are not discovered until *Arundo* control is initiated. Highway and road overpasses occur at numerous points along each

watershed creating conditions where stands can burn from discarded cigarettes. Highway bridges in dense and moderate urban/agricultural areas are particular attractants for transients and homeless use.

Since the pattern and frequency of fires appears to be similar across watersheds, applying the relationships outlined on the San Luis Rey Watershed seems reasonable. This holds true as an approximation of acreage burned on an annual and decade basis for each watershed and the overall study area, with two exceptions (Table 6-7). The Salinas Watershed was adjusted downward as humans report fewer fires there, likely due to a combination of different climatic conditions and lower use of the river. Also, the Santa Margarita River is mostly owned and managed by the Department of Defense, so there is limited use by transients in riparian areas. The lack of fires initiated within *Arundo* on the Santa Margarita River, where there are no encampments, supports that this is a primary ignition source.

6.4.2 Wildland Fires That Burn Arundo Stands

Arundo stands have two main effects on wildfires: 1) when a wildfire burns riparian habitat containing *Arundo*, it burns hotter than the habitat would have without the presence of *Arundo* and 2) *Arundo*-infested riparian habitat can act as a fire conveyor across the landscape. This can increase the size of riparian fires and may spread fires to upland areas that would normally have been separated by less flammable native riparian vegetation.

Wildland fires that burned riparian habitat containing *Arundo* stands are noted in Figure 6-18 and Table 6-6. Events that burned large riparian areas on San Dieguito, Santa Margarita, Santa Ana, and Santa Clara watersheds, as well as smaller events on San Luis Rey, San Diego and Otay watersheds, are noted. These are events that started in upland areas, and then developed into large wildland fires. These large wildfire events will often burn riparian vegetation regardless of how much *Arundo* is present. However, when an area infested with *Arundo* does burn, there is significantly more biomass present than would occur in comparison to uninvaded habitat (see section 6.1 on biomass). *Arundo* fuel loads are more vertical and well ventilated than native vegetation. Wildland fire events frequently have unburned patches within them, and vegetation with higher water content does not burn as well. For this reason, riparian zones often have more unburned or lightly burned areas. Presence of *Arundo* within the riparian zone increases the completeness of the burn, as well as the intensity. Wildland fire events that burn *Arundo* stands also lead to type conversion of those sites to *Arundo* dominated habitat (section 6.5.1).

The increased fuel load within *Arundo*-infested riparian habitat, and the resulting hotter and more complete fire, likely leads to riparian areas acting as fire corridors or areas of connectivity. This was documented for a fire on the Santa Clara River in June 2006 (Figure 6-19). This fire started on the north side of the river, burning 8,474 acres of uplands (A). The fire then moved into a riparian area with dense *Arundo*, crossed the 0.43 mile wide river, and then set the southern upland mountain range on fire (B). This fire burned an additional 107,560 acres, including setting the river on fire again 40 miles downstream (C). The fire crossed the river again, but did not set the north range uplands on fire. Agriculture and development blocked the fire's path (D). *Arundo*-infested riverine areas acting as fire corridors could be occurring in other areas, but it is difficult to prove because the effect of the *Arundo* is not always known. For the 2007 San Dieguito Watershed fire that burned 197,990 acres, there could have been areas that would not have conveyed the fire if *Arundo* had not been present, or there may have been larger central portions within the fire boundary that would not have burned (Figure 6-18). Similar patterns occurred in the 'freeway complex fire' that burned upland, riparian, and urban areas on the Santa Ana (Figure 6-18). The fire moved through *Arundo*-infested riparian habitat areas during early stages of the fire.

Table 6-6. Acreage of *Arundo* by watershed that burned during documented wildfires over a ten-year period.

Watershed	Gross *Arundo* Acres	*Arundo* acreage burned over 10 yrs (gross)	% *Arundo* burned over 10 yrs	Annual % *Arundo* burned over 10 yrs
Calleguas	231.5	71.5	30.9%	3.1%
Otay	18.6	0.5	2.5%	0.3%
San Dieguito	175.0	134.9	77.1%	7.7%
San Luis Rey	683.9	15.6	2.3%	0.2%
Santa Ana	2,723.9	95.7	3.5%	0.4%
Santa Clara	1,081.3	220.5	20.4%	2.0%
Sweetwater	42.3	6.0	14.2%	1.4%
Total:	**4,956.5**	**544.6**	**11.0%**	**1.1%**

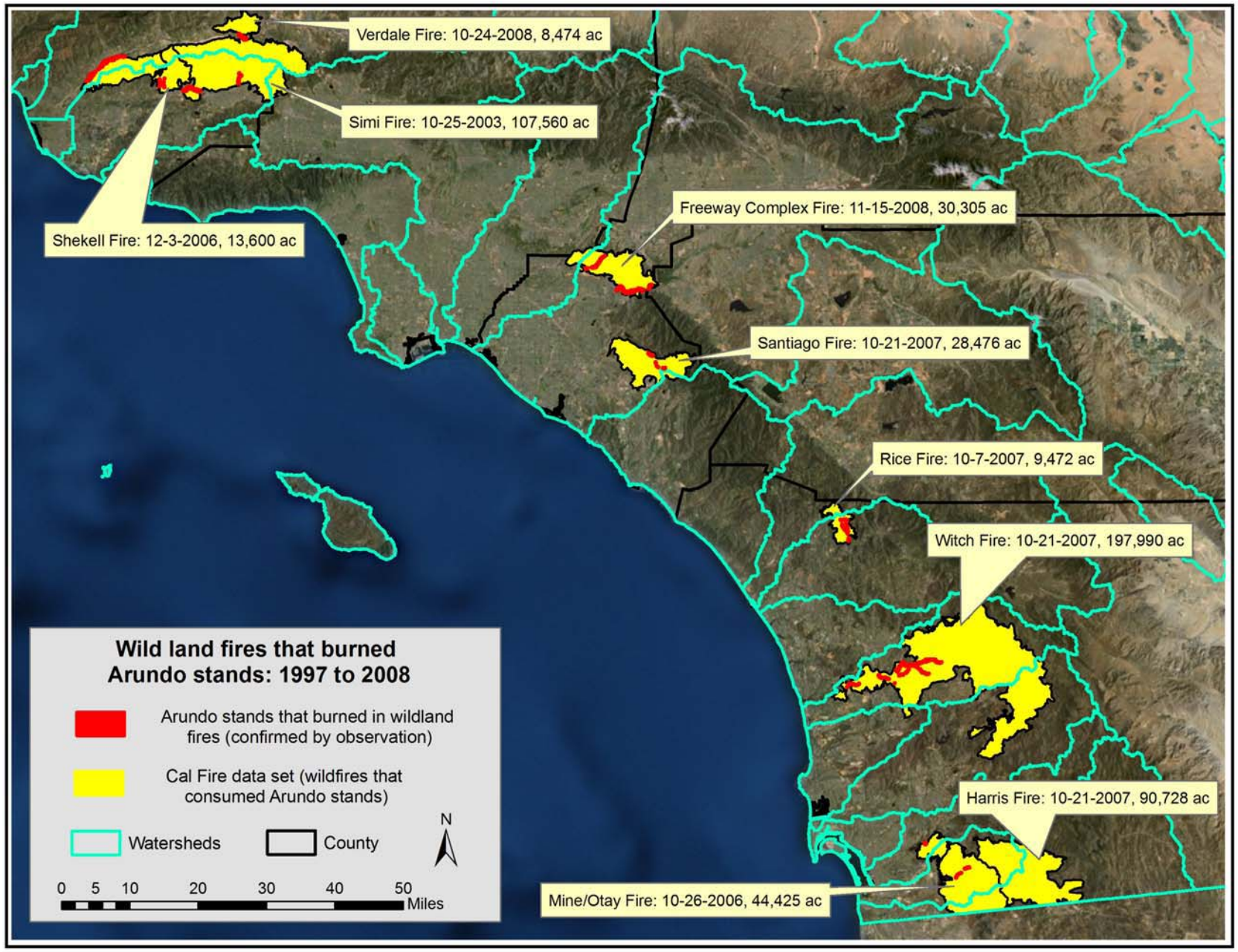


Figure 6-18. Location of wildland fires that burned *Arundo* stands within the project area from 1997 to 2008.

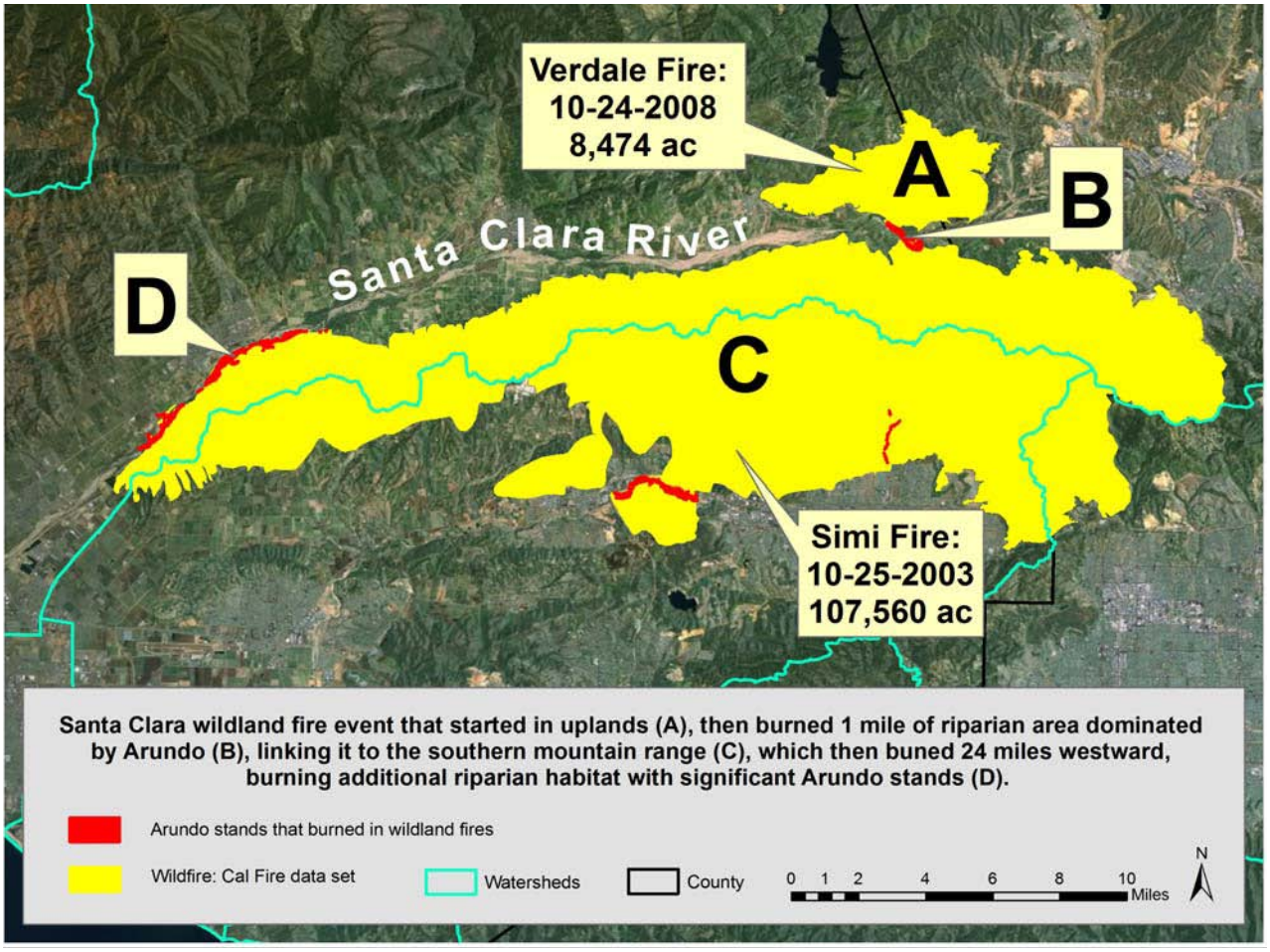


Figure 6-19. Wildfire on the Santa Clara with points A, B, C and D marked.

Conclusions:

- Watersheds with significant *Arundo* stands experience fire events that are due to the presence of *Arundo* (this study). The occurrence of these *Arundo*-initiated fires is quantifiable, both as percent of stands burned and acreage burned (this study).
- *Arundo* is a significant fire threat due to high fuel levels (Spencer et al. 2006, this study) in combination with harboring ignition sources. Fires that start in *Arundo* stands are observed on nearly all watersheds in the project area (this study).
- Wildland fires that burn riparian areas containing *Arundo* burn hotter and more completely due to higher fuel levels associated with the presence of *Arundo* (based on higher fuel loads – Spencer et al. 2006, this study).

Although fire was once a natural part of shrubland ecosystems that characterize the coastal southern California landscape, large riparian ecosystems provided natural firebreaks because native vegetation retains foliar water that resists ignition (Hanes 1971, Naveh 1975, Bell 1997, Rundel 1998, Keeley and Fotheringham 2001). This 'firebreak' function is lost if *Arundo* is present, and is even reversed, whereby riparian areas become 1) a fire source, or 2) a corridor of fire conveyance. Riparian ecosystems infested by *A. donax* adjacent to fire-prone shrublands in southern California appear to be on

a trajectory to an invasive plant-fire regime cycle (Brooks et al. 2004). Clearly wildland fires are burning *Arundo* stands in riparian areas. While it was not documented in this study, it is also likely that *Arundo*-initiated fires will lead to wildland fires given the frequency and intensity of *Arundo* fire events.

Fire Districts/Departments are keenly aware of the fire risks associated with *Arundo* stands. This led the City of Oceanside (San Luis Rey) to enact an ordinance under its code enforcement allowing action to be taken if private property has *Arundo* stands that are a fire risk. This action was driven by two factors: fires occurring in *Arundo* and the identification of wildland fire risk due to fires moving down *Arundo*-infested riparian corridors into urban areas.

6.5 Fire Impacts

In the previous section, it was established that *Arundo* impacts fire events in two general situations: fires that originate in *Arundo* stands (resulting from high fuel load combined with ignition sources) and wildland fires that burn *Arundo*-infested riparian habitat. This chapter will examine and quantify, based on the *Arundo* spatial data set, the impacts that these *Arundo*-driven fires cause.

6.5.1 Type Conversion to Arundo-Dominated Habitat

Arundo stands have high fuel loads and a tall growth form. Infestations of *Arundo* mixed with native species spread fire vertically into the canopy of riparian trees, as well as burning trunks (Figures 6-15 to 17 & 6-20; Ambrose and Rundel 2007). After a fire, *Arundo* immediately (1-2 weeks) begins regrowth from its rhizomes, whereas native riparian plants can remain dormant for several months. High mortality of native trees and shrubs is frequent in comparison to *Arundo*. Furthermore, *Arundo* grows much faster than native plants, up to 3-4 times faster than native riparian plants after fire on the Santa Clara River (Ambrose and Rundel 2007). A year after the fire, *Arundo* dominated the area, comprising 99% relative cover and a 24% increase in relative cover compared to pre-fire conditions (Ambrose and Rundel 2007).



Figure 6-20. *Arundo* one year after a fire, already 2-3 feet high, at the site of fire SLR #6.

A positive-feedback cycle is created whereby the high growth rate of *Arundo*, the fire adapted phenology of *Arundo*, and increased nutrient levels after fire contribute to type conversion. This domination by *Arundo*, in turn leads to more fires, creating an invasive plant-fire regime cycle (Ambrose and Rundel 2007, this study). Results from the mapping data also show that areas with mixed-*Arundo*/native vegetation prior to fire events are dominated by *Arundo* after the fires. This type conversion is important because it is a significant reduction in habitat value (section 7.1, Table 6-5). Fires started within *Arundo* combined with wildfires burned 12% (1,058 ac) of the *Arundo* acreage on all watersheds over a ten-year period (Table 6-7). Type conversion feeds the positive feedback loop. *Arundo*-dominated sites have higher biomass than mixed or patchy stands, increasing the likelihood of fire.

It should be noted that fire only affects within site spread/invasion. It does not allow or cause invasion to the broader system. Invasion outside the site still only occurs through movement of live plant material (flood action and/or human movement of rhizomes). However, the larger the *Arundo* sites, the more material there is for flood-based dispersal.

Table 6-7. Burned *Arundo* acreage from fires that start in *Arundo* and wildfires that burn *Arundo* (for one year and ten-year periods).
Acreages are calculated based on San Luis Rey watershed documented fire events, which is 0.8% of the gross *Arundo* acreage burned annually.

Watershed	Gross *Arundo* Acres	Fires that start in *Arundo*		Wildfires that burn *Arundo*		Combined *Arundo* fire totals	
		Burned *Arundo* acreage* (1 yr)	Burned *Arundo* acreage (10 yrs)	Burned *Arundo* acreage (1 yr)	Burned *Arundo* acreage (10 yrs)	Burned *Arundo* acreage (1 yr)	Burned *Arundo* acreage (10 yrs)
Calleguas	231.5	1.9	18.5	7.2	71.5	9.00	90.0
Carlsbad	147.9	1.2	11.8	-	-	1.18	11.8
Los Angeles River	132.8	1.1	10.6	-	-	1.06	10.6
Otay	18.6	0.1	1.5	0.1	0.5	0.20	2.0
Penasquitos	23.6	0.2	1.9	-	-	0.19	1.9
Salinas[1]	2,006.1	1.6	16.0	-	-	1.60	16.0
San Diego	150.2	1.2	12.0	-	-	1.20	12.0
San Dieguito	175.0	1.4	14.0	13.5	134.9	14.89	148.9
San Gabriel	44.6	0.4	3.6	-	-	0.36	3.6
San Juan	175.2	1.4	14.0	-	-	1.40	14.0
San Luis Rey	683.9	5.5	54.7	1.6	15.6	7.03	70.3
Santa Ana	2,723.9	21.8	217.9	9.6	95.7	31.36	313.6
Santa Clara	1,081.3	8.7	86.5	22.1	220.5	30.70	307.0
Santa Margarita [2,3]	688.9	0.6	5.5	-	-	0.55	5.5
Santa Monica	18.6	0.1	1.5	-	-	0.15	1.5
South Coast	29.8	0.2	2.4	-	-	0.24	2.4
Sweetwater	42.3	0.3	3.4	0.6	6.0	0.94	9.4
Tijuana	135.6	1.1	10.8	-	-	1.08	10.8
Ventura	332.0	2.7	26.6	-	-	2.66	26.6
Total:	**8,841.7**	**51.3**	**513.3**	**54.5**	**544.7**	**105.8**	**1,058.0**
% of Gross Ac:			**5.8%**		**6.1%**		**12%**

[1]Annual fire rate lowered to 10% of that for southern California due to weather conditions and lack of fire reports.
[2]Fires starting in *Arundo* are less common on Camp Pendleton (DoD facility), lowered to 10% for the watershed.
[3]Most *Arundo* had been removed in areas where wildfires burned riverine areas, so no acreage was counted.

6.5.2 Impacts to Fauna,

Fires that are started within *Arundo* stands and wildfires made worse by *Arundo* stands can result in direct mortality of fauna, especially species that cannot escape rapidly. Mortality will vary depending on the season in which the fire occurs. During nesting season, fires may result in direct loss of eggs and young birds. Arroyo toads remain buried during portions of the non-breeding season, and may not survive a fire, depending on the intensity. The addition of ash and other mobilized material (erosion) into breeding pools/ponds may impact fish and amphibians, and the loss of vegetation along waterways may impact shading and water temperature regulation.

After a fire, the habitat is degraded to a condition that does not support species for an amount of time that depends on the fire's intensity and season. One year of functional loss and a degraded condition for 2-5 years are evident on most sites. When the habitat does come back, it may not return to pre-fire conditions and may not be able to support the same abundance and diversity of fauna and flora. Areas that burned may be more open and have more weedy species. If *Arundo* was present before the fire, this is especially a concern, as it re-grows faster than the native species (see Sec 6.5.1).

The degradation of riparian habitat from *Arundo*-initiated fires is estimated for all watersheds based on data from San Luis Rey (Table 6-8). Riparian areas that burn during *Arundo*-initiated fires exceed the *Arundo* acreage that burns (705.8 ac vs. 513.3 ac). Suppression activities impact 32.1 acres of riparian habitat and 43.6 acres of *Arundo* habitat. Cumulatively this covers 1,200 acres of riparian habitat over a ten-year period. This is a significant amount of acreage and it does not include wildfire impacts.

Estimation of the *Arundo* acreage that burns is presented in Table 6-5. Wildfires can burn riparian vegetation during certain conditions, so the entire event cannot be ascribed as an *Arundo* fire impact. The presence of *Arundo* does increase the intensity, and *Arundo* may convey wildfires. These impacts are difficult to quantify and to identify spatially, complicating exploration of their impacts on flora and fauna. No specific accounting of these impacts is presented.

However, fires initiated *within Arundo* stands that result in mortality of fauna and flora are fully ascribed as impacts caused by the *Arundo*. Quantifying this presents challenges, but detailed mapping of fires on the San Luis Rey watershed (Section 6.4.1) present an opportunity to explore this. Very detailed survey data (aggregated from USGS, CalTrans, and ACOE) for least Bell's vireos, Southwestern willow flycatchers, and Arroyo toads indicate that *Arundo* fires that burn riparian habitat have directly impacted occupied habitat for endangered wildlife species (Figure 6-21, Table 6-9). These *Arundo*-dominated areas are of moderate habitat quality to begin with, but flora and fauna utilize pockets of native vegetation. *Arundo* fires can also spread into adjacent higher quality native riparian habitat. Fire suppression activities impact both *Arundo* and native habitat. The area of fires SLR#1, #2 and #3 is very near the mouth of the river, which is at the edge of least Bell's vireo habitat range. Least Bell's vireos were present on the edges of all the fire areas. Fire SLR#4 had least Bell's vireo use on the upstream edge of the fire area. Fire SLR#5 was a fire that occurred during breeding season in a high-use least Bell's vireo area. Mortality likely occurred. Arroyo toads could also have occurred on-site in low numbers. Site SLR#6 is in core, high density Arroyo toad habitat, and mortality likely occurred. Least Bell's vireo use could also occur in this area (only limited surveying was completed for this site, but they are abundant nearby).

In addition to direct take of fauna, habitat that was burned in all of the areas has a significantly reduced habitat value and function. Areas with *Arundo* present would have nearly 100% *Arundo* cover post-fire, while burned native vegetation takes over five years to recover structure and productivity.

Table 6-8. Summary of acreage impacted by burning and fire suppression from fires that start in *Arundo*.
Burned acreage and suppression acreage for watersheds is calculated based on San Luis Rey watershed-documented fire events (multiplying percentage from San Luis Rey by gross *Arundo* acreage for each watershed).

Fires that start in *Arundo*		Fire: *Arundo*		Fire: Riparian		Suppression: *Arundo*		Suppression: Riparian		All Riparian Impacts	
Watershed	**Gross *Arundo* Acres**	**Annual burn ac (0.8%)**	**10 year total**	**Annual burn ac (1.1%)**	**10 year total**	**Annual impacted ac (0.068%)**	**10 year total**	**Annual impacted ac (0.051%)**	**10 year total**	**Annual ac**	**10 year total**
Calleguas	231.5	1.9	18.5	2.5	25.5	0.2	1.6	0.1	1.2	4.7	46.7
Carlsbad	147.9	1.2	11.8	1.6	16.3	0.1	1.0	0.1	0.7	3.0	29.8
Los Angeles River	132.8	1.1	10.6	1.5	14.6	0.1	0.9	0.1	0.7	2.7	26.8
Otay	18.6	0.1	1.5	0.2	2.1	0.0	0.1	0.0	0.1	0.4	3.8
Penasquitos	23.6	0.2	1.9	0.3	2.6	0.0	0.2	0.0	0.1	0.5	4.8
Salinas[1]	2006.1	1.6	16.0	2.2	22.1	0.1	1.4	0.1	1.0	4.0	40.5
San Diego	150.2	1.2	12.0	1.7	16.5	0.1	1.0	0.1	0.8	3.0	30.3
San Dieguito	175.0	1.4	14.0	1.9	19.2	0.1	1.2	0.1	0.9	3.5	35.3
San Gabriel	44.6	0.4	3.6	0.5	4.9	0.0	0.3	0.0	0.2	0.9	9.0
San Juan	175.2	1.4	14.0	1.9	19.3	0.1	1.2	0.1	0.9	3.5	35.3
San Luis Rey	683.9	5.5	54.7	7.5	75.2	0.5	4.7	0.3	3.4	13.8	138.0
Santa Ana	2723.9	21.8	217.9	30.0	299.6	1.9	18.5	1.4	13.6	55.0	549.7
Santa Clara	1081.3	8.7	86.5	11.9	118.9	0.7	7.4	0.5	5.4	21.8	218.2
Santa Margarita [2]	688.9	0.6	5.5	0.8	7.6	0.0	0.5	0.0	0.3	1.4	13.9
Santa Monica	18.6	0.1	1.5	0.2	2.0	0.0	0.1	0.0	0.1	0.4	3.8
South Coast	29.8	0.2	2.4	0.3	3.3	0.0	0.2	0.0	0.1	0.6	6.0
Sweetwater	42.3	0.3	3.4	0.5	4.7	0.0	0.3	0.0	0.2	0.9	8.5
Tijuana	135.6	1.1	10.8	1.5	14.9	0.1	0.9	0.1	0.7	2.7	27.4
Ventura	332.0	2.7	26.6	3.7	36.5	0.2	2.3	0.2	1.7	6.7	67.0
Totals:	**8,841.7**	**51.3**	**513.3**	**70.6**	**705.8**	**4.4**	**43.6**	**3.2**	**32.1**	**129.5**	**1,294.8**

[1]Annual fire rate lowered to 10% of that for southern CA due to weather conditions and lack of fire reports.
[2]Fires starting in *Arundo* are less common on Camp Pendleton (DoD facility), lowered to 10% for the watershed.

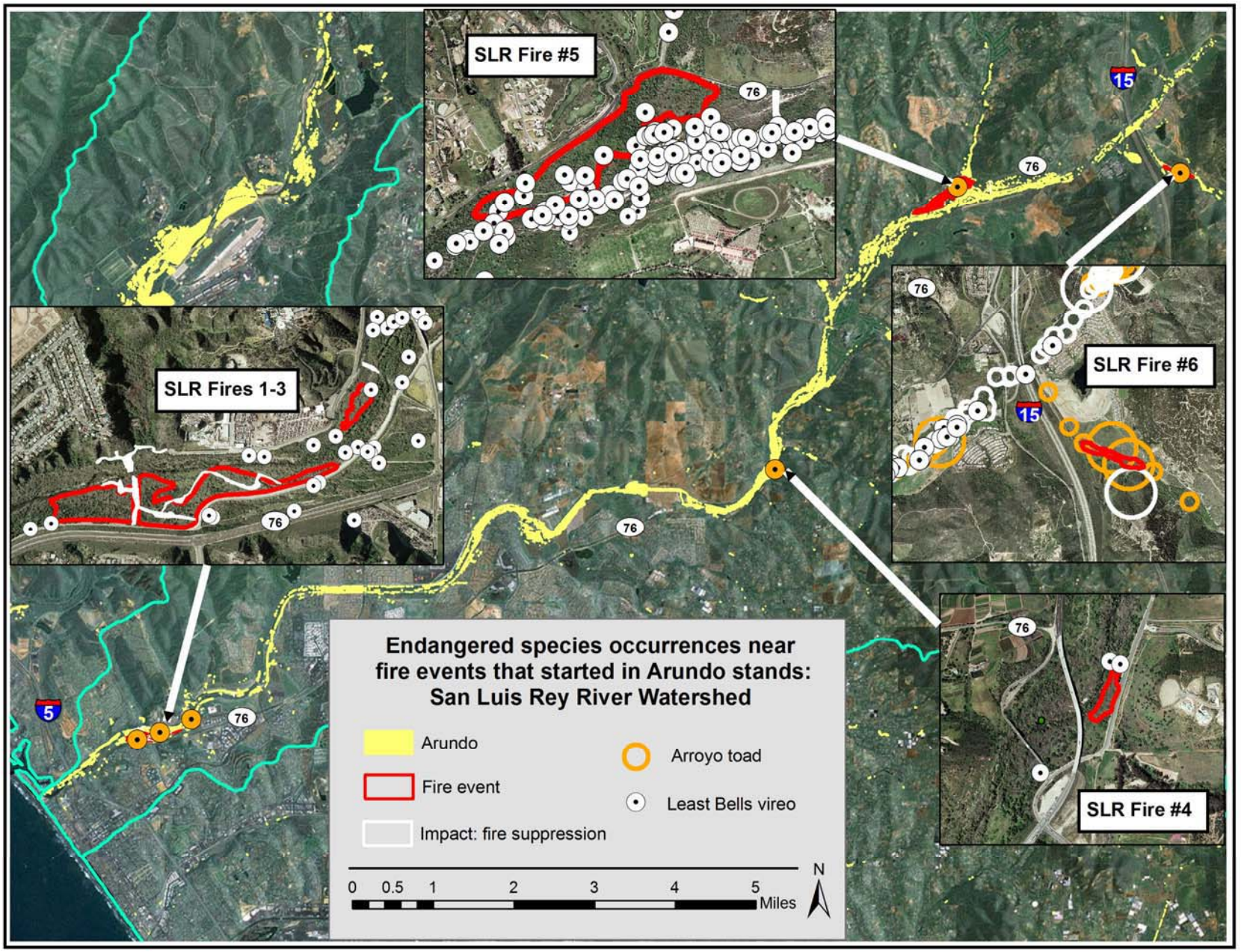


Figure 6-21. Fire events that started in *Arundo* stands on the San Luis Rey River showing sensitive species locations.

Table 6-9. Summary of San Luis Rey River *Arundo* fire impacts on federally endangered species.

Fire Event	Least Bell's vireo	Arroyo toad	Tidewater goby	Southwestern willow flycatcher
SLR#1,2&3	Low	None	Low	Possible
SLR#4	Medium	None	None	Possible
SLR#5	High	Low	None	Possible
SLR#6	Low	High	None	Possible

6.5.3 Impacts from Emergency Acts

Prior to or during fire events, actions are sometimes carried out to reduce the spread of a fire. These actions generally involve clearing vegetated areas to form fire breaks. These cleared areas tend to become weedy due to the disturbance of the soil and removal of established vegetation. If cleared areas are within or near *Arundo* stands, their creation may spread *Arundo* fragments throughout the area and establish new *Arundo* populations. Disturbed areas retain modified topography and poor quality habitat until there is a flow event that resets the geomorphology and allows native recruitment to occur. Depending on the location of the cleared area within the profile, this may occur quickly or after a prolonged period of time.

Emergency actions may also directly impact flora and fauna, as seen in Figure 6-21, where cleared areas were within least Bell's vireo (SLR#1,2,3 & 5) and arroyo toad habitat (SLR#5). The federally endangered plant *Ambrosia pumila* (San Diego ambrosia) also occurred near the disturbance on fire SLR#5.

Although acreage impacted seems minor at first, fire suppression impacts of 43.6 acres of *Arundo* and 32.1 acres of native riparian habitat (Table 6-8) are generated for the study area over 10 years. Many of these impacts are severe modifications (e.g. grading) of occupied threatened and endangered species' habitat.

6.6 Conclusions: Fire Impacts

Arundo significantly changes the intensity, frequency and behavior of fires. It has transformed heavily invaded riparian habitat, which includes many coastal river systems in southern California, from a vegetation type that is normally resistant to fire to a source of fire events. Areas invaded with *Arundo* are flammable, harbor ignition sources, and spread fires both within riparian habitat as well as across the landscape.

- *Arundo* stands are highly flammable throughout the year with large amounts of fuel (15.5 kg/m^2 of biomass), a large amount of energy (287.1 MJ/m^2), and a tall well-ventilated structure with dry fuels distributed throughout the height profile. (Section 6.1)
- Fires frequently start in *Arundo* stands. The primary ignition sources are transient encampments and discarded cigarettes from highway overpasses. (Section 6.1)

- *Arundo* stands strongly attract transient use (dense cover and shelter). This was documented throughout the study area with numerous high use locations noted in both urban and agricultural areas. (Section 6.3.1)
- Fires initiated in *Arundo* stands occur due to fuel and ignition source occurring at the same location. This is a newly defined class of fire events. (Section 6.4.1)
- Fires that are initiated in *Arundo* burn both *Arundo* stands and native riparian areas. In addition, suppression of fires also impacts riparian habitat. Impacts were calculated for all watersheds using San Luis Rey as a case study. Over a ten-year period for the study area, *Arundo*-initiated fire events are estimated to have burned 513 acres of *Arundo* and 706 acres of native riparian habitat. Fire suppression over a ten-year period has impacted 44 acres of *Arundo* and 32 acres of native riparian vegetation. (Section 6.5)
- Wildfires burn a significant acreage of *Arundo* stands. Over ten years, 11% of *Arundo* stands (544 acres) burned within the study area. (Section 6.4.2)
- Due to high fuel load and stand structure, areas with *Arundo* burn hotter and more completely then native vegetation during wildfire events. (Section 6.4.2)
- *Arundo* stands appear to be conveying fires across riparian zones- linking upland vegetation areas that would have been separated by less flammable riparian vegetation. This can have catastrophic impacts like those observed in the 2008 Simi fire. The 8,474-acre fire crossed the Santa Clara River and then burned an additional 107,560 acres. (Section 6.4.2)
- *Arundo* fires accelerate the dominance of *Arundo* in invaded areas due to rapid re-growth and low mortality of *Arundo*. (Section 6.5.1)
- *Arundo* fire events lead to both direct mortality of wildlife and plants (some of which are sensitive) as well as a longer-term quality reduction of burned riparian areas (post-fire recovery of vegetation and structure). (Section 6.5.2)
- Emergency actions tied to *Arundo* fire suppression also result in impacts (disturbance of both *Arundo* and riparian vegetation) that degrade riparian habitat and/or may result in mortality of species. (Section 6.5.4)

7.0 IMPACTS OF *ARUNDO*: Federally Endangered and Threatened Species

7.1 Examination and Characterization of *Arundo* Impacts on Flora and Fauna

Arundo's impacts on federally listed species will be evaluated and described. These species have been intensively studied with: documentation of distribution, assessment of stresses on their habitat, and identification of ecological constraints to their ability to persist in the habitats that they occupy. This allows a thorough exploration of impacts caused by *Arundo,* as well as the subjective ranking of the impact level. The determination of critical habitat areas and extensive survey data collected for the species also allows for a spatial assessment of their interaction with *Arundo* distribution at the watershed level (using the *Arundo* spatial data collected for this study). A total of 22 federally listed species will be examined representing five taxonomic groups: amphibians (4), birds (8), fish (4), mammals (1), and plants (5).

To determine the impacts of *Arundo* on federally listed species, we reviewed documents prepared by the U.S. Fish and Wildlife Service during their evaluations for listing and recovery. We restricted the focal species to federally listed species in order to 'standardize' the individual species descriptions and treatment (biology, reproduction, distribution, review of impacts and stresses). The documents used include: Critical Habitat Designations, Recovery Plans, Incremental Reviews (5 year, 10 year, etc.), and Biological Opinions (Section 7 and 10) issued for projects that may adversely impact listed species. A significant amount of the data presented in this chapter is taken directly from numerous Biological Opinions issued by the USFWS. Many of these Biological Opinions are for *Arundo* control programs on the watersheds within the study area, including: Salinas, Ventura, Santa Clara, Santa Ana, San Juan, Santa Margarita, San Luis Rey, Carlsbad CHU, and San Diego River. Additional Biological Opinions and documents prepared by NOAA/NMFS for programs carrying out activities (channel maintenance, sand extraction, etc.) in the project watersheds were also reviewed. These documents are a significant resource as they specifically examine: population status (distribution and abundance, sometimes trends), general biology (reproduction, foraging, movement/migration, predation, habitat needs), and stressors for the species (abiotic, biotic, and anthropogenic). Impacts caused by *Arundo* invasion are evaluated for each of these areas.

7.1.1 Determine Arundo Impact Score

Information from USFWS documents, this report, and other data, literature, and expert opinions was used to determine an 'Impact Score' for each species on a 10-point scale (Table 7-1). Impacts of *Arundo* on each sensitive species are described in Section 7.2, with evaluation of general ecological and habitat needs, reproduction, movement, range and other impacts/threats. Higher scores reflect significant *Arundo* impacts to both abiotic and biotic modification of riparian systems. A general discussion of *Arundo* impacts (both biotic and abiotic) is presented in section 2.7.

Table 7-1. *Arundo* Impact Score for each sensitive species.

Score	Impact Level	Impacts
10	Very severe	Very significant alteration of abiotic structure and biological function, and direct take of individuals
9	Severe	Significant alteration of abiotic structure and biological function and direct take of individuals
8	Very high	Alteration of abiotic structure and biological function, direct take possible
7	High	Alteration of abiotic structure and biological function: impacts on mobility
6	Moderate/High	Moderate alteration of abiotic structure and/or biological function
5	Moderate	Minor alteration of abiotic structure and/or biological function
4	Low/Moderate	Low abiotic or biotic impacts
3	Low	Slight changes in food resources, harboring pathogen/predator OR Minor changes to estuary systems
2	Very low	Minor interaction: mobility
1	Very low/Improbable	Difficult to describe any interaction with *Arundo*
0	None	No interaction

7.1.2 Determine Arundo and Federally Listed Species 'Overlap Score'

To characterize the level of interaction between each sensitive species and *Arundo*, a watershed specific 'Overlap Score' was created (Table 7-2). This metric measures the abundance and distribution of *Arundo* and the sensitive species, with a specific focus on overlap in spatial distribution. The score for the metric captures the level of interaction between *Arundo* and the listed species. The *Arundo* spatial data set was examined with GIS data for each listed species (Maps 1-30, Appendix B).

A listed species with large populations high on the watershed where *Arundo* does not occur would be ranked with a low score, even if the watershed has high *Arundo* abundance overall. A high metric score (10) requires frequent occurrence of the sensitive species within portions of the watershed that have high *Arundo* abundance. Low scores are given for species that have low occurrences within areas of low *Arundo* cover. Intermediate scores are given for co-occurrence, where there are moderate levels of abundance for *Arundo* and/or sensitive species. Species that occur at or near the end of the watershed may not have significant co-occurrence with *Arundo* stands, but they may have significant *Arundo* upstream of them that is modifying abiotic processes or generating *Arundo* biomass into the sensitive species habitat (*Arundo* debris, or modified hydrology). These interactions, which are often for estuarine or river mouth species, have a full range of overlap/interaction scores from low to high.

Table 7-2. Definition of overlap scores that are assigned to federally listed species.

Overlap Score	*Arundo* abundance (nearby or upstream of sensitive species)	Listed species *relative* abundance & distribution	Interaction Level
10	Very High	Very high (core area)	High interaction
9	High	High	
8	High	Moderate	
7	Moderate	High	
6	Moderate	Moderate	Moderate interaction
5	Low	High	
4	High/Moderate	Low	
3	Low	Moderate	
2	Low	Low	Low interaction
1	Any	Historic range* or a few records of more 'abundant species	Possible or potential interaction
0	Any	Not recorded	No interaction

* Sensitive species not currently known to occur in the area, but has confirmed historic distribution.

7.1.3 Calculate 'Cumulative Arundo Impact Scores'

The 'Impact Score' for each species is then multiplied by the 'Overlap Score' on each watershed to generate a 'Cumulative *Arundo* Impact Score' for each sensitive species. This data can be examined for each species, taxonomic group, and watershed. Scores highlight species and those watersheds that are most impacted by *Arundo*.

7.2 Species Descriptions and *Arundo* Impacts Elucidated

Each federally listed species is evaluated below for potential impacts caused by *Arundo*. These impacts may be either indirect (modification of habitat) or direct (loss of life- such as fire or emergency response to fire or flood). All types of impacts are explored and relative importance/magnitude of the impact is described for each species. A general discussion of *Arundo* impacts (both biotic and abiotic) is presented in section 2.7.

Interaction of *Arundo* distribution and species occurrences is presented by watershed in Table 7-3 and Appendix B. Information on the biology and distribution of each species is taken from USFWS documents and other reports, which are listed at the end of each species' summary. Citations to particular studies within these documents are not listed here.

7.2.1 California Tiger Salamander (*Ambystoma californiense*)

Federal status: Endangered for the Santa Barbara Distinct Population Segment (September 2000). Critical habitat was designated in August 2005, but may change as it is under review.
State status: Threatened (May 2010).
Arundo impact score: 1

General Ecological Needs/Habitat Affinities:
The California tiger salamander is a stocky, terrestrial amphibian. Adult males are about 20 cm (8 in) long, and females a little less than 18 cm (7 in). It is restricted to grasslands and low foothill regions (typically below 2000 feet/610 meters) where lowland aquatic sites are available for breeding. They prefer natural ephemeral pools, or ponds that mimic them (e.g. stock ponds that are allowed to go dry). While on land they are generally underground in burrows. They are poor burrowers, therefore require refuges provided by ground squirrels and other burrowing mammals in which to enter a dormant state called *estivation* during the dry months.

Arundo impacts: *Arundo is not typically abundant on the low order streams and steeper hilly terrain that are favored by the tiger salamander. No significant alteration of abiotic process would occur.*

Breeding/Life History:
California tiger salamanders require lowland aquatic sites for breeding. They prefer natural ephemeral pools, or ponds that mimic them. Around November, salamanders come out of their burrows, usually on a wet, stormy night. They may travel as much as a mile to a pond to breed. They prefer natural ephemeral pools, or ponds that mimic them. Females lay eggs singly or in small groups. They may lay as many as 1,300 eggs. These are usually attached to vegetation. Eggs hatch in about 10 to 14 days. Larvae require significantly more time to transform into juvenile adults than other amphibians such as the western spadefoot toad and Pacific tree frog. Around late spring, salamanders leave the ponds to find burrows. Adults reach sexual maturity in 4 or 5 years. Although they may live as long as 10 years, they may reproduce only once, or not at all. Some salamanders die before they reach sexual maturity, and others may not find a suitable pond for mating in very dry years. The main predators of the California tiger salamander are birds such as egrets and herons, fish, and bullfrogs.

Arundo impacts: *Little impact as Arundo not abundant enough to impact hydrology of pools.*

Diet:
Adults mostly eat insects. Larvae eat algae, mosquito larvae, tadpoles and insects.

Arundo impacts: *Little impact as Arundo not abundant enough to impact food resources or habitat that food resources depend on.*

Movement:
A California tiger salamander spends most of its life on land underground. It uses burrows made by squirrels and other animals. Around November, usually on a wet night, salamanders come out of their burrows and may go as much as a mile to a pond to breed. In late spring, salamanders leave the ponds to find burrows.

Arundo impacts: *Little impact as Arundo not abundant enough to impact movement of salamanders or change distribution of mammals that create micro habitat needed by the species.*

Status/Distribution or Historic and Current Range:
This species is restricted to California and does not overlap with any other species of tiger salamander. They are found in grassland and oak savannah plant communities with vernal pools and/or seasonal ponds (including constructed stock ponds). They predominantly occur from sea level to 2,000 feet in central California. In the Coastal region, populations are scattered from Sonoma County in the northern San Francisco Bay Area to Santa Barbara County (up to elevations of 3,500 ft/1,067 m), and in the Central Valley and Sierra Nevada foothills from Yolo to Kern counties (up to 2,000 ft/610 m).

Arundo impacts: *There is very low interaction between Arundo distribution and salamanders. Critical areas have almost no overlap and occurrence data has a few points of interaction (Appendix B). Pajaro River in San Benito would be the greatest interaction and Salinas is very low (based on current Salinas survey data). If salamanders were found to occur in the Salinas River itself significant revision of impact scores would be needed.*

Decline and Threats:
The primary cause of the decline of California tiger salamander populations is the loss and fragmentation of habitat from human activities and the encroachment of non-native predators. All of the estimated seven genetic populations of this species have been significantly reduced because of urban and agricultural development, land conversion, and other human-caused factors. A typical salamander breeding population in a pond can drop to less than twenty breeding adults and/or recruiting juveniles in some years, making these local populations prone to extinction. California tiger salamanders therefore require large contiguous areas of vernal pools (vernal pool complexes or comparable aquatic breeding habitat) containing multiple breeding ponds to ensure re-colonization of individual ponds.

Arundo impacts*: No additional Arundo interaction with decline and threats.*

Overall impact metric for *Arundo* on CA tiger salamander: Very low/improbable impact, score of 1

Interaction of *Arundo* distribution and CA tiger salamander occurrence is presented by watershed in Table 7-3 and Appendix B.

Sources:
Species Account, California Tiger Salamander (*Ambystoma californiense)*, U.S. Fish & Wildlife Service Sacramento Fish & Wildlife Office.

7.2.2 Arroyo Toad (*Bufo californicus*)

Federal status:	Endangered, December 16, 1994. Critical habitat designated April 13, 2005. Recovery plan completed in 1999.
State status:	Not listed?
Arundo impact score:	10

General Ecological Needs/Habitat Affinities:
Arroyo toads breed and deposit egg masses in shallow sandy pools, which are usually bordered by sand-gravel flood-terraces. Optimal breeding habitat consists of low-gradient sections of slow-moving streams with shallow pools, nearby sandbars, and adjacent stream terraces. Stream order, elevation, and floodplain width appear to be important factors in determining habitat capacity. High stream order (i.e., 3rd to 6th order), low elevation (particularly below 3,000 ft/914 m) and wide floodplains seem to be positively correlated with arroyo toad population size. However, small populations are also found in 1st and 2nd order streams up to 4,600 ft (1,402 m). Outside the breeding season, arroyo toads are

essentially terrestrial and use a variety of upland habitats including (but not limited to): sycamore-cottonwood woodlands, oak woodlands, coastal sage scrub, chaparral, and grasslands.

Arundo impacts: *Changing geomorphic processes- rivers and streams move away from complex multi-channel structure with elevational complexity to a single narrow channel. The single channel is also deeper, typically transporting sediment out of the system under low flow events. Larger events also may not be generating as much sediment deposition in open areas. Because there are fewer open areas sediment is being trapped within Arundo stands which themselves have low arroyo toad use (Camp Pendleton management reports). Arundo has a very strong affinity for the same areas favored by arroyo toads: low elevation, broad floodplains and especially high stream order systems. Direct take of the species can occur during Arundo fire events and fire suppression efforts.*

Breeding/Life History:
Breeding is typically from February to July on streams with persistent water. Eggs are deposited and develop in shallow pools with minimal current and little to no emergent vegetation. Substrate is generally sand or fine gravel overlain with silt. Eggs hatch in 4-5 days, and hatchlings are immobile for 5-6 days. They then disperse from the pool margin into surrounding shallow water and develop for 10 weeks. After metamorphosis (typically June/July) the juvenile toads remain on the bordering gravel bars until the pool dries out (8-12 weeks, depending on site and rainfall/conditions).

Arundo impacts: *Arundo does not typically occur within pools/stream channel, but it may overhang pools/stream channel. Arundo does use large amounts of water, which could alter hydrology of the stream, potentially accelerating the dropping of the water table and the drying of pools. Arundo biomass in pools would likely be a negative impact. The greatest impact is that the system has fewer areas for pools to form. The areas that would be open/bar habitat are filled in with Arundo (Sections 5.1 & 2). This restricts pools to the narrow channel zone where pools are less likely to form. Pools that do form are also at greater risk of late season flow events that purge pools of egg masses and possibly even breeding adults.*

Diet:
Arroyo toad tadpoles feed on loose organic material such as algae, bacteria, and diatoms. They do not forage on macroscopic vegetation. Juvenile toads feed almost exclusively on ants. By the time they are 0.7 to 0.9 inch length they forage on beetles and ants. Adults consume a wide range of insects and arthropods.

Arundo impacts: *Arundo litter provides limited food for aquatic insects (Going & Dudley 2008) in comparison to native litter. This would reduce forage for aquatic insects which could be a food source for tadpoles. Decaying Arundo litter would be little nutritional value for insects. Arundo does support ants (particularly non-native argentine ants), but diversity and abundance is low for other arthropods (Herrera & Dudley 2003, Lovich et al. 2009). Arundo stands also are a barrier to toad movement and studies looking at toad use of Arundo showed little use, presumably indicating a low function for foraging.*

Movement: Arroyo toads have been observed moving one mile within the stream reach and 0.6 miles away from the stream into upland native habitat and agricultural areas. Movement may be regulated by topography and channel morphology. Toads are critically dependent on upland terraces and the marginal zone between stream channels and upland terraces during the non-breeding season, especially during periods of inactivity (generally late fall and winter). Toads generally burrow within sandy or loamy substrate with no associated canopy cover, within mulefat scrub, or within arroyo willow patches. The majority of individuals tracked in one study were located immediately adjacent to the active channel or within the bench habitats within the flood prone areas.

Arundo impacts: *Movement of toads both within and through the system is significantly restricted in highly invaded systems. Arundo can also be abundant in the area between the channel and terraces, filling open spaces in the habitat. This area is specifically noted as being a critical portion of the habitat for the first year toads. Chapter 5 demonstrates that this is where Arundo is most abundant and dense.*

Status/Distribution or Historic and Current Range:
Current estimated distribution is shown in Appendix B. Critical habitat areas have been designated. Survey data is of high quality in San Diego and Orange Counties and lower quality as one moves north. Santa Clara and Salinas in particular have not had substantial uniform survey work, but these areas do not have large populations (according to Biological Opinions). Distribution and abundance levels have been assessed from FWS data, CNDDB data, critical habitat areas, and verbal descriptions in USFWS Biological Opinions (all watersheds). Arroyo toads have disappeared from 75% of occupied habitat in California. Arroyo toads once occurred on 22 river basins from Monterey County (upper Salinas) to San Diego County southward to San Quintin, Baja CA, Mexico. In Orange and San Diego Counties the species occurred from estuaries to the headwaters of many drainages. Populations now are restricted to headwaters and small isolated populations along streams/rivers. The arroyo toad is principally along coastal drainages, although it has also been found on the desert facing slopes of San Gabriel and San Bernardino Mountains. Core populations occur on: Santa Margarita, San Luis Rey and San Juan Watersheds. Secondary watersheds are San Dieguito and Sweetwater. Additional smaller populations occur on San Diego, Los Angeles, Santa Clara and Salinas Watersheds.

Arundo impacts: *Arundo is abundant within core population areas as well as satellite populations. Arundo is less abundant in some of the more mountainous areas where toad populations occur. Significant overlap in Arundo and toad distribution exists (Table 7-3).*

Decline and Threats: Dam building and operation (modification of hydrologic regime and flushing events). Urban and agriculture development, sand and gravel mining. Impacts from vehicle and recreation activities. Non-native predators (bull frogs, fish, crayfish, etc.). Non-native plants (*Arundo* and tamarisk). Loss of habitat, modification of hydrology, and non-native predation have caused arroyo toads to disappear from a large portion of previously occupied habitat. Currently the greatest threats to arroyo toads are continued stream modification, development, and pressure from non-native organisms. Most systems have already had significant hydromodification.

Arundo impacts: *Arundo does interact with human hydromodification and flood management. Clearing of areas for reduced flood risk increases dispersal and spread of the plant. Reduced flow capacity and higher flood risk, exacerbated by Arundo stands, can lead to engineered solutions that contain and restrict flows.*

Overall impact metric for *Arundo* on Arroyo toad: Very severe impacts (10)

Interaction of *Arundo* distribution and occurrence of arroyo toads is presented by watershed in Table 7-3 and Appendix B.

Sources:
Arroyo toad (*Bufo californicus*) Five Year Review: Summary and Evaluation, U.S. Fish and Wildlife Service, Ventura, CA. August 2009. http://ecos.fws.gov/docs/five_year_review/doc2592.pdf

Stillwater Sciences. 2007. Focal Species Analysis and Habitat Characterization for the Lower Santa Clara River and Major Tributaries, Ventura County, California. Santa Clara River Parkway Floodplain Restoration Feasibility Study.
Formal Section 7 Consultation for Invasive Plant Removal in the San Juan Hydrologic Unit, Orange County, CA, U.S. F&WS, Carlsbad Fish and Wildlife Office, Carlsbad, CA.

7.2.3 California Red-Legged Frog *(Rana aurora draytonii)*

Federal status: Threatened, May 23 1996. Critical habitat was first designated in 2001, but has been changed several times, with the most recent designation occurring in 2010.
State status: None
Arundo impact score: 3

General Ecological Needs/Habitat Affinities:

California red-legged frogs live from sea level to about 5,000 ft/1,524 m in California and Baja California, Mexico, and may be found in a variety of habitats. The frogs breed in aquatic habitats such as streams, ponds, marshes and stock ponds. Larvae, juveniles and adults have been collected from streams, marshes, plunge pools and backwaters of streams, dune ponds, lagoons, and estuaries. They frequently breed in artificial impoundments such as stock ponds, if conditions are appropriate. If riparian vegetation is present, red-legged frogs spend considerable time resting and feeding in it. The moisture and camouflage provided by the riparian plant community apparently provides good foraging habitat and may facilitate dispersal in addition to providing pools and backwater aquatic areas for breeding. Frogs may move through upland habitats, primarily in wet weather. For the California red-legged frog, suitable habitat is potentially all aquatic and riparian areas within the range of the species and includes any landscape features that provide cover and moisture.

The riparian and upland habitats adjacent to aquatic areas used by the California red-legged frog are essential in maintaining frog populations, and for protecting the appropriate hydrological, physical, and water quality conditions of the aquatic areas. The frog uses both riparian and upland habitats for foraging, shelter, cover, and non-dispersal movement. One researcher who studied California red-legged frog's terrestrial activity in coastal forest and grassland habitats recommends at least a 328 ft (100m) buffer zone for protection of adjacent aquatic and upland habitat, as well as seasonal restrictions for activities within this zone. In a recent study also specific to the California red-legged frog, the recommendation was for establishing zones around breeding habitat, non-breeding habitat, and migration corridors that are sufficient to protect function of the amphibian habitat. However, the study authors discourage setting specific distances for these zones due to differences in biological or site-specific requirements; they further state that any distances set for avoidance of upland habitat should be made on a case-by-case basis, taking into account the need to protect breeding and non-breeding habitat as well as any migration corridors. Without protecting and maintaining the upland areas surrounding breeding and non-breeding habitats the quality of the water feature may deteriorate to such an extent as to not support the California red-legged frog.

Arundo impacts: *Red legged frogs have very wide distribution among habitat types but tend to occur in steeper terrain than Arundo. Arundo is typically not abundant enough to alter abiotic factors that would severely degrade frog habitat.*

Breeding/Life History:
Red-legged frogs breed from November through March, though earlier breeding has been recorded in southern localities. Males appear at breeding sites 2-4 weeks prior to females. Females deposit egg

masses on emergent vegetation so that the masses float on the surface of the water. Eggs hatch in 6 to 14 days, and larvae undergo metamorphosis 3.5 to 7 months after hatching. Sexual maturity is attained at 2 years by males and 3 years by females. Adults may live 8 to 10 years, although the average life span is considered much lower.

Arundo impacts : *Impacts would be minor as breeding pools are not usually in close proximity to Arundo stands. Arundo is not abundant enough to alter hydrology and pool duration.*

Diet:
The diet of the red-legged frog is highly variable. Tadpoles probably eat algae, and invertebrates seem to be the most common food of adults. Larger frogs can eat vertebrates such as Pacific chorus frogs and California mice. Feeding activity probably occurs along the shoreline and on the surface of the water. Juveniles have been found to be active diurnally and nocturnally, but adults are largely nocturnal.

Arundo impacts: *Minor impacts, if any, as Arundo is not abundant enough to typically affect abundance of food resources.*

Movement:
Juvenile and adult California red-legged frogs may disperse long distances from breeding sites throughout the year. They can be encountered living within streams at distances exceeding 1.8 miles from the breeding site, and have been found up to 400 feet from water in adjacent dense riparian vegetation. During period of wet weather, some individuals may make overland excursions through upland habitats, mostly at night. In Santa Cruz County, red-legged frogs made overland movements of up to 2 miles over the course of a wet season. Most of these long-distance movements were over variable upland terrain. Adult California red-legged frogs may disperse from breeding sites at any time of year depending on habitat availability and the environmental conditions of the aquatic habitat. In addition, a few frogs may disperse long distances in search of additional breeding or non-breeding habitat.

Arundo impacts: *Low likely hood of impact except on Ventura River watershed where dense Arundo stands could impede movement (as seen with arroyo toads).*

Status/Distribution or Historic and Current Range:
The current distribution of the red-legged frog is primarily in the coastal drainages of central California. Today, only 28 counties have known populations. Monterey, San Luis Obispo and Santa Barbara counties have the greatest amount of currently occupied habitat. Only four areas within the entire historic range of this species may currently harbor more than 350 adults.

Arundo impacts: *Arundo does have some overlap in distribution (Appendix B). Arundo is not usually abundant in these areas- particularly on smaller size watersheds, but localized high Arundo cover can exist and could lead to impacts (fire, limited movement, impacts to breeding pools). A significant noted exception occurs on Ventura River watershed where dense Arundo overlaps with core population areas.*

Decline and Threats:
The frog and its habitat are threatened by a multitude of factors including but not limited to:
1) Degradation and loss of habitat through urbanization, mining, improper management of grazing, recreation, invasion of nonnative plants, impoundments, water diversions and degraded water quality, 2) Introduced predators, such as bullfrogs, and 3) Previous overexploitation.

Historically, the California red-legged frog was found in 46 counties. The range was thought to extend coastally from Sonoma County (but recently has been confirmed further north in Mendocino County)

and inland from the vicinity of Redding, Shasta County, south to northwestern Baja California, Mexico. The frog has sustained a 70 percent reduction in its geographic range in California as a result of habitat loss and alteration, overexploitation, and introduction of exotic predators.

Arundo impacts: *Little interaction between Arundo and these factors.*

Overall impact metric for *Arundo* on California red-legged frog: Low impact, score of 3.

Interaction of *Arundo* distribution and CA red-legged frog occurrence is presented by watershed in Table 7-3 and Appendix B.

Sources:

Biological and Conference Opinions for Annual Removal of Giant Reed and Tamarisk in Upper Santa Clara River Watershed, Los Angeles county, CA (File No. 2004-01540-AOA)(1-8-06-F-5).

Endangered and Threatened Wildlife and Plants; Revised Designation of Critical Habitat for the California Red-Legged Frog: Final Rule. 50 CFR Part 17 [FWS-R8-ES-2009-0089], U.S. Fish and Wildlife Service.

7.2.4 Mountain Yellow-Legged Frog (*Rana muscosa*)

Federal status:	Endangered (Southern California DPS July 2 2002), Endangered Candidate List (frogs occurring north of the Tehachapi Mountains). Critical habitat for the southern California DPS designated on September 14 2006.
State status:	Candidate species
Arundo impact score:	4

General Ecological Needs/Habitat Affinities:

Mountain yellow-legged frogs live in glaciated alpine lakes, ponds, tarns, springs, and streams. Lakes used usually have grassy or muddy margins, and adults are typically found sitting on wet rocks along the shoreline, usually where there is little or no vegetation. Field research conducted by USGS and the San Diego Zoo within the current and historic range of the mountain yellow-legged frog in the San Jacinto, San Bernardino, and San Gabriel mountains has been carried out to improve understanding of habitat preferences of this species. Results indicate that adult frogs prefer deep, long, pools with little understory and ample leaf litter. Tadpoles also were more likely to be found in pools with less understory and more leaf litter, but showed no preference for pool depth or length. They did, however, demonstrate a preference for pools with rock substrate. Mountain yellow-legged frogs have been observed in the field basking in direct sunlight, sometimes in aggregations of more than 20. It is hypothesized that frogs aggregate to reduce the surface area exposed to the air and thus reduce water loss. Suitable habitat for mountain yellow-legged frogs presumably must include appropriate basking structures

Arundo impacts: *Low level of Arundo impacts due to little overlap in range. Frogs are restricted to higher elevations in general. But overlap in occurrence in two areas create the potential for interaction (Los Angeles River, in the San Gabriel Mountains and Santa Ana River in San Bernardino Mountains). Frogs appear to prefer little vegetative cover- Arundo would therefore be negatively associated with prime habitat.*

Breeding/Life History:

Breeding sites are generally located in, or connected to, lakes and ponds that do not dry up in the summer, and that are sufficiently deep not to freeze through in winter. The frogs breed in June or July.

Eggs hatch within several weeks and larvae usually transform during July or August. Larvae at high elevations, or subject to severe winters, may not metamorphose until the end of their fourth summer. Adults hibernate in water during the coldest months, under ice or near shore under ledges and in underwater crevasses.

Arundo impacts: *Arundo may add to water stress in foothill washes shortening pool duration.*

Diet:
Adults feed on terrestrial insects and adult aquatic insects: beetles, flies, wasps, bees, ants, true bugs, and spiders. They also consume large quantities of Yosemite toad and Pacific treefrog tadpoles and can be cannibalistic. Tadpoles graze on algae and diatoms along rocky bottoms of streams, lakes, and ponds.

Arundo impacts: *Limited impacts to food resources.*

Movement:
This species has no distinct breeding migration, as adults are almost always found within two to three feet of water. In some areas, there is a seasonal movement of frogs from deeper lakes to nearby breeding areas after overwintering. Frogs typically move less than a few hundred meters.

Arundo impacts: *Limited impacts to movement- very localized at stream/pool edges.*

Status/Distribution or Historic and Current Range:
Once common throughout much of southern California, the mountain yellow-legged frog has been decreasing in numbers since the 1970s. The frog lives in the Sierra Nevada Mountains of California and Nevada from southern Plumas County to southern Tulare County, at elevations mostly above 6,000 feet. A genetic study published in 2007 revealed that there are two distinct mountain yellow-legged frog species that do not overlap in range or interbreed: a northern and central Sierra Nevada species and a southern Sierra Nevada and southern California species. In southern California, only a small wild population of less than 200 individuals can be found in the San Gabriel, San Bernardino, and San Jacinto Mountains. For the first time in April 2010, scientists reintroduced its eggs to its former habitat at University of California Riverside's James San Jacinto Mountains Reserve.

Arundo impacts: *The frogs have isolated small populations (Appendix B). The fact that several of the San Gabriel Mountain populations co-occur with Arundo is of concern. Impacts related to water use, shading, and the frogs' preference for less vegetated pools indicates that Arundo is likely a minor to moderate stressor on habitat fitness. Arundo could become a more pronounced impact if it continued to increase in abundance at sites where overlap in ranges occurs.*

Decline and Threats:
These frogs are threatened by predation by introduced trout, pesticides, environmental changes from drought and global warming, disease, and habitat degradation due to livestock grazing. More than 93 percent of northern and central Sierra Nevada populations, and more than 95 percent of southern Sierra Nevada and southern California populations, are already extinct.

Arundo impacts: *Little interaction with other stressors- but the species very tenuous persistence makes low to moderate levels of impacts already outlined potentially significant for the species especially for isolated southern CA populations.*

Overall impact metric for *Arundo* on mountain yellow-legged frog: Low/Moderate impact (4)

Interaction of *Arundo* distribution and mountain yellow-legged frog occurrence is presented by watershed in Table 7-3 and Appendix B.

Sources:
USGS, Mountain yellow-legged frogs reintroduced to wild 4/16/2010.
Mountain Yellow-legged Frog Update, Mountain Yellow-legged Frog Captive Breeding 2009 Annual Report, San Diego Zoo.
Species Profile for the Mountain Yellow-Legged Frog, U.S. Fish & Wildlife Service.

7.2.5 Western Snowy Plover (*Charadrius alexandrinus nivosus*)

Federal status: Threatened, March 1993. Critical habitat designated September 2005. Recovery Plan published in 2007.
State status: Species of special concern
Arundo impact score: 5

General Ecological Needs/Habitat Affinities:
The Pacific coast population of the western snowy plover breeds primarily above the high tide line on coastal beaches, sand spits, dune-backed beaches, sparsely-vegetated dunes, beaches at creek and river mouths, and salt pans at lagoons and estuaries. This habitat is unstable because of unconsolidated soils, high winds, storms, wave action, and colonization by plants. Less common nesting habitats include bluff-backed beaches, dredged material disposal sites, salt pond levees, dry salt ponds, and river bars. In winter, western snowy plovers are found on many of the beaches used for nesting as well as on beaches where they do not nest, in man-made salt ponds, and on estuarine sand and mud flats.

Arundo impacts: *Arundo is typically not abundant in beach and estuary habitats (although it can develop into large stands if left to persist there). The major impacts from Arundo are related to biomass accumulating in these areas. Additionally there may be impacts to sediment transport (Chapter 5) which could be effecting beach and estuaries. These impacts are speculative but possible given Arundo strong effect of fluvial and processes. Plovers have strong preference for river mouths and estuaries in comparison to beach areas along bluffs (Appendix B).*

Breeding/Life History:
The Pacific coast population of the western snowy plover breeds primarily on coastal beaches from southern Washington to southern Baja California, Mexico. Nesting western snowy plovers at coastal locations consist of both year-round residents and migrants. Migrants begin arriving at breeding areas in central California as early as January, although the main arrival is from early March to late April. Since some individuals nest at multiple locations during the same year, birds may continue arriving through June. In California, pre-nesting bonds and courtship activities are observed as early as mid-February. Eggs are laid in scrapes (depression in the sand or other substrate created by the male). The earliest nests on the California coast occur during the first week of March in some years and by the third week of March in most years. Peak initiation of nesting is from mid-April to mid-June. Nests typically occur in flat, open areas with sandy or saline substrates; vegetation and driftwood are usually sparse or absent. In southern California, western snowy plovers nest in areas with 6 to 18 percent vegetative cover and 1 - 14 % inorganic cover; vegetation height is usually less than six centimeters (2.3 inches).
Nests consist of a shallow scrape or depression, sometimes lined with beach debris (*e.g.*, small pebbles, shell fragments, plant debris, and mud chips); nest lining increases as incubation progresses. Driftwood, kelp, and dune plants provide cover for chicks that crouch near objects to hide from predators. Although driftwood is an important component of western snowy plover habitat, too much driftwood on a beach, which may occur after frequent and prolonged storm events, can be detrimental if there is not sufficient open habitat to induce the birds to nest. In southern California nests are usually located within 328 ft

(100 m) of water, which could be either ocean, lagoon, or river mouth. Invertebrates are often found near debris, so driftwood and kelp are also important for harboring western snowy plover food sources. Hatching lasts from early April through mid-August, with chicks reaching fledging age approximately one month after hatching. Fledging of late-season broods may extend into the third week of September throughout the breeding range.

Arundo impacts: *Arundo biomass significantly degrades nesting habitat by covering open sandy substrate. Additional impacts are outlined in FWS BO's: In some areas of California, such as the Santa Margarita River in San Diego County, and the Santa Clara and Ventura Rivers in Ventura County, giant reed has become a problem along riparian zones. During winter storms, giant reed is washed downstream and deposited at the river mouths where western snowy plovers nest. Large piles of dead and sprouting giant reed eliminate nesting sites and increase the presence of predators, which use it as perches and prey on rodents in the piles of vegetation.*

Diet:
Western snowy plovers are primarily visual foragers, using the run-stop-peck method of feeding. They forage on invertebrates in the wet sand and amongst surf-cast kelp within the intertidal zone, in dry sand areas above the high tide, on salt pans, on spoil sites, and along the edges of salt marshes, salt ponds, and lagoons. They sometimes probe for prey in the sand and pick insects from low-growing plants. Western snowy plover food consists of immature and adult forms of aquatic and terrestrial invertebrates.

Arundo impacts: *Arundo debris and stands reduce habitat quality for food (invertebrates); impacts feeding as well as foraging for prey.*

Movement:
While some western snowy plovers remain in their coastal breeding areas year-round, others migrate south or north for winter. In Monterey Bay, California, 41 % of nesting males and 24 % of the females were consistent year-round residents. At Marine Corps Base Camp Pendleton in San Diego County, California, about 30 % of nesting birds stayed during winter. The migrants vacate California coastal nesting areas primarily from late June to late October.

Arundo impacts: *Arundo debris piles limit movement of young.*

Status/Distribution or Historic and Current Range:
The Pacific coast population is defined as those individuals that nest within 50 miles of the Pacific Ocean on the mainland coast, peninsulas, offshore islands, bays, estuaries, or rivers of the United States and Baja California, Mexico. By the late 1970s, nesting western snowy plovers were absent from 33 of 53 locations with breeding records prior to 1970. By 2000 populations had declined further to 71 % of the 1977-1980 levels along the California coast and 27 % of the 1977-1980 levels in San Francisco Bay. However, since then populations have grown substantially, roughly doubling along the coast while fluctuating irregularly in San Francisco Bay. Recent population increases along the coast have been associated with implementation of management actions for the benefit of western snowy plovers and California least terns, including predator management and protection and restoration of habitat.

Arundo impacts: *Arundo is abundant on several key watersheds that support plover populations (Appendix B).*

Decline and Threats:
Habitat degradation caused by human disturbance, urban development, introduced beachgrass (*Ammophila* spp.), and expanding predator populations have resulted in a decline in active nesting areas and in the size of the breeding and wintering populations.

Arundo impacts: *As indicated Arundo stands are correlated with predation as predators use stands for perching in nesting areas.*

Overall impact metric for *Arundo* on the Western snowy plover: Moderate, score of 5.

Interaction of *Arundo* distribution and the Western snowy plover's occurrence is presented by watershed in Table 7-3.

Sources:

Recovery Plan for Pacific Coast Population of the Western Snowy Plover, USFWS, 2001 http://www.fws.gov/arcata/es/birds/WSP/documents/RecoveryPlanWebRelease_09242007/WSP%20Final%20RP%2010-1-07.pdf

Powell, A.N., J.M. Terp, C.L. Collier, and B.L. Peterson. 1997. The status of western snowy plovers (*Charadrius alexandrinus nivosus*) in San Diego County, 1997. Report to the California Department of Fish and Game, Sacramento, CA, and U.S. Fish and Wildlife Service, Carlsbad CA, & Portland OR.

7.2.6 Western Yellow-Billed Cuckoo (*Coccyzus americanus*)

Federal status: Species of Concern
State status: Endangered
Arundo impact score: 7

General Ecological Needs/Habitat Affinities:
Western yellow-billed cuckoos typically inhabit densely foliated, stands of deciduous trees and shrubs, particularly willows, with a dense understory formed by blackberry, nettles, and/or wild grapes, adjacent to slow-moving watercourses, backwaters, or seeps. River bottoms and other mesic habitats, including valley-foothill and desert riparian habitats, are necessary for breeding. Dense low-level or understory foliage with high humidity is preferred. Field studies and habitat suitability modeling have concluded that vegetation type (*e.g.*, willow scrub and cottonwood-willow forest), patch size, patch width, and distance to water are important factors determining the suitability of habitat for yellow-billed cuckoo breeding. Patch size is an important variable determining presence of cuckoos in California, with a trend toward increasing occupancy with increased patch size. Few cuckoos have been found in forested habitat of less than 25 acres. Willow-cottonwood habitat patches greater than 1,970 ft (600 m) in width were found to be optimal, and typically anything less than 328 ft (100 m) is unsuitable.

Arundo impacts: *Arundo and cuckoos both prefer broad river bottoms creating a significant interaction between the species. Cuckoos prefer well-developed riparian habitat that is dense with large gallery trees. Arundo displaces native vegetation and fires generate create younger serial stages that cuckoos do not prefer or utilize as habitat.*

Breeding/Life History:
Western cuckoos breed in large blocks of riparian habitats, particularly woodlands with cottonwoods (*Populus fremontii*) and willows (*Salix* spp.). Dense understory foliage appears to be an important factor in nest site selection, while cottonwood trees are an important foraging habitat in areas where the species has been studied in California. Clutch size is usually two or three eggs, and development of the young is very rapid, with a breeding cycle of 17 days from egg-laying to fledging of young. Although yellow-billed cuckoos usually raise their own young, they are facultative brood parasites, occasionally laying eggs in the nests of other yellow-billed cuckoos or of other bird species. Males and females reach

sexual maturity the first year after hatching. Chicks are able to fly between 17 and 21 days after hatching and within a few weeks will migrate to South America.

Arundo impacts: *Arundo significantly degrades habitat by impacting lager mature trees (fire) and displacing the dense native understory vegetation. Arundo fragments and degrades riparian habitat through fire and swaths of low value habitat isolating higher quality patches.*

Diet:
More than 75 % of the yellow-billed cuckoo's diet is comprised of grasshoppers and caterpillars, though the species has been known to eat other insects such as beetles, cicadas, wasps, flies, katydids, dragonflies, and praying mantids.

Arundo impacts: *Arundo provides none of the preferred food sources and displaces native vegetation- particularly native willows and cottonwoods that are habitat for mourning cloak butterfly and caterpillars.*

Movement:
Cuckoos leave North America in August and head to their wintering grounds in northwestern Costa Rica, Panama, and west of the Andes in Columbia, Ecuador, and Peru. It is believed that western cuckoos migrate primarily to southern Central America, remaining along the Pacific, and down into northwestern South America, remaining west of the Andes.

Arundo impacts: *No impact to migration. Movement within habitat is impacted.*

Status/Distribution or Historic and Current Range:
Yellow-billed cuckoos occur in the western United States as a distinct population segment (DPS). The area for this DPS is west of the crest of the Rocky Mountains. In California prior to the 1930s, the species was widely distributed in suitable river bottom habitats, and was locally common. It is estimated that in California the species' range is now about 30 % of its historical extent. Studies since the 1970s indicate that there are fewer than 50 breeding pairs in all of California. Given that only Santa Ana and Santa Clara have had reported sightings since 1989, it is possible that the species may become or is already functionally extirpated from Southern California. Sightings may be individuals migrating to the South Fork of the Kern River or the Sacramento River.

Arundo impacts: *Arundo* is abundant on the two watersheds with cuckoo occurrence data collected since 1989; all other occurrence data is from the 1970s or late 1800s/early 1900s (Los Angeles region- Appendix B).

Decline and Threats:
Adequate patch size and loss of habitat are the primary threats to western yellow-billed cuckoo populations. Principal causes of riparian habitat losses are conversion to agricultural and other uses, dams and river flow management, stream channelization and stabilization, and livestock grazing. Available breeding habitats for cuckoos have also been substantially reduced in area and quality by groundwater pumping and the replacement of native riparian habitats by invasive non-native plants, particularly tamarisk and *Arundo*. Fragmentation effects include the loss of patches large enough to sustain local populations, leading to local extinctions, and the potential loss of migratory corridors, affecting the ability to recolonize habitat patches. Much of the catastrophic decline of the cuckoo in California has been directly attributed to breeding habitat loss from clearing and removal of huge areas of riparian forest for agriculture, urban development and flood control (see chapter 5.3- historic trends of geomorphology, particularly the loss of terraces, where mature gallery forest would occur). Another likely factor in the loss and modification of the yellow-billed cuckoo is the invasion by exotic tamarisk

(*Tamarisk* spp.) and *Arundo*. The spread and persistence of tamarisk and *Arundo* has resulted in significant changes in riparian plant communities. In monotypic tamarisk and *Arundo* stands, the most striking change is the loss of community structure. The multi-layered community of herbaceous understory, small shrubs, middle-layer willows, and over-story deciduous trees is often replaced by one monotonous layer. Plant species diversity has declined in many areas and relative species abundance has shifted in others. Other effects include changes in percent cover, total biomass, fire cycles, thermal regimes, and perhaps insect fauna. Conversion to tamarisk or *Arundo* typically coincides with reduction or complete loss of bird species strongly associated with cottonwood-willow habitat including the yellow-billed cuckoo

Overall impact metric for *Arundo* on the Western yellow-billed cuckoo: High impact, score of 7.

Interaction of *Arundo* distribution and the Western yellow-billed cuckoo's occurrence is presented by watershed in Table 7-3 and Appendix B. Note that although there is high impact to habitat function for the species- the species is only present as 'historic occurrences' on most watersheds. Santa Ana and Santa Clara still have periodic sightings. These watersheds score high in relative abundance: there are not many sightings but these are a large proportion of sightings for the species. It is not locally abundant anywhere.

Sources:

U.S. Fish and Wildlife Service Species Assessment and Listing Priority Assignment Form for: *Coccyzus americanus* (Yellow-billed Cuckoo), Western United States Distinct Population Segment. http://ecos.fws.gov/docs/candforms_pdf/r8/B06R_V01.pdf

Stillwater Sciences. 2007. Focal Species Analysis and Habitat Characterization for the Lower Santa Clara River and Major Tributaries, Ventura County, California. Santa Clara River Parkway Floodplain Restoration Feasibility Study.

7.2.7 Southwestern Willow Flycatcher (*Empidonax trailii extimus*)

Federally status: Endangered, February 1995. Critical habitat designated October 2005. Final recovery plan completed August 2002.
State status: Endangered, January 1991.
Arundo impact score: 8

General Ecological Needs/Habitat Affinities:
The southwestern willow flycatcher occurs in riparian woodlands along streams and rivers with mature, dense stands of willows (*Salix* spp.), cottonwoods (*Populus* spp.), or smaller spring fed areas with willows or alders (*Alnus* spp.). Riparian habitat is used for both foraging and breeding.

Suitable habitat typically consists of the following habitat features: 1) Nesting habitat with trees and shrubs that include, but are not limited to, willow (*Salix* spp.) species and boxelder (*Acer negundo*), 2) Nesting habitat with a dense (*i.e.*, 50- 100 %) tree and/or shrub canopy, 3) Dense riparian vegetation with thickets of trees and shrubs, 4) Dense patches of riparian forest interspersed with small areas of open water or marsh, creating a mosaic; patch size may be as small as 0.25 ac or as large as 175 ac.

Arundo impacts: *Arundo displaces native vegetation forming monotypic stands or co-occurring with native woody vegetation. Both of these situations degrade habitat value. Abiotic system changes caused by Arundo related to fire and more frequent flooding degrade habitat value by creating more areas with early serial stages.*

Breeding/Life History:
Nests are typically placed in even-aged, structurally homogeneous and dense plant communities. They usually nest in the upright fork of a shrub, but occasionally nest on horizontal limbs within trees and shrubs. Historically the flycatcher nested primarily in willows and mulefat (*Baccharis salicifolia*) with a scattered overstory of cottonwood. With changes to riparian plant communities, they still nest in willows where available, but are also known to nest in thickets dominated by the non-native shrub tamarisk (*Tamarix* species) and Russian olive (*Elaeagnus angustifolia*). Males typically arrive in California at the end of April and females arrive approximately one week later. They have a home range that is larger than the defended territory. Territorial defense usually begins in late May. Territory size varies from 0.25 to 5.7 acres, with most in the range between 0.5 and 1.2 aces. They typically raise one brood per year, with a clutch size usually 3-4. The fledglings leave the nest at age 12-15 days in early July, and usually disperse from the natal territory at age 26-30 days. In southern California flycatchers usually leave the breeding grounds by the end of August, and it is exceeding scarce in the United States after mid-October.

Arundo impacts: *Arundo degrades habitat quality as it displaces vegetation with suitable nesting structure.*

Diet:
The southwestern willow flycatcher is an insectivore that forages within and above dense riparian vegetation, taking insects on the wing or gleaning them from foliage. They may also forage in areas adjacent to nest sites which may be more open. They are active diurnally.

Arundo impacts: *Arundo appears to have little foraging value for the southwestern willow flycatcher as it supports a reduced diversity and abundance of aerial insects compared to native vegetation (Herrera & Dudley 2003). Arundo displaces vegetation that supports food species.*

Movement:
Males usually arrive in California at the end of April, and females about a week later. They generally leave in August. The migration routes and destination of the willow flycatcher are not well known. The flycatcher most likely winters in Mexico, Central America and perhaps northern South America, however, the habitat is uses as wintering grounds are unknown.

Arundo impacts: *No impact to migration- but Arundo interferes with movement within the territory- obstructing access to lower canopy and impeding foraging.*

Status/Distribution or Historic and Current Range:
Current estimated distribution of the southwestern willow flycatcher in California is shown in Figure 7-16/19. The current breeding range includes southern California, southern Nevada, Arizona, New Mexico and western Texas. The historic range in California apparently included all lowland riparian areas of the southern third of the state. In the 1930 it was considered a common breeder in coastal southern California, but it declined precipitously over the last 50 years or so.

Arundo impacts: *Arundo is abundant on two specific watersheds with large numbers of flycatchers (Table 7-3, Appendix B). One watershed has moderate interaction/overlap in distribution and eight watersheds have slight interaction. The species has a wide distribution but low populations on most watersheds.*

Decline and Threats:
The major threats to the flycatcher are the destruction, modification, or curtailments of habitat, and nest parasitism by cowbirds. Loss and modification of riparian habitat has occurred due to urban and agricultural development, water diversion and impoundments, channelization, livestock grazing, off-road vehicle and other recreational uses, and hydrological changes resulting from these and other land uses.

Overall impact metric for *Arundo* on southwestern willow flycatcher: Very high impact, score of 8.

Interaction of *Arundo* distribution and southwestern willow flycatcher occurrence is presented by watershed in Table 7-3 and illustrated in Appendix B.

Sources:
U.S. Fish and Wildlife Service. 2002. Southwestern Willow Flycatcher Recovery Plan. Albuquerque, New Mexico. http://ecos.fws.gov/docs/recovery_plans/2002/020830c.pdf
Stillwater Sciences. 2007. Focal Species Analysis and Habitat Characterization for the Lower Santa Clara River and Major Tributaries, Ventura County, California. Santa Clara River Parkway Floodplain Restoration Feasibility Study.

7.2.8 Belding's Savannah Sparrow (*Passerculus sandwichensis beldingi*)

Federal status: Species of Concern
State status: Endangered, 1974.
Arundo impact score: 2

General Ecological Needs/Habitat Affinities:
Belding's are ecologically associated with dense pickleweed, particularly *Sarcocornia pacifica (formerly Salicornia virginica)*, within which most nests are found.

Arundo impacts: *Arundo is not typically abundant in estuaries although it can occur there. Of more concern is biomass from upstream sources that accumulates in estuaries. Most of the estuaries where the sparrows occur are connected to smaller stream order riverine systems. Less Arundo is found on these size systems. Arundo impacts to system hydrology and geomorphic processes could be of concern in certain situations- sediment loads, biomass blocking flows. But these impacts are probably less on the size river systems that support sparrow habitat in estuaries.*

Breeding/Life History:
Breeding territories can be very small and they nest semi-colonially or locally concentrated within a larger block of habitat, all of which may appear generally suitable.

Arundo impacts: *Minimal impact.*

Diet:
Feeds mostly on the ground (seeds), generally alone or, during the non-breeding season, in small flocks.

Arundo impacts: *Minimal impact.*

Movement:
They remain within the salt marsh year round.

Arundo impacts*: Minimal impact.*

Status/Distribution or Historic and Current Range:
Based upon the 2010 surveys, Belding's sparrows are doing well within their range in California but particularly at Point Mugu, Seal Beach National Wildlife Refuge (NWR), Bolsa Chica, Upper Newport Bay, Sweetwater Marsh NWR, and Tijuana Slough NWR. This is associated in part with the levels and quality of hands-on efforts at these wetlands. For example, Point Mugu has one of the most active and successful Natural Resources Management programs of any of the coastal wetlands in the southern California Bight. At San Elijo and Los Peñasquitos Lagoons the ocean inlets are being monitored and kept open as much as possible. This often minimizes flooding and hyper-saline conditions that greatly reduce Belding's sparrows nesting success.

Arundo impacts: *There is interaction between sparrow and Arundo distributions. Arundo occurs within occupied habitat in a few areas, but as noted it is not abundant in estuaries. Arundo debris is not mapped, but is predicted based on abundance of Arundo upstream of occupied sites. Many of the occupied estuaries are on smaller lower energy systems so significant Arundo biomass inputs are not likely. Calleguas Watershed is a noted potential exception but much of the estuary complex is not well connected to the river mouth. This partly protects it from Arundo debris being pulled back into the estuary complex after it has been dispersed into the ocean or from deposition as debris racks during flow events.*

Decline and Threats:
Over 75% of the coastal wetland habitats within this range have been lost or highly degraded and the remainder suffer from the effects of increasing human populations.

Overall impact metric for *Arundo* on the Belding's savannah sparrow: Very low impact, score of 2.

Interaction of *Arundo* distribution and the Belding's savannah sparrow's occurrence is presented by watershed in Table 7-3 and Appendix B.

Sources:
A Survey of the Belding's Savannah Sparrow in California 2010, State of California, The Resources Agency, Department of Fish and Game Wildlife Branch. Prepared by Richard Zembal and Susan M. Hoffman, Clapper Rail Recovery Fund, Huntington Beach Wetlands Conservancy, September 2010.

7.2.9 Coastal California Gnatcatcher (*Polioptila californica californica*)

Federal status: Threatened, March 1993. Critical habitat (Revised) designated December 2007.
State status: None?
Arundo impact score: 2

General Ecological Needs/Habitat Affinities:
The range and distribution of the gnatcatcher is closely aligned with coastal scrub vegetation. This vegetation is typified by low (<1m), shrub and sub-shrub species that are often drought deciduous. The coastal scrub plant communities that overlap the range of the gnatcatcher include Venturan, Diegan, and Riversidean coastal sage scrub (CSS) communities, and Martirian and Vizcainan coastal succulent scrub communities. Gnatcatchers may also occur in other nearby plant communities, especially during the non-breeding season, but gnatcatchers are closely tied to coastal scrub for reproduction.

Arundo impacts: *Arundo is not typically found in coastal sage scrub, but CSS habitat and riparian zones are closely aligned in most areas along the coast. Impacts related to fire, both fires starting in*

Arundo and Arundo contributions to wildland fires, can have impacts to adjacent habitat. Fire impacts to CSS can result in both direct take of the species as well as degradation of habitat (short term functional loss, and potentially long term degradation- dependent on fire history and recovery of site). Gnatcatchers are also year round residents and riparian vegetation offers refuge and food resources in late summer/fall/winter when coastal sage scrub is less productive.

Breeding/Life History:
The gnatcatcher is non-migratory and defends breeding territories ranging in size from 1 - 6 hectares (2 - 14 acres). The home range size of the gnatcatcher varies seasonally and geographically, with winter season home ranges being larger than breeding season ranges and inland populations having larger home ranges than coastal. The breeding season of the gnatcatcher generally extends from late February through July (sometimes later), with the peak of nest initiations occurring from mid-March through mid-May. Nests are composed of grasses, bark strips, small leaves, spider webs, down, and other materials and are often located in California sagebrush (*Artemisia californica*) plants about 1 m above the ground. The incubation and nestling periods encompass about 14 and 16 days, respectively.

Arundo impacts: *No impact except those related to fire.*

Diet:
California gnatcatchers are ground and shrub-foraging insectivores. They feed on arthropods, beetles, spiders, leafhoppers, and other small insects. Most of their water intake is obtained through their diet.

Arundo impacts: *Little impact-although riparian areas can be used for foraging during times of low productivity in CSS, and high Arundo cover degrades this function.*

Movement:
The gnatcatcher is non-migratory. Dispersal of juveniles generally requires a corridor of native vegetation that provides certain foraging and sheltering requisites and that connects to larger patches of appropriate sage scrub vegetation. These dispersal corridors facilitate the exchange of genetic material and provide a path for re-colonization of extirpated areas. The gnatcatcher generally disperses short distances through contiguous, undisturbed habitat, but juvenile gnatcatchers are capable of dispersing long distances (up to 22km/14 mi) across fragmented and highly disturbed sage scrub habitat, such as that found along highway and utility corridors or remnant mosaics of habitat adjacent to developed lands.

Arundo impacts: *No impact.*

Status/Distribution or Historic and Current Range:
The range of the gnatcatcher is coastal southern California and northwestern Baja California, Mexico, from southern Ventura and San Bernardino Counties, California, south to approximately El Rosario, Mexico, at about 30 degrees north latitude.

Arundo impacts: *See Appendix B.*

Decline and Threats:
The main threat to the coastal California gnatcatcher is habitat loss, fragmentation, and degradation. Urban and agricultural development, livestock grazing, invasion of exotic grasses, off-road vehicles, pesticides, and military training activities all contribute to the destruction of gnatcatcher habitat.

Overall impact metric for *Arundo* on the coastal California gnatcatcher: Very low impact, score of 2. If wildland fires were documented to have greater extent due to presence of *Arundo* stands in core gnatcatcher upland areas this score should be elevated. Significant take and/or long term degradation would occur to upland habitat.

Interaction of *Arundo* distribution and the coastal California gnatcatcher's occurrence is presented by watershed in Table 7-3 and Appendix B.

Sources:

Coastal California Gnatcatcher Five Year Review, U.S. Fish and Wildlife Service, Carlsbad, CA. September 2010. http://ecos.fws.gov/docs/five_year_review/doc3571.pdf

7.2.10 Light Footed Clapper Rail (*Rallus longirostris levipes*)

Federal status: Endangered, October 1970. No critical habitat designated.
State status: Endangered, June 1971
Arundo impact score: 3

General Ecological Needs/Habitat Affinities:
The light-footed clapper rail uses coastal salt marshes, lagoons, and their maritime environs. Nesting habitat includes tall, dense cordgrass (*Spartina foliosa*) and occasionally pickleweed (*Sarcocornia pacifica* – formerly *Salicornia virginica*) in the low littoral zone, wrack deposits in the low marsh zone, and hummocks of high marsh within the low marsh zone. Fringing areas of high marsh serve as refugia during high tides. Although less common, light-footed clapper rails have also been observed to reside and nest in freshwater marshes.

Activities of the light-footed clapper rail are tide-dependent. They require shallow water and mudflats for foraging, with adjacent higher vegetation for cover during high water. They forage in all parts of the salt marsh, concentrating their efforts in the lower marsh when the tide is out, and moving into the higher marsh as the tide advances.

Arundo impacts: *Arundo does not occur in the lower estuary habitat that rails use. However, biomass of Arundo from upstream stands can be deposited in estuaries (relevance is tied to abundance of Arundo on a given system). Also, larger order systems that are significantly invaded may have significant modification of flow dynamics, sediment transport, and hydrology which may affect quality of estuary habitat at the river mouth (if estuaries are still connected to the river system).*

Breeding/Life History:
Nesting usually begins in March and late nests hatch by August. Nests are placed to avoid flooding by tides, yet in dense enough cover to be hidden from predators and to support the relatively large nest. Potential predators on eggs, nestlings, or adults include California ground squirrels, old world rats, striped skunk, feral house cats, dogs, gray fox, red fox, Virginia opossum, and raptors.

Arundo impacts: *Arundo harbors a range of mammals and predators that use the physical structure.*

Diet:
Light-footed clapper rails are omnivorous and opportunistic foragers, which rely mostly on salt marsh invertebrates such as beetles, garden snails, California horn snails, salt marsh snails, fiddler and hermit crabs, crayfish, isopods, and decapods.

***Arundo impacts**: No impact.*

Movement:
The light-footed clapper rail is resident in its home marsh except under unusual circumstances. Within-marsh movements are also generally confined and usually of no greater spread than 1,312 feet (400m). However, a banded captive-bred female rail which was released at Point Mugu in August of 2004 was found in December of 2004 at Upper Newport Bay, a distance of 145 km (90 mi) along the coast. Minimum home range sizes for nine clapper rails that were radio-harnessed for telemetry at Upper Newport Bay varied from approximately 0.8 - 4.1 acres. The larger areas and daily movements were by first year birds attempting to claim their first breeding territories.

***Arundo impacts:** No impact.*

Status/Distribution or Historic and Current Range:
The historical range of the light-footed clapper rail was originally described as extending from Santa Barbara County, California to San Quintin Bay, Baja California, Mexico. In the early 1900s, ornithologists noted a decrease in the abundance of rails and observed that they were no longer found in areas, which were formerly occupied. Since 1900, 75 %of the coastal estuaries and wetlands in southern California have been destroyed or adversely modified. Light-footed clapper rails have not been detected in Santa Barbara County since 2004 or in Los Angeles County since 1983. The range in California now extends from Ventura County in the north to the Mexican border in the south.

***Arundo impacts:** Rails occur in estuaries of both large and small watershed systems- particularly in San Diego County (Appendix B). Rails can extend fairly far into the watershed (where pickleweed occurs), but some of these are historic records. Arundo is abundant on some of these watersheds.*

Decline and Threats:
Continued loss and degradation of salt marsh habitat.

Overall impact metric for *Arundo* on the light-footed clapper rail: Low impact, score of 3.

Interaction of *Arundo* distribution and the light footed clapper rail's occurrence is presented by watershed in Table 7-3 and Appendix B.

Sources:
Light-footed Clapper Rail Five Year Review, U.S. Fish and Wildlife Service, Carlsbad, CA. August 2009. http://ecos.fws.gov/docs/five_year_review/doc2573.pdf

7.2.11 California Least Tern (*Sterna antillarum browni*)

Federal status: Endangered June 2, 1970. Final Recovery Plan 1980, revised 1985.
State status: Endangered, June 27, 1971.
Arundo impact score: 4

General Ecological Needs/Habitat Affinities:
California least terns nest on beaches, usually choosing locations in an open expanse of light-colored sand, dirt or dried mud close to a lagoon or estuary with a dependable food supply. Formerly, sandy open beaches were used, but human activity on beaches has forced terns to nest on mud and sand flats back from the ocean, and on man-made habitats. In addition to nesting areas, California least terns also require secure roosting and foraging areas. Roosting areas are of two kinds: pre-season nocturnal roosts and post-season dispersal sites where adults and fledglings congregate. Terns forage primarily in nearshore ocean waters and in shallow estuaries and lagoons.

Arundo impacts: *Arundo is not abundant in the beach and estuary habitat- but there can be locally occurring stands and occurrences of the plant. Arundo debris and to a lesser degree hydrologic and geomorphic alteration of river systems can have impacts on terns.*

Breeding/Life History:
Most least terns begin breeding in their third year. Mating begins in April or May. The nest is a simple scrape in the sand and may be lined with shell fragments, pebbles, twigs. Typically there are 2 eggs. Both parents incubate and care for the young. They can re-nest up to two times if eggs or chicks are lost early in the breeding season. Nesting season extends from approximately May 15 into early August, with the majority of nests completed by mid June. A second wave of nesting occurs from mid-June to early August. These are mainly re-nests after initial failures, and second year birds nesting for the first time. Predators of the California least tern are larger birds, mammals such as raccoons and foxes, and domestic dogs and cats.

Arundo impacts: *Most tern breeding areas are nearly devoid of vegetation and plant debris (observation of nesting sites in San Diego and Ventura Counties). Arundo debris and live plant structure is a degradation of habitat. Debris reduces useable area. Any structure fosters predation from birds and any concealment encourages predatory mammals.*

Diet:
California least terns eat small fish.

Arundo impacts: *No impact.*

Movement:
The California least tern is migratory, usually arriving in its breeding area by mid April and departing again in August. However, terns have been recorded in the breeding range as early as March 13 and as late as October 31. Adult terns move south along the California coast with their fledglings in the autumn, stopping to rest and feed along the migration route.

Arundo impacts: *No impact.*

Status/Distribution or Historic and Current Range:
Historically California least terns nesting in large colonies spread along undisturbed beaches. However with development of the California coast and fragmentation of large beach areas, birds now nest in the small fragments of habitat remaining in the same general areas. The nesting range in California is discontinuous, with large colonies spread out along beaches at estuaries. The northern limit for nesting is San Francisco Bay, and the southern limit is in Baja California, Mexico. Today the tern is concentrated in three southern California counties: Los Angeles, Orange and San Diego.

Arundo impacts: *Arundo is abundant on several watersheds in Orange and San Diego Counties (Appendix B).*

Decline and Threats:
California least terns were apparently once abundance and well distributed on barrier beaches and beach strand along the southern California coast. The reduction in tern numbers was apparently gradual and associated with human population increases in the area. The species was noted as seriously declining within its range before the 1930s. Today the tern is concentrated in three southern California counties: Los Angeles, Orange and San Diego. Since 1973 there has been on overall increase in least tern in California due to recovery efforts such as site management and protection of known nesting sites (fencing, predator control, monitoring, research). Decline of the California least tern is due to loss and degradation of beach habitat, impacts and disturbance from human and domestic animal use of beaches, and loss and fragmentation of wintering habitat.

Overall impact metric for *Arundo* on the coastal California least tern: Low/Moderate, score of 4.

Interaction of *Arundo* distribution and the coastal California least tern's occurrence is presented by watershed in Table 7-3 and Appendix B.

Sources:
California Least Tern Five Year Review Summary and Evaluation, U.S. Fish and Wildlife Service, Carlsbad, CA. September 2006. http://ecos.fws.gov/docs/five_year_review/doc775.pdf
Revised California Least Tern Recovery Plan, U.S. Fish and Wildlife Service, Portland, Oregon. April 1980. http://ecos.fws.gov/docs/recovery_plan/850927_w%20signature.pdf

7.2.12 Least Bell's Vireo (*Vireo bellii pusillus*)

Federal status: Endangered, May 1986. Critical habitat designated February 1994. Draft recovery plan completed in 1998.
State status: Endangered, October 1980.
Arundo impact score: 9

General Ecological Needs/Habitat Affinities:
Least Bell's vireo is a small, olive-grey migratory songbird that nests and forages almost exclusively in riparian woodland habitats. Primary constituents of critical habitat for the vireo include riverine and floodplain habitat, and adjacent coastal sage scrub, chaparral, or other upland communities. Nesting habitat typically consists of well-developed overstories and understories, and low densities of aquatic and herbaceous cover. The understory frequently contains dense subshrub or shrub thickets. These thickets are often dominated by sandbar willow (*Salix hindsiana*), mulefat (*Baccharis salicifolia*), young individuals of other willow species, such as arroyo willow (*Salix lasiolepis*) or black willow (*Salix gooddingii*), and one or more herbaceous species. Important overstory specie include mature arroyo willow and black willows; occasional cottonwoods (*Populus* spp.) and western sycamores (*Platanus racemosa*) occur in some habitats. Additionally, coast live oak (*Quercus agrifolia*) can be a locally important overstory component, as can mesquite (*Prosopis* spp.).

Arundo impacts: *Arundo and vireos prefer the same broad coastal riparian habitat types. Significant impacts from abiotic modification of the riverine system impact ecosystem to the detriment of the vireo. There changes include fire, geomorphic impacts that interfere with vegetation succession, and outright displacement of vegetation that vireos are dependent on. Direct take and long term degradation of habitat occurs after fires initiating in Arundo stands as well as wildland fires that are larger are more intense when Arundo is present.*

Breeding/Life History:
Following pair formation, it takes approximately 5 - 7 days for them to finish nest construction and egg laying. Young typically fledge within 20 - 24 days after eggs are laid. The egg laying and incubation periods are critical to the nesting success, as disturbance at this point may result in abandonment of the nest.

Arundo impacts: *Arundo displaces native vegetation reducing available habitat for nesting. Arundo does not have suitable structure for vireo nests.*

Diet:
They are almost exclusively insectivorous, and forage in riparian woodland and suitable adjacent upland habitat.

Arundo impacts: *Arundo support a low abundance and diversity of insects, particularly in comparison to native vegetation (Herrera & Dudley 2003, Going & Dudley 2008). Vireos are rarely seen feeding on Arundo as the plants has few insects that directly feed on it. Birds are rarely seen feeding in Arundo.*

Movement:
Least Bell's vireos generally begin to arrive from their wintering range in southern Baja California and establish breeding territories by mid- to late March. Most breeding vireos depart by the third week of September and only a very few individuals are found wintering in California. Most vireos occupy home ranges that are typically from 0.5 - 4.5 acres, but a few may be as large as 7.5 acres. Once the young are fledged they wander widely throughout the parents' territory.

Arundo impacts: *Arundo stands inhibit movement of avian species as the feed, spatially segregating the habitat. Territories frequently include Arundo stands but there is always a native component of the territory. Territories are roughly drawn- it would be interesting to see if territory size is larger when Arundo is present.*

Status/Distribution or Historic and Current Range:
Historically the vireo was described as common to abundant in the appropriate riparian habitat from as far north as Tehama County, CA to northern Baja, Mexico. Habitat loss has fragmented most remaining populations into small, disjunct, widely dispersed subpopulations. Currently the largest population of vireos is on Marine Corps Base Camp Pendleton in San Diego County. This population combined the population in the Prado Basin represent approximately 60 % of all known territories in California.

Arundo impacts: *Arundo is abundant on the three largest population centers for the vireo: Santa Margarita, Santa Ana, and San Luis Rey. Vireos are in greater abundance on larger systems, but they do occur on smaller watersheds if riparian vegetation is well developed (Appendix B). Vireos also occur in greater abundance in urban riparian areas then other federally listed species.*

Decline and Threats:
Decline of vireos is primarily the result of habitat loss and degradation, and cowbird nest-parasitism. The historic loss of wetlands (including riparian woodlands) has been estimated at 91 %. Much of the potential remaining habitat is infested with non-native plants and cowbirds. Ongoing causes of destruction or degradation of habitat include: removal of riparian vegetation; invasion of non-native species (e.g. *Arundo*, cowbird); thinning of riparian growth, especially near ground level; removal or destruction of adjacent upland habitats used for foraging; increases in human-associated or human induced disturbances; and flood control activities, including dams, channelization, water impoundment or extraction, and water diversion. Vireos are also sensitive to many forms of human disturbance, including noise, night lighting, and consistent human presence in an area.

Overall impact metric for *Arundo* on least Bell's vireo: Severe impact, score of 9.

Interaction of *Arundo* distribution and least Bell's vireo occurrence is presented by watershed in Table 7-3 and Appendix B.

Sources:

Stillwater Sciences. 2007. Focal Species Analysis and Habitat Characterization for the Lower Santa Clara River and Major Tributaries, Ventura County, California. Santa Clara River Parkway Floodplain Restoration Feasibility Study.

Programmatic Biological Opinion for the Salinas River Watershed Permit Coordination Program, Monterey County, CA (1-8-02-F-19), US Fish and Wildlife Service, Ventura, CA. 2002.

7.2.13 Tidewater Goby (*Eucyclogobius newberryi*)

Federal status: Endangered, March 7 1994. Critical habitat designated November 20 2000.
State status: none
Arundo impact score: 7

General Ecological Needs/Habitat Affinities:
The tidewater goby, a species endemic to California, is found primarily in waters of coastal lagoons, estuaries, and marshes. The species is benthic in nature, and its habitat is characterized by brackish, shallow lagoons and lower stream reaches where the water is fairly still but not stagnant. Tidewater gobies prefer a sandy substrate for breeding, but they can be found on rocky, mud, and silt substrates as well. The species is typically found in water less than 1 m deep. Tidewater gobies have been documented in waters with salinity levels from 0 - 42 parts per thousand (ppt), temperature levels from 8 - 25 ° C (46 - 77° F), and water depths from 25 200 cm (10 to 79 in). Critical habitat includes the stream channels and their associated wetlands, flood plains, and estuaries.

Arundo impacts : *Alteration of geomorphology and accumulation of excessive dead biomass in habitat areas are the primary impacts. It is possible that abundant Arundo is extremely detrimental to the species as they have not been observed on the Salinas River, Santa Clara, and Santa Margarita, and San Luis Rey Rivers in recent time frames. River channels could be becoming too deep for the species on some systems (such as San Luis Rey) resulting from excessive vegetation on floodplains (see chapter 5). The species now seems to occur on smaller river/creek systems, many of which have no or little Arundo on them (areas of Camp Pendleton and Estero Bay).*

Breeding/Life History:
The tidewater goby is typically an annual species, although some variation has been observed. Reproduction occurs year-round although distinct peaks in spawning, often in early spring and late summer, do occur. Male tidewater gobies begin digging breeding burrows in relatively unconsolidated, clean, coarse sand (averaging 0.5 mm diameter), in April or May after lagoons close to the ocean. Female tidewater gobies can lay 300 - 500 eggs per clutch, and can lay 6 - 12 clutches per year. Male tidewater gobies remain in the burrow to guard the eggs that are attached to sand grains in the burrow ceiling and walls. The male tidewater goby cares for the embryos for approximately 9 - 11 days until they hatch. Tidewater goby larvae are planktonic for 1 - 3 days and then become benthic from that point on. Tidewater goby are preyed upon by native and non-native fish, and by fish eating birds.

Arundo impacts: *Accumulated biomass within the channel near the river mouth would cover substrate needed for reproduction.*

Diet:
Tidewater gobies feed mainly on small animals, usually mysid shrimp, amphipods, ostracods, and aquatic insects. Juvenile tidewater gobies are generally day feeders, although adults mainly feed at night.

Arundo impacts: *Unknown if biomass would impacts aquatic food resources. Excessive channel depth would negatively affect feeding (individuals prefer a water depth of up to 1 m).*

Movement:
The tidewater goby appears to spend all life stages in lagoons, estuaries, and river mouths. Tidewater gobies may enter marine environments only when flushed out of lagoons, estuaries, and river mouths by normal breaching of the sandbars following storm events. Tidewater gobies generally select habitat in the upper estuary, usually within the fresh-saltwater interface. Tidewater gobies range upstream a short distance (up to 1.5 miles/2.41 km) into fresh water, and downstream into water of up to about 75 % sea water (28 ppt).

Arundo impacts this by: *The preferred habitat zone frequently has significant Arundo on the banks (in highly invaded systems) It is possible that Arundo debris in these systems interferes with movement during and after flood events- particularly if there are large rafts vegetation (Arundo canes and native vegetation).*

Status/Distribution or Historic and Current Range:
Tidewater gobies are endemic to California and historically ranged from Tillas Slough near the Oregon border to Agua Hedionda Lagoon in northern San Diego County, and are found today entirely within the original known range of the species. The known localities are discrete lagoons, estuaries, or stream mouths separated by mostly marine conditions. Tidewater gobies are absent from areas where the coastline is steep and streams do not form lagoons or estuaries. Tidewater gobies have recolonized areas where they have been extirpated.

Arundo impacts: *Arundo and goby distributions are shown Appendix B. As noted, the species has not been found in several large and heavily invaded watersheds since 2001. But there are smaller watersheds with populations nearby. Goby populations and distribution may naturally fluctuate in response to large flooding events. It will be informative to see if they return to systems that have had Arundo neatly eradicated (Santa Margarita and San Luis Rey).*

Decline and Threats:
The tidewater goby is threatened by modification and loss of habitat as a result of coastal development, channelization of habitat, diversions of water flows, groundwater overdrafting, and alteration of water flows. Potential threats to the tidewater goby include discharge of agricultural and sewage effluents, increased sedimentation due to cattle grazing and feral pig activity, summer breaching of lagoons, upstream alteration of sediment flows into the lagoon areas, introduction of exotic gobies and rainwater killifish, habitat damage, and watercourse contamination resulting from vehicular activity in the vicinity of lagoons.

Arundo impacts: *Arundo effects several of these parameters (water availability, sediment transport), but it is unclear exactly how these factors interact with goby habitat.*

Overall impact metric for *Arundo* on the tidewater goby: High impact, score of 7.

Interaction of *Arundo* distribution and tidewater goby occurrence is presented by watershed in Table 7-3 and Appendix B. It is important to note that there are many smaller watersheds that have no or very low *Arundo* presence and therefore impacts are non-existent. Goby have occurred on large systems- and they are in significant decline or do not occur on these systems over the time period when *Arundo* has become a significant impact. Other hydrologic factors have also changed significantly over that time frame (water flows, sediment transport, etc.) so several factors may be at play.

Sources:

Programmatic Biological Opinion for the Salinas River Watershed Permit Coordination Program, Monterey County, CA (1-8-02-F-19), US Fish and Wildlife Service, Ventura, CA. 2002.

U.S. Fish and Wildlife Service. 2005. Recovery Plan for the Tidewater Goby (*Eucyclogobius newberryi*). U.S. Fish and Wildlife Service, Portland, Oregon.

7.2.14 Unarmored Three Spine Stickleback (*Gasterosteus aculeatus williamsoni*)

Federal status: Endangered, October 13 1970. Designation of critical habitat remains pending. Recovery Plan completed in 1985.
State status: Endangered, June 27 1971.
Arundo impact score: 8

General Ecological Needs/Habitat Affinities:

The unarmored three-spine stickleback inhabits slow moving reaches or quiet water microhabitats of streams and rivers. Favorable habitats usually are shaded by dense and abundant vegetation, but in more open reaches algal mats or barriers may provide refuge. The best habitat seems to be a small clean pond in the stream with a constant flow of water through it. Adults are found in all areas of the stream and tend to gather in areas of slower moving or standing water. In areas where water is moving rapidly, adults tend to be found behind obstructions, or at the edge of the stream, particularly under the edge of algal mats. No adults have been found to be living permanently in ponds isolated from the main stream.

Arundo impacts: *Arundo occurs within the core stickleback population area of the upper Santa Clara Watershed. There is Arundo present within much of the stickleback's range and significant Arundo in the fish's lower range on the main stem of the river. For more invaded portions of the river changes to sediment transport and high water use of Arundo could be impacting pool persistence and quality. Arundo fires in more invaded habitat would also cause impacts.*

Breeding/Life History:

There is some reproduction during almost every month. A large increase in reproductive activity occurs in the spring in about March, and continues at lower levels throughout summer and fall. Males build nests of aquatic vegetation on the bottom within his territory. Nests are located where there is ample vegetation and a gentle flow of water. After the female lays the eggs, the male fertilizes them, guards them, and fans them. Young sticklebacks hatch in a nest from eggs which have been brooded for several days by the adult male. The exact amount of time the young stay in the nest is unknown. Larger juveniles and sub-adults tend to be found in the protection of vegetation, in slow moving or standing water. Fish apparently only live for one year.

Arundo impacts: *Pool/channel water quality and duration may be impacted.*

Diet:

The stickleback feeds mostly on benthic insects, small crustaceans, and snails, and to a lesser degree flat worms and nematodes. Males may also eat stickleback eggs.

Arundo impacts: *Pool/channel water quality and duration may be impacted- which could effect abundance and diversity of food resources.*

Movement:
The unarmored three-spine stickleback remains within stream channels and ponds within the stream area. No adults have been found to be living permanently in ponds isolated from the main stream.

Arundo impacts: *Minimal impacts.*

Status/Distribution or Historic and Current Range:
Historically they were distributed throughout southern California, but are now restricted to the upper Santa Clara River and its tributaries in northern Los Angeles and Ventura Counties, San Antonio and Canada Honda creeks on Vandenberg Air Force Base in Santa Barbara County, and San Felipe Creek in San Diego County. The Canada Honda and San Felipe Creek populations were transplanted.

Arundo impacts: *Arundo and stickleback overlap in distribution (Appendix B).*

Decline and Threats:
Habitat degradation from flood control and channelization are the primary threats to the unarmored three-spine stickleback. Habitat degradation also occurs from trampling of stream banks by humans and livestock, causing increased soil erosion and sedimentation which reduces availability of plants and insects for habitat and food. Damage to emergent vegetation along stream banks degrades the nursery areas. Stream channelization allows increased water velocity in pools, eliminates shallow backwaters and reduces aquatic vegetation. Channelization also increases peak flows during floods, and large flood events scour the channel and wash stickleback individuals downstream. Urbanization has caused a degradation of water quality due to increased run-off, siltation, nutrients, pesticides and other pollutants. These pollutants affect the health of the sticklebacks and can cause deformities. Introduced predators and competitors negatively affect the stickleback by directly removing individuals or restricting them to habitats that predators cannot enter. Other threats to the stickleback include genetic introgression, agricultural impacts, oxygen reduction, groundwater removal, possibly water loss due to transpiration from increase plant growth, and off-road vehicle use.

Arundo impacts: *Arundo stands on floodplains can create many of the same hydrologic and flow conditions as man-made channelization such as faster flows, high erosion within channels, etc. These factors may contribute to the sticklebacks decline by decreasing the elevation and channel complexity that stickleback may prefer over a simple deeper channel form. These factors are more relevant in the lower portions of the sticklebacks' range on the Santa Clara.*

Overall impact metric for *Arundo* on unarmored three-spine stickleback: Very high, score of 8.

Interaction of *Arundo* distribution and unarmored three-spine stickleback occurrence is presented by watershed in Table 7-3 and Appendix B.

Sources:
Unarmored Threespine Stickleback Recovery Plan (Revised), U.S. Fish and Wildlife Service, Portland, Oregon, 1985.
Biological and Conference Opinions for Annual Removal of Giant Reed and Tamarisk in Upper Santa Clara River Watershed, Los Angeles county, CA (File No. 2004-01540-AOA)(1-8-06-F-5).

7.2.15 Southern Steelhead (*Oncorhynchus mykiss*)

Southern California Distinct Population Segment (DPS)
Federal status: Endangered August 18 1997. Critical habitat was designated on September 2 2005.
South-Central California Coast DPS
Threatened Jan 5 2006, Critical habitat designated September 9 2005.
Arundo impact score: 7

General Ecological Needs/Habitat Affinities:
Southern steelhead can survive a wide range of temperature conditions, but require streams with adequate dissolved oxygen. Adult steelhead migrate from the ocean to freshwater spawning grounds. Spawning habitat consists of gravel substrates free of excessive silt. Adults do not feed during their upstream journey, rather use their energy reserves. Once they are large enough, smolts migrate downstream to the ocean, and to successfully complete this journey they require refuge areas with good cover and water quality.
Riparian vegetation provides cover and protection from predators and areas of refuge from high velocities. Riparian vegetation is also important in maintaining low stream temperature, stabilizing banks, and providing food sources for migrating steelhead. To provide these benefits, riparian vegetation needs high vigor, density, and species diversity, including a mixture of canopy trees, brush and grasses. Areas of lowered velocity or reverse flow areas within the channel allow steelhead to use energy reserves efficiently during migration in order to save energy for spawning. Sediment removal of sandbars reduces flow-field complexity, particularly of edgewater eddies and low velocity zones. This likely results in adult steelhead migrating through higher velocities and consuming higher levels of reserved energy. If too much reserved energy is consumed, and sufficient resting pools are not available, adults could be unable to reach spawning grounds, or have less energy for reproductive development. Furthermore, modification of sandbars and velocities could also simply increase the amount of time it takes for steelhead to reach spawning grounds. Removing and/or altering sandbars also reduces the convergence of flows through pools, thus reducing the processes that maintain pools. Pools provide cover and refuge. During the upstream migration steelhead rest in pools and during downstream migration smolts take refuge in pools during the day. Adults and smolts both require adequate flows for migration; they need enough water flow to travel up and down the river/stream, and to keep the river mouth open to the ocean.
Steelhead metabolism can be impacted by high water temperatures and the associated reduction in dissolved oxygen. Temperatures above 20° C have been known to stop fish migration, and temperatures above 25° C can be lethal to salmon and trout. High levels of suspended sediment (e.g. 3,000-4,000 mg/L), generally the result of large storm events or channel grading activities, can significantly impact fish migration and survival. Fish can suffer from gill abrasion and reduced visibility, and suffer mortality after exposure of two or more days. Fish at the mouth of a river would be delayed 1-2 days until the initial flush of sediment passes after a storm.

Arundo impacts: *Arundo has a significant number of impacts on river systems- some of which are negative and others that may be positive. Arundo typically occurs in areas that steelhead pass through so impacts to migration are important to explore. Arundo is not good at stabilizing eroding banks stands and clumps break off and are undercut by flows. This may increase erosion rates locally. Arundo does form dense stands of vegetation on floodplains. These dense stands create conditions that deepen low flow channels and push systems to single thread form in comparison to more complex braided systems or broader shallow systems. This single deep channel may aid migration of steelhead. However, single thread narrow channels have higher velocity and fewer areas to rest; this could be a detriment. Single thread channels also tend to transport (carry) greater suspended loads under a larger*

range of flow events. This could also be a detriment to steelhead, particularly if there a large number of sediment inputs (such as agricultural inputs or other disturbed sites). Highly invaded systems may have Arundo water use that reduces duration of surface flows- this would be a severe impact to steelhead. Water use may be lower at the time of year when fish migration occurs, partially offsetting transpiration rates. Arundo biomass could be a significant stressor as both a physical hindrance to passage and as a contamination in the water column. Water temperature impacts for portions of the habitat where fish passage is occurring are extremely difficult to quantify. It is not clear that large systems would have significant shading of the channel from mature gallery trees. Arundo shades a narrow band of the bank if the low flow channel is directly adjacent to the bank. More complex, but probably more relevant is water depth which may be strongly affected by Arundo stands (by effecting channel depth- chapter 5). Shading would be more relevant in upper portions of the watersheds where fish develop; these areas do not typically have Arundo in them.

Breeding/Life History:
Adult steelhead migrate from the ocean into freshwater streams to spawn between December and April. Female steelhead dig a nest in a stream area with suitable gravel composition, water depth, and velocity. Females may deposit eggs in four to five nests. Steelhead eggs hatch three to four weeks after being deposited. Juvenile steelhead typically spend one to two years rearing in freshwater before migrating to estuarine areas as smolts and then into the ocean to feed and mature. The majority of smolts enter the ocean at age two in March and April. They migrate at night and seek refuge and feed during the day. Steelhead can then remain at sea for up to three years before returning to fresh water to spawn.

Arundo impacts: *Arundo impacts on migration have been reviewed. Arundo debris in estuaries and Arundo effects on sediment movement could degrade estuarine habitat where smolts reside prior to entering the ocean.*

Diet:
Young steelhead fry feed mostly on zooplankton. Adult steelhead eat aquatic and terrestrial insects, mollusks, crustaceans, fish eggs, minnows, and other small fishes.

Arundo impacts: *Little impact as Arundo is not typically present or abundant in the upper portions of watersheds where juveniles develop. There could be greater impacts on Ventura River, Estero Bay and Santa Ynez, but spawning grounds are not clearly indicated on data sets.*

Status/Distribution or Historic and Current Range:
Steelhead within the Southern California DPS includes all naturally spawned anadromous steelhead populations below natural and manmade impassable barriers in streams from the Santa Maria River, San Luis Obispo County, California, to the U.S.-Mexico Border. South-Central California Coast DPS includes all naturally spawned anadromous steelhead from the Pajaro River (inclusive) to, but not including, the Santa Maria River, California. An estimated 30,000 - 50,000 steelhead once spawned in southern California rivers, but the recent runs in four major river systems were made by fewer than 500 adults total. Steelhead could once be found in 46 watersheds in the region, but only remained in 17 - 20 drainages by 2002. Many of these creeks and rivers now sustain only the resident form of steelhead, rainbow trout. Anadromous steelhead currently occur in only four large river systems in southern California: the Santa Maria, Santa Ynez, Ventura, and Santa Clara rivers. But periodic sightings have occurred on San Mateo (San Juan HU) and the San Luis Rey River.

Arundo impacts: *Arundo occurs in abundance on several critical watersheds and may occur on portions of spawning areas on a subset (Appendix B).*

Decline and Threats:
Decline is due to long-standing human induced factors such as lack of flows due to groundwater pumping, dams and water diversions, blocked access to historic spawning and rearing areas upstream of dams, and channel modification.

Arundo impacts: *Arundo has significant impacts on water use, channel form, and sediment transport. These are complex hydro geomorphic processes explored in chapter 5. Most impacts would appear to be strongly negative, others could facilitate migration.*

Overall impact metric for *Arundo* on the southern steelhead: High impact, score of 7.

Interaction of *Arundo* distribution and southern steelhead occurrence is presented by watershed in Table 7-3 and Appendix B.

Sources:
Programmatic Biological Opinion for the United States Army, San Francisco District Corps of Engineers' permit pursuant to 404 of the Clean Water Act for Monterey County Water Resources Agency regional General Permit for the Salinas River Channel Maintenance Program; National Marine Fisheries Service, Southwest Region, Long Beach CA. July 2003.

7.2.16 Santa Ana Sucker (*Catostomus santaanae*)

Federal status: Endangered, April 12 2000. Critical habitat has not been designated.
State status: Species of special concern.
Arundo impact score: 6

General Ecological Needs/Habitat Affinities:
The sucker is fairly general in its habitat requirements, occupying both low-gradient, lowland reaches, and high-gradient, mountain streams. The sucker seems to do best in small to medium streams with higher gradients, clear water, and coarse substrates, such as the east fork of the San Gabriel River. Flowing water is essential, but can vary from slight to swift. It is typically associated with gravel, cobble, and boulder substrates, although it is also found over sand and mud substrates.

Arundo impacts: *Arundo abiotic impacts are of particular concern for the sucker, particularly high water use and modification of geomorphology and sediment transport on the Santa Ana. Arundo is not abundant in the low channel areas where fish occur. The Los Angeles River is steeper in gradient and Arundo, though present, is not abundant enough to significantly impact water availability and fluvial processes.*

Breeding/Life History:
They live three to four years, but reach sexual maturity in one year and have high fecundity. Spawning generally occurs from late March to early July, with the peak in May and June.

Arundo impacts: *Probably low impact- but water use and drying of pools/stream sections could be a factor in some portions of the Santa Ana.*

Diet:
The sucker feeds mostly on algae, diatoms, and detritus scraped form rocks and other hard substrate. Aquatic insects comprise only a small part of their diet.

Arundo impacts: *Probably low impact- but water use and drying of pools/stream sections could be a factor in some portions of the Santa Ana.*

Movement:
Little is known about sucker movements, however other species in the same family are known to be high vagile and undertake spawning migrations.

Arundo impacts: *Probably low impact- but water use and drying of pools/stream sections could be a factor in some portions of the Santa Ana. Modification of sediment transport and fluvial processes would also affect channel forms and movement.*

Status/Distribution or Historic and Current Range:
Historically the sucker occupied the Los Angeles, San Gabriel, and Santa Ana Rivers from near the Pacific Ocean to their uplands. It was described as common in the 1970s, but has since experienced declines throughout most of its range, and now persists in isolated, remnant populations. Approximately 70-80% of its historic range in the Los Angeles, San Gabriel and Santa Ana Rivers has been destroyed. Currently the sucker is found 1) in portions of Big Tujunga Creek between the Big Tujunga and Hansen dams along the Los Angeles River, 2) in the west, east and north forks of the San Gabriel River above Morris Dam, and 3) reaches of the Santa Ana River between the city of San Bernardino and the vicinity of Anaheim. There is also a population of suckers in the Santa Clara River that is thought to be introduced and that has hybridized with the Owen's sucker, so it is not included within the range of the native sucker.

Arundo impacts: *Arundo significantly overlaps with the Santa Ana population and to a lesser degree the Los Angeles River population (Appendix B). There is also a hybridized population on the Santa Clara that may be introduced. There is significant Arundo within this populations range. The Santa Clara watershed is given a distribution score (Appendix B) but it is lowered to reflect the questionable genetic integrity of the resident population. If revisions to the Santa Clara's population value are made a higher impact interaction score should be given.*

Decline and Threats:
Threats that have contributed to the decrease in the sucker include 1) destruction and degradation of habitat through urbanization, channelization, flood control structures, water diversion, water withdrawal, and water quality reduction, 2) direct loss of suckers due to water diversion, 3) competition and predation from non-native species, and 4) loss of connectivity.

Overall impact metric for *Arundo* on the Santa Ana sucker: Moderate/High, score of 6.

Interaction of *Arundo* distribution and Santa Ana sucker occurrence is presented by watershed in Table 7-3 and Appendix B.

Sources:
Biological Opinion on the Prado Mainstem and Santa Ana River Reach 9 Flood Control Projects and Norco Bluffs Stabilization Project, Orange, Riverside, and San Bernardino Counties, California; U.S> Fish and Wildlife Service, Carlsbad, CA, December 2005.

7.2.17 San Joaquin Kit Fox (*Vulpes macrotis mutica*)

Federal status: Endangered, March 11, 1967. No critical habitat has been designated.
State status: Threatened, June 27, 1971.
Arundo impact score: 1

General Ecological Needs/Habitat Affinities:
This species historically inhabited grassland, scrubland, and wetland communities in the San Joaquin Valley and adjacent habitat. Today kit foxes are found in grassland and scrubland communities, most of which have been extensively modified by humans.

Kit foxes use dens for temperature regulation, shelter from adverse weather and protection from predators. They either dig their own dens, use those constructed by other animals, or use human-made structures (culverts, abandoned pipelines, or banks in sumps or roadbeds). Kit foxes often change dens and many dens may be used throughout the year. The majority of their dens lie in relatively flat terrain or gently sloping hills, in washes, drainages, and roadside berms.

Arundo impacts: *Arundo is not abundant within the habitat occupied by foxes. However, it does degrade the habitat as foxes prefer very open habitat with little or no vegetation structure to avoid predation. Arundo creates structure and may interact with dens that occur on washes.*

Breeding/Life History:
Kit foxes can breed when one year old. Adult pairs stay together all year. During September and October, females begin to clean and enlarge their pupping dens. Mating occurs between December and March. Litters of two to six pups are born in February or March. Pups emerge from the den after about a month.

Arundo impacts: *Very minor impacts related to potentially higher predation and lower denning quality.*

Diet:
Kit fox eat small mammals such as mice, kangaroo rats, squirrels and rabbits. They also eat ground-nesting birds and insects. They are primarily nocturnal hunters.

Arundo impacts: *No impact likely.*

Movement:
The kit fox is mostly nocturnal, but can be active in the daytime during cool weather. Home ranges of approximately one to twelve square miles have been reported. Development has significantly degraded movement and dispersal corridors for young kit foxes. Juvenile survival and successful dispersal has been declining in recent years. Three occurrences of kit fox movement have been documented between the Salinas-Pajaro region and the Carrizo Plain Natural Area. Although the total movement of kit foxes between these areas is unknown, land development along the natural movement corridors between Carrizo Plain and the Salinas Valley, as well as development within Salinas Valley has probably reduced immigration of kit foxes into the Salinas Valley, possibly contributing to their decline.

Arundo impacts: *Dense Arundo stands may inhibit movement to new areas as kit foxes prefer open areas. Riparian corridors are extremely important for movement of wildlife. Foxes may use roads as alternate corridors if riparian zones are overly vegetated (Arundo), leading to increased mortality from vehicles. Arundo is not abundant enough on the upper Salinas to significantly discourage use of riparian habitat as a corridor- but migration and use of riparian habitat downstream (north) in Salinas valley could be reduced by Arundo, particularly below King City where Arundo cover is very high.*

Status/Distribution or Historic and Current Range:
In the San Joaquin Valley before 1930, the range of the San Joaquin kit fox is believed to have extended from southern Kern County north to Contra Costa County on the west side and near La Grange, Stanislaus County, on the east side. Until the 1990s, Tracy was the farthest northwest record, but now there are records from the Antioch area of Contra Costa County. By 1930, the kit fox range had been reduced by more than half, with the largest portion remaining in the southern and western parts of the Valley. By 1958, an estimated 50% of the Valley's original natural communities had been lost, due to extensive land conversions, intensive land uses, and the use of pesticides. In 1979, only about 6.7% of the San Joaquin Valley's original wildlands south of Stanislaus County remained untilled and undeveloped. Today many of these communities are represented only by small, degraded remnants. Kit foxes are, however, found in grassland and scrubland communities, which have been extensively modified by humans with oil exploration, wind turbines, agricultural practices and/or grazing. The kit fox population is fragmented, particularly in the northern part of the range.

Arundo impacts: *Arundo and foxes co-occur in the Salinas watershed (Appendix B).*

Decline and Threats:
Kit foxes are subject to competitive exclusion or predation by other species, such as the nonnative red fox, coyote, domestic dog, bobcat, and large raptors. Loss and degradation of habitat by agricultural, industrial, and urban developments and associated practices continue, decreasing the carrying capacity of remaining habitat and threatening kit fox survival. Such losses contribute to kit fox declines through displacement, direct and indirect mortalities, barriers to movement, and reduction of prey populations.

Overall impact metric for *Arundo* on the San Joaquin kit fox:
Extremely low/improbable, score of 1. If high quality habitat was identified north of Salinas range where Salinas River could serve as a corridor, then Impact score should be increased.

Interaction of *Arundo* distribution and the San Joaquin kit fox occurrence is presented by watershed in Table 7-3 and Appendix B.

Sources:
Programmatic Biological Opinion for the United States Army, San Francisco District Corps of Engineers' permit pursuant to 404 of the Clean Water Act for Monterey County Water Resources Agency regional General Permit for the Salinas River Channel Maintenance Program; National Marine Fisheries Service, Southwest Region, Long Beach CA. July 2003.
Species Account SAN JOAQUIN KIT FOX (*Vulpes macrotis mutica)*, U.S. Fish & Wildlife Service, Sacramento Fish & Wildlife Office.

7.2.18 San Diego Ambrosia (*Ambrosia pumila*)

Federal status: Endangered, July 2 2002. Final critical habitat designated November 30 2010.
State status: None?
Arundo impact score: 7

General Ecological Needs/Habitat Affinities:
Ambrosia pumila is a perennial herb in the sunflower family (Asteraceae). It occurs primarily on upper terraces of rivers and drainages. Within these areas, the species is found in open grassland of native and nonnative plant species, and openings in coastal sage scrub, and primarily on sandy loam or clay soils. The species may also be found in ruderal habitat types (disturbed communities containing a mixture of

native and non-native grasses and forbs) such as fire fuel breaks and edges of dirt roadways. Non-native grassland and ruderal habitat types provide adequate habitat for *A. pumila*; however, non-native plants can out-compete *A. pumila* plants for resources in some situations. *Ambrosia pumila* consistently occurs in areas near waterways such as upper terraces of rivers or other water bodies. These areas do not necessarily provide high levels of soil moisture, and *A. pumila* is adapted to dry conditions. *A. pumila* may require periodic flooding for some segment of its life cycle. Additionally, areas subject to periodic flooding may be less amenable to competing non-native and native plants. *A. pumila* is a clonal herbaceous perennial plant that spreads vegetatively by means of slender, branched, underground root like rhizomes from which new aboveground stems (aerial stems or ramets) arise each year. Aerial stems of *Ambrosia pumila* sprout from their underground rhizomes in early spring after winter rains, and flower between May and October. However, aerial stems have been observed sprouting under dry conditions in late fall. The aerial stems senesce after the growing season, leaving the rhizome system in place from which new aerial stems may sprout when environmental conditions are appropriate. Little is known about its reproductive system, but it is presumed to be wind-pollinated. It is thought to have limited sexual reproductive output due to low production of viable seed. The dispersal strategy of *A. pumila* is unknown and the seeds lack structures that facilitate dispersal by wind or passing animals. It may depend on periodic flooding of nearby waterways for dispersal of seeds and rhizomes that can produce new aerial stems. The longevity of individual plants and of seeds, and the potential for buried seed banks to develop in the soil are unknown.

Arundo impacts: *Arundo and A. pumila overlap in range and in habitat. This creates the potential for direct competition and for impacts related to water use, fire and modification of geomorphic processes. These are slightly mitigated by the fact that ambrosia is present in the higher elevation portions of the riparian zone- higher terraces and transition/eco-tones with scrub and grass lands. Arundo debris may cover plants habitat. Arundo fires may result in take and or type conversion. Modified flood and sediment transport may decrease habitat fitness and interfere with seed dispersal of ambrosia.*

Status/Distribution or Historic and Current Range:
Ambrosia pumila is distributed in southern California from northwestern Riverside County, south through western San Diego County, to northwestern Estado de Baja California, Mexico. It is generally found at or below elevations of 487 m (1,600 ft) in Riverside County, and 183 m (600 ft) in San Diego County. At the time of listing, 15 native occurrences of *A. pumila* were considered extant in the United States: 3 in Riverside County and 12 in San Diego County (native is used here to differentiate these from occurrences derived from plants translocated to another site).

Arundo impacts: *Ambrosia is present on highly invaded watersheds, specifically San Diego and San Luis Rey (Appendix B). The strong overlap in range makes larger scale impacts to ambrosia relevant. On Santa Ana one population near Lake Elsinore appears to above the river and little Arundo is present up stream or nearby. The other Santa Ana population is historic (1940), but is near large Arundo infestations on the main river. If new populations were found there could be greater potential for impacts on Santa Ana.*

Decline and Threats:
Loss and degradation of *Ambrosia pumila* habitat is the result of development, non-native plants, fuel modification, altered hydrology and fragmentation. Development results in direct loss of habitat. Competition from non-native plants, primarily non-native grasses and forbs, pose a significant threat to the species throughout its range. No research has been done to clarify the specific effects of non-native plants on *Ambrosia pumila*, but a recent study by the Center for Natural Lands Management in San Diego County demonstrated that reduction of non-natives increased percent cover of *Ambrosia pumila.* Fuel modification activities that can negatively affect *Ambrosia pumila* include weed abatement, fire

suppression, and landscaping practices (including mowing, discing, and plowing). Altered hydrology has the potential to impact *Ambrosia pumila.* It almost always occurs on the upper terraces of rivers/streams or near the margins of vernal pools, where under natural conditions the plants would likely be subjected to inundation during large-scale flooding events. If *Ambrosia pumila* is dependent on these periodic flooding events for some aspect of its life history (e.g., seed germination, dispersal) or control of competing plants, altering the flooding regimes of associated waterways or vernal pools could have a significant impact on the species. However, it is unknown if and to what degree *Ambrosia pumila* is dependent upon periodic flooding or other aspects of its proximity to waterways.

Overall impact metric for *Arundo* on the San Diego ambrosia: High impact, score of 7.

Interaction of *Arundo* distribution and San Diego ambrosia occurrence is presented by watershed in Table 7-3 and Appendix B.

Sources:
Ambrosia pumila (San Diego ambrosia) 5 Year Review and Summary, US Fish and Wildlife Service, Carlsbad Office, CA, July 15 2010. http://ecos.fws.gov/docs/five_year_review/doc3557.pdf

7.2.19 Marsh Sandwort (*Arenaria paludicola*)

Federal status: Endangered, August 3, 1993. Critical habitat has not been designated.
State status: Endangered, February 1990.
Arundo impact score: 4

General Ecological Needs/Habitat Affinities:
Marsh sandwort is an herbaceous green perennial in the Caryophyllaceae family that is often supported by surrounding vegetation. The trailing stems often root at the nodes and can be up to 1 m long. The opposite leaves are lanceolate and narrowly sharp pointed with a solitary mid-vein. It blooms from May to August. Flowers are small, white and borne singly on long stalks. Marsh sandwort is found in freshwater marshes from elevations to about 1,476 ft (450 m) with saturated soils and acidic bog soils, predominantly sandy with high organic content. Vegetation around the Black Lake Canyon population includes emergent freshwater marsh species and some riparian woodland or wetland tree species, mainly willow and wax myrtle. The two existing populations of marsh sandwort in San Luis Obispo County are found in freshwater marshes located within a system of active to partly-stabilized sand dunes.

Arundo impacts: *Minor impacts on the upper Santa Ana to a very old historic sighting (1899).*

Status/Distribution or Historic and Current Range:
Historically it has been collected by botanists from scattered locations near the Pacific coast in southern and central California and Washington. Only two of California's seven historical populations are known to exist today, near the southern San Luis Obispo County coast at Black Lake Canyon on Nipomo Mesa and at Oso Flaco Lake further south.

Arundo impacts: *Only one historic signing on Santa Ana River (Appendix B).*

Decline and Threats:
Immediate threats to the survival of marsh sandwort include habitat destruction, habitat degradation, and competition with non-native species for light, nutrients and space.

Arundo impacts: *Arundo would be a stressor and competitor if it were re-discovered on the Santa Ana River.*

Overall impact metric for *Arundo* on the marsh sandwort: Low/moderate impact, score of 4.

Interaction of *Arundo* distribution and marsh sandwort occurrence is presented by watershed in Table 7-3 and Appendix B.

Sources:

Recovery Plant for marsh sandwort (*Arenaria paludicola*) and Gambel's watercress (*Rorippa gambelii*). U.S. Fish and Wildlife Service, Portland, Oregon, 1998.

7.2.20 San Jacinto Valley Crownscale (*Atriplex coronata* var. *notatior*)

Federal status: Endangered, October 1998. Critical habitat has not been designated.
State status: none
Arundo impact score: 7

General Ecological Needs/Habitat Affinities:
San Jacinto Valley crownscale is an annual plant in the goosefoot family (Chenopodiaceae). It grows 4 to 12 inches (30.5 cm) tall with grayish colored leaves. The plant generally flowers in April and May. This bushy plant can have one or several gray-green stems, which turn deep yellow as it grows older and dies. San Jacinto Valley crownscale is restricted to highly alkaline and silty-clay soils. These soils are found in certain alkali sink scrub, alkali playa, vernal pool, and annual alkali grassland habitats. Habitat for San Jacinto Valley crownscale is typically flooded during winter rains and the plant emerges as waters recede in the spring.

Arundo impacts: *Crownscale does occur in wash areas/floodplain on Alberhill Creek north of Lake Elsinore, where significant Arundo stands also occur. Therefore the two species interact and compete with each other for resources and space.*

Status/Distribution or Historic and Current Range:
San Jacinto Valley crownscale has a narrow range of distribution and is only known to occur in western Riverside County. Within western Riverside County, there are four general population centers of the plant – in the floodplain of the San Jacinto River at the San Jacinto Wildlife Area/Mystic Lake; in the San Jacinto River floodplain between the Ramona Expressway and Railroad Canyon Reservoir; in the Upper Salt Creek Vernal Pool Complex in the west Hemet area; and in the floodplain of Alberhill Creek north of Lake Elsinore. The San Jacinto Valley crownscale experienced a severe decline between 1992 and 1999, when it lost 70 % of its population; it continues to decline today. Because floodwaters carry crownscale seeds over long distances, population ranges may shift from year to year.

Arundo impacts: *As shown in Appendix B Arundo and San Jacinto Valley crownscale overlap in range. Closer examination of polygon data shows clear co-occurrence within the riparian areas.*

Decline and Threats:
The San Jacinto Valley crownscale is in particular danger from increased urbanization because its habitat is nearly flat and therefore easy to develop. It is also threatened by habitat fragmentation, agricultural weed-control measures where its habitat is repeatedly disked, off-road vehicle use, alteration of hydrology, deliberate manure and sludge dumping, trampling by livestock, and competition from nonnative species.

Arundo impacts: *The sites have all of these impacts: agricultural use, urban use, water management facilities. Arundo adds to the population's stress by directly competing against it. Arundo is also dense enough to add biomass debris over crownscale habitat following flood events. Fire could also impact habitat and sedimentation. Of added concern is response to fire and flood events that are of greater magnitude due to high Arundo cover. The area has heavy infrastructure (roads, water transfer, levees, agriculture use, etc.) that would likely lead to damaging emergency actions in response to events.*

Overall impact metric for *Arundo* on the San Jacinto Valley crownscale: High Impact, score of 7.

Interaction of *Arundo* distribution and San Jacinto Valley crownscale occurrence is presented by watershed in Table 7-3 and Appendix B.

Sources:

Species Profile for San Jacinto Valley crownscale (*Atriplex coronata notatior*), U.S. Fish and Wildlife Service, http://ecos.fws.gov/speciesProfile/profile/speciesProfile.action?spcode=Q2ZR

7.2.21 Nevin's Barberry (*Berberis nevinii)*

Federal status: Endangered, October 13, 1998. Critical habitat designated on February 13 2008.
State status: Endangered, January 1987.
Arundo impact score: 4

General Ecological Needs/Habitat Affinities:

Nevin's barberry is a large rounded shrubby member of the barberry family (Berberidaceae) that grows up to 13 ft (4 m) tall, with blue-green, spiny pinnate leaves. It is widely cultivated and popular in xeric gardens, in part for its bright red edible berries and bright yellow flowers that bloom March through April. Nevin's barberry generally grows within sandy, gravelly soil, on north facing slopes or low gradient washes. 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. In general, the plant occurs from 800-5200 ft (1,585 m) above sea level, with local distribution potentially related to the presence of groundwater. Associated plant communities are alluvial scrub, riparian scrub or woodland, coastal sage scrub, chaparral, and/or oak woodland.

Arundo impacts: *Arundo occurs within population ranges of barberry when plants are located within low gradient washes. These are not usually areas where Arundo becomes overly abundant, but it be locally abundant. Direct competition between plants as sites could occur. Abiotic impacts are unlikely due to limited extent of Arundo upstream of washes where barberry occurs.*

Status/Distribution or Historic and Current Range:

The distribution of Nevin's barberry is scattered, with populations located throughout southern California in Los Angeles, Riverside, and San Bernardino counties. There have been a total of 34 occurrences of *Berberis nevinii* reported in southern California, five of which have been or are presumed extirpated and 7 considered to have been introduced. Total number of individuals is estimated at 500, with approximately half of those as naturally occurring individuals. In addition, the majority of occurrences are comprised of only one to few individuals, with little to no reproduction observed.

Arundo impacts: *Arundo and barberry co-occur in Santa Clara (Arundo is scattered to dense), and several area on the Los Angeles and San Gabriel Rivers (Arundo is scattered, Appendix B).*

Decline and Threats:
Population decline is likely related to low fecundity and habitat loss. 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. While population sizes vary considerably among extant groups, the majority of occurrences are comprised of only one to a few individuals, with little to no reproduction observed. Most of the historic habitat of Nevin's barberry has been eliminated by agriculture, urban development, and flood control and stream channelization.

Overall impact metric for *Arundo* on the Nevin's barberry: Low/moderate impact, score of 4.

Interaction of *Arundo* distribution and Nevin's barberry occurrence is presented by watershed in Table 7-3 and distribution is shown in Appendix B.

Sources:
Stillwater Sciences. 2007. Focal Species Analysis and Habitat Characterization for the Lower Santa Clara River and Major Tributaries, Ventura County, California. Santa Clara River Parkway Floodplain Restoration Feasibility Study.
Center for Plant Conservation, National Collection Plant Profile for Nevin's Barberry, http://www.centerforplantconservation.org/collection/cpc_viewprofile.asp?CPCNum=2777

7.2.22 Spreading Navarretia (*Navarretia fossalis*)

Federal status:	Threatened, October 13 1998. Critical habitat: October 18 2005. A proposal for revised critical habitat was initiated on June 10 2009.
State status:	None
Arundo impact score:	6

General Ecological Needs/Habitat Affinities:
Spreading navarretia is an annual plant in the Polemoniaceae (phlox family). It is a low, mostly spreading or ascending plant 4 - 6 inches (10 - 15 cm) tall. The leaves are long and finely divided into slender spine-tipped lobes and the lavender-white flowers are arranged in flat-topped, compact, leafy heads. Each seed is covered by a layer that becomes sticky and viscous when the capsule is moistened. Spreading navarretia is typically found in vernal pool (seasonal depression wetlands) habitat, particularly in Los Angeles and San Diego Counties. In western Riverside County, however, *Navarettia fossalis* is associated with seasonally flooded alkali vernal plain habitat that includes alkali playa (highly alkaline, poorly drained), alkali scrub, alkali vernal pool, and alkali annual grassland components. *Navarretia fossalis* depends on the inundation and drying cycles of its habitat for survival. It germinates from seeds left in the seed bank. Most *Navarretia* species have indehiscent fruit, or fruit with fibers that absorb water and expand to break open the fruit after a substantial rain. The timing of germination is important so that the plant germinates under favorable conditions in the spring rather than the summer, autumn, or winter. *Navarretia fossalis* abundance also varies from year to year depending on precipitation and the inundation/drying time of the vernal pool. The occurrences of plants can also vary spatially in alkali playa habitat where pools are not in the same place from year to year. After germination, the plant usually flowers in May and June as the vernal pool is devoid of water. The plant then produces fruit, dries out, and senesces in the hot, dry summer months.

Arundo impacts: *Although navarretia habitat sounds restrictive Arundo co-occurs with the Riverside San Jacinto Valley navarretia population (Appendix B). This area is a broad floodplain and is the same area where San Jacinto crownscale is found. This area has a narrow river thread heavily invaded with*

Arundo bordered by flat floodplains. Impacts described in the crownscale section ally to this species as well (risk of fire, Arundo debris, flood damage and 'emergency actions' to repair and protect infrastructure.

Status/Distribution or Historic and Current Range:
Spreading navarretia extends from northwestern Los Angeles County to western Riverside County, and coastal San Diego County in California, to San Quintin in northwestern Baja California, Mexico.

Arundo impacts this by: *As noted these species co-occur in San Jacinto Valley (Appendix B).Populations of navarretia that occur in San Diego County watersheds typically occur in vernal pools where Arundo is not present. The Santa Clara navarretia population also occurs in a vernal pool.*

Decline and Threats:
Threats include agriculture, fragmentation, grazing and urbanization.

Overall impact metric for *Arundo* on spreading navarretia: Moderate/high Impact, score of 6.

Interaction of *Arundo* distribution and spreading navarretia occurrence is presented by watershed in Table 7-3.

Sources:
Center for Plant Conservation, National Collection Plant Profile for spreading navarretia, http://www.centerforplantconservation.org/collection/CPC_ViewProfile.asp?CPCNum=2930
5-Year Review for spreading navarretia (*Navarretia fossalis*) U.S. Fish and Wildlife Service, http://ecos.fws.gov/docs/five_year_review/doc2574.pdf

Table 7-3. Examination of *Arundo* impacts on federally listed species by watershed.
'*Arundo* impact rank' and 'overlap rank' (potential for interaction between *Arundo* and listed species distribution and abundance) for each species. The cumulative impact score is in Table 7-4.

Category	Federal Listing[1]	Scientific name	Common name	*Arundo* Impact	Tijuana Estuary	Otay	Sweet-water	S.Diego/ Penasquitos	San Dieguito	Carlsbad	San Luis Rey	Santa Margarita	San Juan	San Francisquito Crk/ Newport	Santa Ana	L.A./ San Gabriel/ Santa Monica	Calleguas	Santa Clara	Ventura	S.Barbara, SouthCoast &S.Ynez	Estero Bay	Salinas	S.Cruz/ Benito	Count
Amphibian	En	*Ambystoma californiense*	California tiger salamander[2]	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	3	2
Amphibian	En	*Bufo californicus*	Arroyo toad	10	-	-	5	3	7	-	10	10	7	7	-	3	-	4	-	-	-	2	-	10
Amphibian	Th	*Rana aurora draytonii*	California red-legged frog	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8	2	5	2	3	5
Amphibian	En	*Rana muscosa*	Mountain yellow-legged frog	4	-	-	-	-	-	-	-	-	-	-	4	6	-	-	-	-	-	-	-	2
Bird	Th	*Charadrius alexandrinus nivosus*	Western snowy plover	5	1	1	1	6	-	8	-	9	-	-	0	4	0	1	-	1	-	-	-	9
Bird	Sp of Concern	*Coccyzus americanus occidentalis*	Western yellow-billed cuckoo	7	-	-	1	-	-	-	-	1	0	-	7	-	-	4	-	-	1	-	-	5
Bird	En	*Empidonax traillii extimus*	Southwestern willow flycatcher	8	-	-	2	2	3	2	10	10	3	-	6	1	-	2	-	2	-	-	-	11
Bird	Sp of Concern	*Passerculus sandwichensis beldingi*	Belding's savannah sparrow	2	3	3	3	3	3	3	-	-	-	2	2	2	6	-	-	2	-	-	-	11
Bird	Th	*Polioptila californica californica*	Coastal California gnatcatcher	2	3	3	3	3	3	3	4	4	3	4	4	2	2	1	-	-	-	-	-	14
Bird	En	*Rallus longirostris levipes*	Light-footed clapper rail	3	2	2	3	2	2	4	2	3	-	2	-	-	1	-	-	1	-	-	-	11
Bird	En	*Sterna antillarum browni*	California least tern	4	-	1	-	3	2	4	-	7	-	1	-	1	-	1	-	-	-	-	-	8
Bird	En	*Vireo bellii pusillus*	Least Bell's vireo	9	4	4	4	4	4	3	9	10	6	6	10	4	3	3	3	1	-	-	-	14
Fish	En	*Eucyclogobius newberryi*	Tidewater goby	7	-	-	-	-	-	4	8[a]	8[a]	-	-	-	-	3	6[a]	8	5	3	4	1	7
Fish	En	*Gasterosteus aculeatus williamsoni*	Unarmored three spine stickleback	8	-	-	-	-	-	-	-	-	-	-	-	-	-	8	-	-	-	-	-	1
Fish	En&Th[3]	*Oncorhynchus mykiss*	Steelhead	7	-	-	-	-	-	-	1	-	1	-	-	4	-	8	8	7	5	8	5	9
Fish	Th	*Catostomus santaanae*	Santa Ana sucker	6	-	-	-	-	-	-	-	-	-	-	9	7	-	4	-	-	-	-	-	3
Mammal	En	*Vulpes macrotis mutica*	San Joaquin kit fox	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	1
Plant	En	*Ambrosia pumila*	San Diego ambrosia	7	-	2	-	-	7	-	7	-	-	-	2	-	-	-	-	-	-	-	-	4
Plant	En	*Arenaria paludicola*	Marsh sandwort	4	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	1
Plant	En	*Atriplex coronata var. notatior*	San Jacinto Valley crownscale	7	-	-	-	-	-	-	-	-	-	-	10	-	-	-	-	-	-	-	-	0
Plant	En	*Berberis nevinii*	Nevin's Barberry	4	-	-	-	-	-	-	-	-	-	-	-	5	-	3	-	-	-	-	-	2
Plant	Th	*Navarretia fossalis*	Spreading navarretia	6	-	-	-	-	-	-	-	-	-	-	10	-	-	1	-	-	-	-	-	1

[1] En = Endangered, Th = Threatened, Sp of Concern = Species of Concern
[2] Santa Barbara Distinct Population Segment (DPS)
[3] Southern California (DPS) is endangered, South-Central California Coast DPS is threatened.
[a] Recent historic 1990s/2000

Table 7-4. Cumulative impact scores for *Arundo* impacts on threatened and endangered species by watershed.
The cumulative impact score is calculated by multiplying the *Arundo* impact rank by overlap rank. Impact scores are for each watershed and species, and are totaled for each watershed and species.

Category	Federal Listing[1]	Scientific name	Common name	Tijuana Estuary	Otay	Sweet-water	S.Diego/ Penasquitos	San Dieguito	Carlsbad	San Luis Rey	Santa Margarita	San Juan	San Francisquito Crk/ Newport	Santa Ana	L.A./ San Gabriel/ Santa Monica	Calleguas	Santa Clara	Ventura	S.Barbara, SouthCoast &S.Ynez	Estero Bay	Salinas	S.Cruz/ Benito	Total
Amphibian	En	*Ambystoma californiense*	California tiger salamander[2]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	3	**6**
Amphibian	En	*Bufo californicus*	Arroyo toad	-	-	50	30	70	-	100	100	70	70	-	30	-	40	-	-	-	20	-	**580**
Amphibian	Th	*Rana aurora draytonii*	California red-legged frog	-	-	-	-	-	-	-	-	-	-	-	-	-	-	24	6	15	6	9	**60**
Amphibian	En	*Rana muscosa*	Mountain yellow-legged frog	-	-	-	-	-	-	-	-	-	-	16	24	-	-	-	-	-	-	-	**40**
Bird	Th	*Charadrius alexandrinus nivosus*	Western snowy plover	5	5	5	30	-	40	-	45	-	-	-	20	-	5	-	5	-	-	-	**160**
Bird	Sp of Concern	*Coccyzus americanus occidentalis*	Western yellow-billed cuckoo	-	-	7	-	-	-	-	7	-	-	49	-	-	28	-	-	7	-	-	**98**
Bird	En	*Empidonax traillii extimus*	Southwestern willow flycatcher	-	-	16	16	24	16	80	80	24	-	48	8	-	16	-	16	-	-	-	**344**
Bird	Sp of Concern	*Passerculus sandwichensis beldingi*	Belding's savannah sparrow	6	6	6	6	6	6	-	-	-	4	4	4	12	-	-	4	-	-	-	**64**
Bird	Th	*Polioptila californica californica*	Coastal California gnatcatcher	6	6	6	6	6	6	8	8	6	8	8	4	4	2	-	-	-	-	-	**84**
Bird	En	*Rallus longirostris levipes*	Light-footed clapper rail	6	6	9	6	6	12	6	9	-	6	-	-	3	-	-	3	-	-	-	**72**
Bird	En	*Sterna antillarum browni*	California least tern	-	4	-	4	8	16	-	28	-	4	-	4	-	4	-	-	-	-	-	**72**
Bird	En	*Vireo bellii pusillus*	Least Bell's vireo	36	36	36	36	36	27	81	90	54	54	90	36	27	27	27	9	-	-	-	**702**
Fish	En	*Eucyclogobius newberryi*	Tidewater goby	-	-	-	-	-	-	56	56	-	-	-	-	21	42	-	35	21	28	7	**266**
Fish	En	*Gasterosteus aculeatus williamsoni*	Unarmored three spine stickleback	-	-	-	-	-	-	-	-	-	-	-	-	-	64	-	-	-	-	-	**64**
Fish	En&Th[3]	*Oncorhynchus mykiss*	Steelhead	-	-	-	-	-	-	7	-	7	-	-	28	-	56	56	49	35	56	35	**329**
Fish	Th	*Catostomus santaanae*	Santa Ana sucker	-	-	-	-	-	-	-	-	-	-	54	42	-	24	-	-	-	-	-	**120**
Mammal	En	*Vulpes macrotis mutica*	San Joaquin kit fox	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	**2**
Plant	En	*Ambrosia pumila*	San Diego ambrosia	0	14	-	-	49	-	49	-	-	-	14	-	-	-	-	-	-	-	-	**126**
Plant	En	*Arenaria paludicola*	Marsh sandwort	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	**4**
Plant	En	*Atriplex coronata var. notatior*	San Jacinto Valley crownscale	-	-	-	-	-	-	-	-	-	-	70	-	-	-	-	-	-	-	-	**70**
Plant	En	*Berberis nevinii*	Nevin's Barberry	-	-	-	-	-	-	-	-	-	-	-	20	-	12	-	-	-	-	-	**32**
Plant	Th	*Navarretia fossalis*	Spreading navarretia	-	-	-	-	-	-	-	-	-	-	60	-	-	6	-	-	-	-	-	**66**
			Total:	**59**	**77**	**135**	**134**	**205**	**123**	**387**	**423**	**161**	**146**	**417**	**220**	**67**	**326**	**107**	**127**	**78**	**115**	**54**	**3,361**

[1] En = Endangered, Th = Threatened, Sp of Concern = Species of Concern
[2] Santa Barbara Distinct Population Segment
[3] Southern California Distinct Population Segment (DPS) is endangered, South-Central California coast DPS is threatened.

Table 7-5. Cumulative *Arundo* impact score for each species for all watersheds combined, and sum and average for each taxa group.

Category	Federal Listing[1]	Scientific name	Common name	Cumulative Impact Score for all watersheds	Summary for Taxa Group
Amphibian	En	*Ambystoma californiense*	California tiger salamander[2]	6	Sum – 686 Ave – 171.5
Amphibian	En	*Bufo californicus*	Arroyo toad	580	
Amphibian	Th	*Rana aurora draytonii*	California red-legged frog	60	
Amphibian	En	*Rana muscosa*	Mountain yellow-legged frog	40	
Bird	Th	*Charadrius alexandrinus nivosus*	Western snowy plover	160	Sum – 1,596 Ave – 199.5
Bird	Sp of Concern	*Coccyzus americanus occidentalis*	Western yellow-billed cuckoo	98	
Bird	En	*Empidonax traillii extimus*	Southwestern willow flycatcher	344	
Bird	Sp of Concern	*Passerculus sandwichensis beldingi*	Belding's savannah sparrow	64	
Bird	Th	*Polioptila californica californica*	Coastal California gnatcatcher	84	
Bird	En	*Rallus longirostris levipes*	Light-footed clapper rail	72	
Bird	En	*Sterna antillarum browni*	California least tern	72	
Bird	En	*Vireo bellii pusillus*	Least Bell's vireo	702	
Fish	En	*Eucyclogobius newberryi*	Tidewater goby	266	Sum – 779 Ave – 194.8
Fish	En	*Gasterosteus aculeatus williamsoni*	Unarmored three spine stickleback	64	
Fish	En&Th[3]	*Oncorhynchus mykiss*	Steelhead	329	
Fish	Th	*Catostomus santaanae*	Santa Ana sucker	120	
Mammal	En	*Vulpes macrotis mutica*	San Joaquin kit fox	2	2
Plant	En	*Ambrosia pumila*	San Diego ambrosia	126	Sum – 298 Ave – 59.6
Plant	En	*Arenaria paludicola*	Marsh sandwort	4	
Plant	En	*Atriplex coronata var. notatior*	San Jacinto Valley crownscale	70	
Plant	En	*Berberis nevinii*	Nevin's Barberry	32	
Plant	Th	*Navarretia fossalis*	Spreading navarretia	66	
			Total:	**3,361**	

7.3 Results

7.3.1 Summary by Species and Group

7.3.1.1 Impact Scores

Within the study area, 22 federally protected species were found to be impacted at some level by the presence of *Arundo*. The magnitude of the impact score ranged from 10 (very severe) to 1 (very low/improbable) (Table 7-3). Five taxonomic groups are represented: amphibian, avian, fish, mammal, and plant. All groups have a minimum of four species with the exception of mammal, which had one.

Amphibians had the widest range of *Arundo* impact scores among the groups. Arroyo toads had severe impacts from *Arundo*, both abiotic and biotic. The other amphibian species (California tiger salamander, California red-legged frog, and mountain yellow-legged frog) were less impacted due to greater habitat use in foothills and mountains where *Arundo* is less abundant. In these areas, *Arundo* is less likely to directly impact the species or to generate enough biomass to degrade habitat significantly.

Avian species fell into two general classes based on the habitat they use. Species that use riparian habitat had impact scores that ranged from high (7) to severe (9), reflecting both abiotic and biotic impacts. This included the least Bell's vireo, southwestern willow flycatcher and yellow-billed cuckoo. Species that use estuary and beach areas were also impacted by *Arundo*, usually as a function of biomass accumulating in habitat areas (discharged from upstream riparian areas), but also to a lesser degree from *Arundo* growing in estuaries and on beaches. Avian species that use beach and estuary habitat had impact scores ranging from moderate (5) to very low (2), reflecting *Arundo* impacts on breeding and predation. In addition to these two classes, the gnatcatcher had a low impact score (2), because it does not breed or feed exclusively in riparian habitat. Avian species were also, as a group, susceptible to physical changes in habitat structure, encouraging predators that use *Arundo* as perches and/or dense cover for denning.

Fish species had fairly uniform impacts from *Arundo* related to modification of abiotic processes that control geomorphology and hydrology. Modification of channel form and depth is a significant change to habitat structure. *Arundo* biomass and shading also have possible effects on habitat quality. Fish habitat varies depending on the species. It may occur only near the river mouth (tidewater goby), reside along river/stream corridors (Santa Ana sucker, stickleback), or pass through the main river corridor to headwaters that are relatively uninvaded by *Arundo* (southern steelhead). Southern steelhead also reside for part of their life-cycle in estuaries. *Arundo* impact scores ranged from very high (8) to moderate/high (6).

The only federally listed mammal species examined was the San Joaquin kit fox, which resides in the northern part of the study area. It has a very low/improbable (1) impact score from *Arundo*. The kit fox does not utilize riparian habitat frequently, and is not dependent on it. It may use riparian areas as corridors for movement.

Water use, fire, biomass and modification of geomorphology are the primary *Arundo* impacts on the five plant species examined. Four of the plant species occur on upper portions of the riparian zone (San Diego ambrosia and Nevin's barberry) or broad areas within the floodplain (San Jacinto crownscale and spreading navarretia). These four species have *Arundo* impact scores ranging from high (7) to low/moderate (4). San Jacinto crownscale and spreading navarretia occur at a single location within the San Jacinto/Santa Ana watershed, so it is possible to look at very specific interactions for these two species. The fifth plant species, marsh sandwort, occurs in inland freshwater marsh. It is a historic occurrence, so *Arundo* impacts were projected to the species' habitat preferences. Although it is

unlikely that marsh sandwort still occurs at this location, *Arundo* is having abiotic and biotic impacts that degrade habitat characteristics favored by the plant.

7.3.1.2 Overlap or Spatial Interaction Scores

Overlap rank scores are given in Table 7-3. These were generated by interpreting distribution maps of *Arundo* and each listed species. Species occurring in downstream portions of the watersheds (river mouth, estuaries, beaches) can receive high scores if significant *Arundo* infestations occur upstream. Scores ranged from 1 (no interaction) to 10 (very high interaction).

Overlap scores captured the interaction between *Arundo* and each species' distribution and abundance. Avian species were the widest ranging, with high numbers of watersheds recording occurrences, particularly in the southern and middle of the study area. Fish species also had large numbers of watersheds with occurrences, but more in the middle and northern portions of the study area. Plants were the most restricted, each species typically occurring on only one or two watersheds.

7.3.1.3 Cumulative Impact Scores

The *Arundo* impact score is multiplied by the overlap score to generate a cumulative impact score for each species in each watershed. This metric highlights watersheds, species and taxa groups that are under the most significant pressure from *Arundo*. The avian group is the most impacted by *Arundo*, with a score of 1,596 (199.5 average). This is followed closely by amphibians at 686 (171.5 average). The plant group has the lowest score at 298 (59.6 average), largely due to very limited population ranges for the listed species. Mammals also rank very low, being represented by a single species with low abundance and low impacts from *Arundo*.

Several species stand out as having severe cumulative *Arundo* impact scores across the study area (Figure 7-1). The highest scoring species in the 'severe' category are the least Bell's vireo (702) and the arroyo toad (580). The southwestern willow flycatcher has a 'very high' cumulative impact score of 344. The three species are frequently cited as being under significant pressure from *Arundo* within their ranges. These data strongly supports these accounts.

The cumulative impact scores for the fish are 'very high' for two species (steelhead and tidewater goby), 'high' for the third (Santa Ana sucker) and 'moderate' for the fourth species (unarmored three spine stickleback). *Arundo* impacts on fish have not been recognized in the literature or explored in detailed studies. *Arundo*'s influence on abiotic processes indicates that significant impacts and degradation are likely occurring on heavily *Arundo* invaded watersheds.

The 'high' score for the western snowy plover (160) and the tidewater goby (266), and to a lesser degree the California least tern (72), demonstrate that estuaries, beaches and river mouth areas that support these listed species are impacted by *Arundo* on a number of watersheds within the study area. This has been alluded to in numerous studies and it appears to be a valid area of concern. *Arundo* not only degrades riparian habitat, but it also impacts estuaries and beaches, both of which are wetlands of high value and diversity.

Watershed totals for cumulative *Arundo* impact scores clearly demonstrate that those highly-invaded larger watersheds have the most severe impacts to federally listed species (Santa Margarita = 423, Santa Ana = 417, San Luis Rey = 387 and Santa Clara = 326) (Figure 7-2). The Salinas River is the exception, likely due to its more northern position and its lower diversity and abundance of federally listed species. The next tier of highly-impacted watersheds is well separated from the higher tier with scores of 220 for Los Angeles./San Gabriel/Santa Monica and 205 for San Dieguito. The moderate impact tier includes

eight watersheds whose cumulative *Arundo* impact scores range from 161 to 107 (Figure7-2). These include San Juan, San Francisquito/Newport, Sweetwater, San Diego, Ventura, Carlsbad, Santa Barbara, and Salinas. The low cumulative *Arundo* impact tier includes five watersheds whose values range from 78 to 54 (Figure 7-2).:Estero Bay, Otay, Calleguas, Tijuana, and Santa Cruz/Benito. The cumulative *Arundo* impact scores highlight watersheds with *Arundo* impacts to a number of federally listed species. Low ranking watersheds may still have a high cumulative impact for a single species, such as steelhead on the Ventura watershed.

7.3.2 Discussion

Arundo impact scores are very severe (10) to moderate/high (6) for 11 out of the 22 evaluated federally listed species. This indicates that *Arundo*'s modification of abiotic and biotic ecosystem processes is having significant impacts on a wide range of species:

Listed fish as a taxonomic group has high impact scores from *Arundo*. This has not been widely recognized in conservation biology. Listed avian species that fairly exclusively use riparian habitat (least Bell's vireo, southwestern willow flycatcher, yellow-billed cuckoo) had high impact scores and are recognized as being impacted by fires and habitat degradation. Arroyo toads appear to be severely impacted by *Arundo* invasion as they are dependent on geomorphic forms and hydrology that are severely degraded by *Arundo*. Listed plants also had significant impacts tied to specific sites where populations occur.

The cumulative impact scores, which account for the interaction in actual distributions of *Arundo* and the individual listed species, highlight particular species that are under significant pressure within the study area. Five species stand out: least Bell's vireo, arroyo toad, southwestern willow flycatcher, steelhead and tidewater goby. Arroyo toad, steelhead and tidewater goby have not been previously highlighted as species under significant pressure due to habitat and ecosystem modification by *Arundo*.

The impacts described to estuarine and beach avian species are an important extension of impacts to additional habitat types. These impacts typically rank as moderate to low, but they are well documented as pressures on breeding areas, as well as predation.

Prioritization of watersheds by impacts caused by *Arundo* to federally listed species is complicated. The larger watersheds clearly have the greatest impacts on federally listed species (Figure 7-2). These systems are heavily invaded and are having the most severe modification of abiotic and biotic processes, which is reflected in impact scores. It is interesting to note that three of the four systems also have the most active and comprehensive *Arundo* eradication programs. These systems have already been prioritized in terms of on the ground activity.

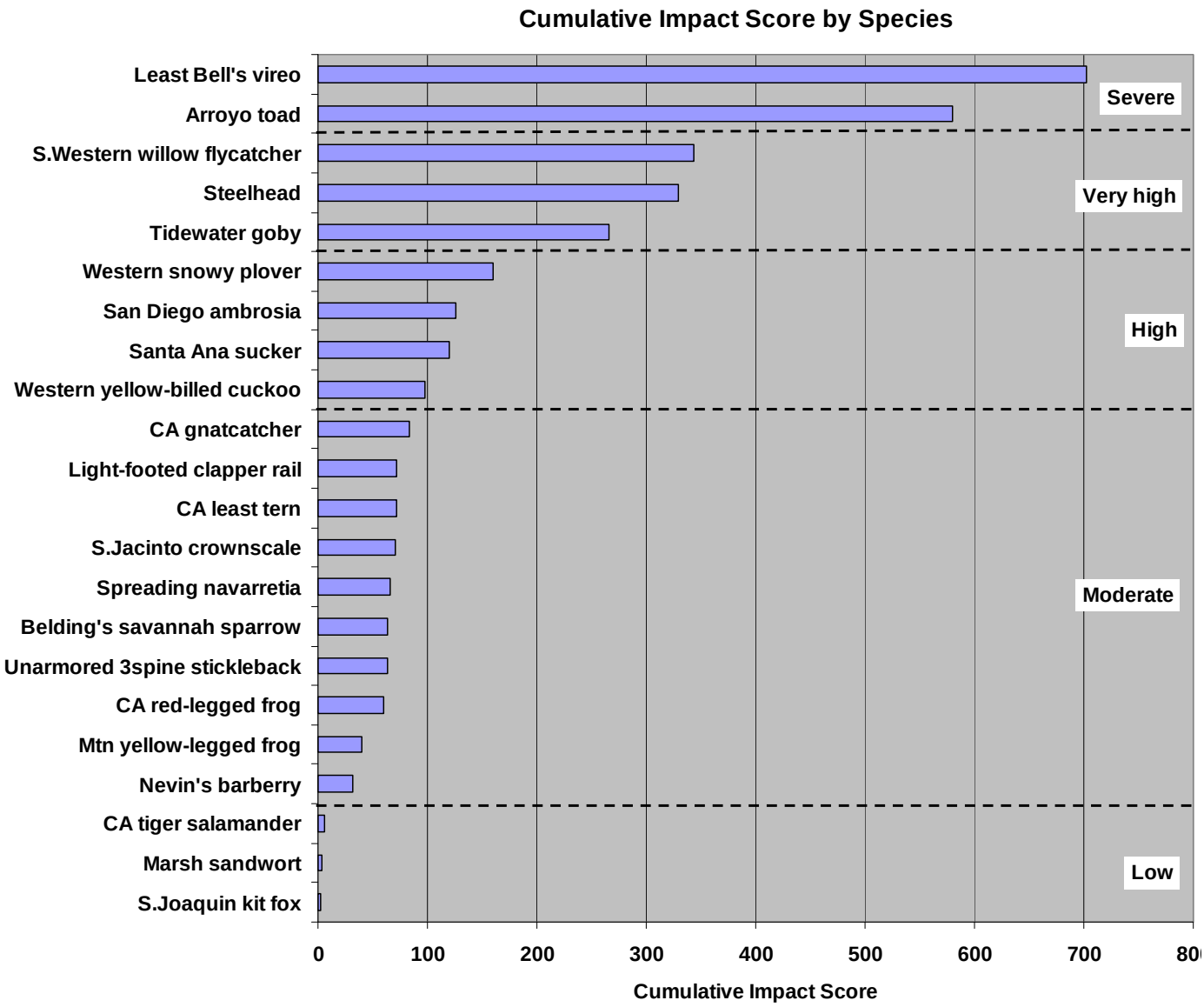


Figure 7-1. Cumulative *Arundo* impact score by species for all watersheds.

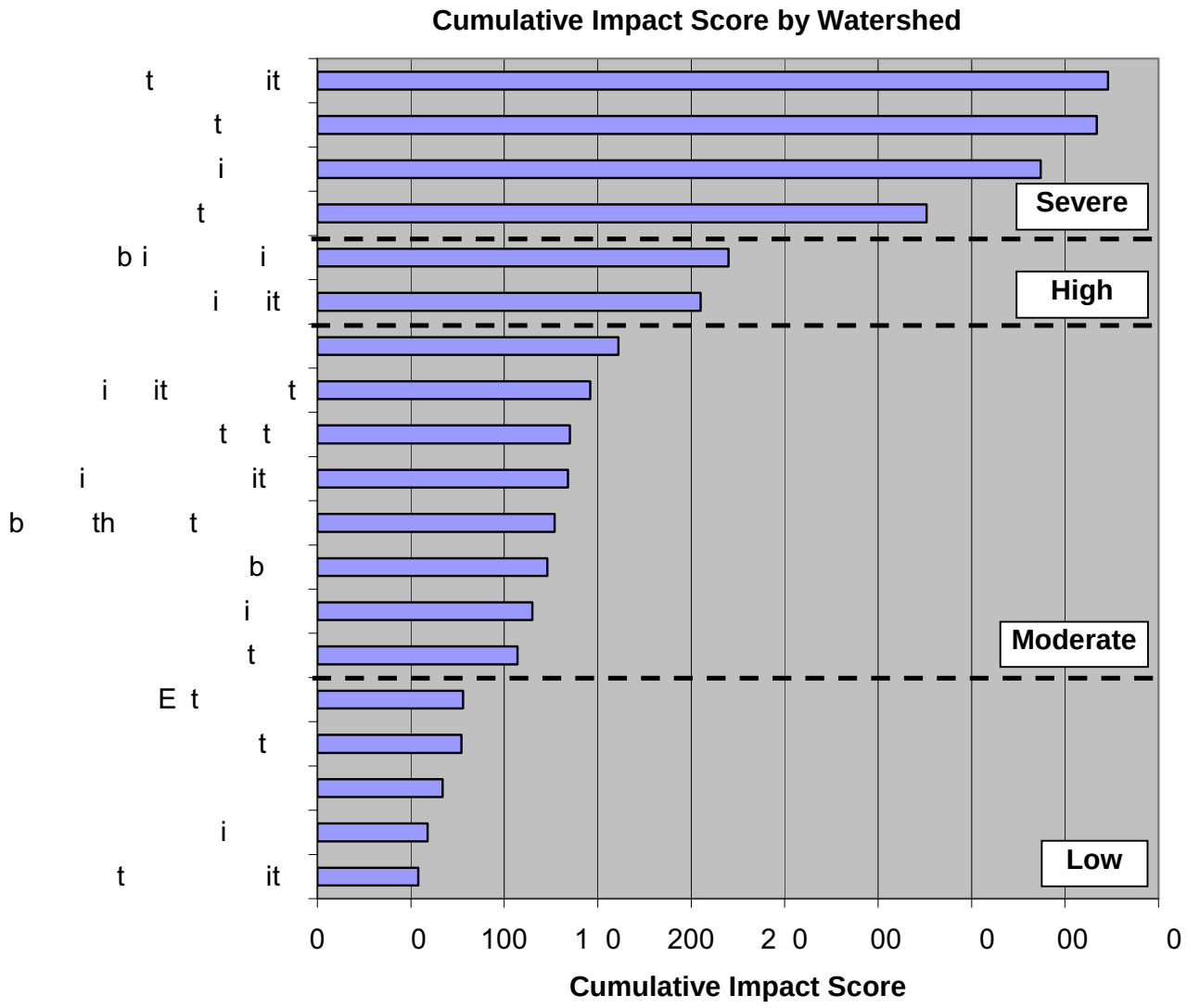


Figure 7-2. Cumulative *Arundo* impact scores by watershed for all federally listed species combined.

8.0 COST TO BENEFIT ANALYSIS

A cost-to-benefit analysis (CBA) is often used to evaluate the desirability of a given action or intervention. CBAs use a monetary valuation of costs and benefits, which are then expressed as a ratio. This allows the many impacts of an invasive species, such as *Arundo*, to be synthesized into a common measure, namely dollars. The results can then be used to show how much benefit is obtained by removing the species and where the most substantial benefits accrue. This in turn could help focus control efforts on watersheds or sites with the greatest potential benefit.

Multiple CBAs have examined the potential net economic benefit of programs to control *Arundo*. A detailed examination of benefits related to water savings on the Rio Grande River in Texas found a net benefit four to eight times greater than the cost (Seawright 2009). Broader CBAs covering multiple factors on watersheds within California have found benefit to cost ratios of 3.9:1 for the Santa Clara (Swezey 2008) and 1.1:1 for the Santa Margarita (Hastings et al. 1998). These CBAs were far less intensive analyses compared to the Seawright study. All CBAs for *Arundo* that could be found showed a positive benefit to cost ratio.

Completing a CBA for *Arundo* control is more straightforward than many that are completed for other types of environmental programs. This is due to reasonably well-defined impacts (potential benefits when *Arundo* is controlled) and applicable cost valuations. Impacts from *Arundo* within the study area have been quantified in this report using the mapped spatial distribution of *Arundo*. This information is used in this CBA, which applies to the entire study area. Cost and benefits are generated for both the peak *Arundo* distribution and current infestation level (which reflects control work over the past 15 years). A ten-year evaluation period was selected as many impacts are periodic in nature and control programs typically take many years to implement. This CBA is a rudimentary analysis and was not completed by an economist. Many complexities were excluded from the analysis including discounting and depreciation over time. As both the benefits and the costs are accrued on a similar timeline, this simplification is not likely to adversely affect the analysis. Also, unlike other CBA studies (such as Seawright 2009), this CBA did not project future increases in acreage of *Arundo* (increases the valuation of benefits in the future).

For this CBA, the costs of controlling *Arundo* will be evaluated, and then the benefits will be presented. This includes an analysis for each benefit (impact) class to clearly outline what approach was used in determining valuations. Results are then presented as a Benefit to Cost ratio to determine the net benefit or cost of controlling *Arundo* within the study area. The higher the benefit is in relation to the cost, the better the economic justification for the action.

8.1 Cost

Generating the cost of controlling *Arundo* for watersheds within the study area is straightforward. The spatial data set gives acreage for *Arundo* within each watershed, and therefore a good estimate of cost per acre for control is all that is needed. Over $70 million have already been spent controlling *Arundo* within the study area over the past 15 years. The approximate amount of money spent treating *Arundo* on each watershed is known as most programs share this information in news updates, proposals and other outreach material. For each watershed treated, acreage and cost of work completed is given in Table 8-1. This data is based on the author's knowledge of federal, state, and local funding of implementation programs, as well as information published by watershed programs. The average cost is $25,000 per acre of *Arundo* controlled. This is a strongly supported valuation based on over fifty projects within nine watersheds that have large implementation programs. This cost is subdivided into $5,000 for management and $20,000 for implementation, based on the author's knowledge of typical cost subdivisions in proposals and reports. Program management costs are high (management of

contractors, right of entry agreements, permitting, etc.) as are implementation costs (treatment, biomass reduction, re-vegetation, etc.). It is not surprising that *Arundo* control is an expensive undertaking given that *Arundo* stands have high biomass per acre, are difficult to control, and exist in sensitive habitat that is highly regulated. *Arundo* is also distributed across the landscape making program implementation complex and management intensive.

It should be noted that control costs vary substantially between watersheds and projects. This can be attributed to different treatment approaches, how biomass is dealt with, efficiency, and if re-vegetation is included in the project. The $25,000 average cost per acre for control is a well-supported cost estimate for watersheds taken as a whole, or for larger implementation projects. This estimate should not necessarily be used for site-specific projects, particularly if they are small.

The total cost of controlling all *Arundo* at the peak of its acreage would have been $196 million for 7,859 net acres (Table 8-2). A significant amount of control has already occurred, and the current cost of controlling *Arundo* at current distribution levels is $124 million for 4,997 net acres.

Table 8-1. Existing program costs used to generate cost basis for *Arundo* control by watershed within the study area.

Watershed	Treated net acres	Expenditure	Cost per acre
Calleguas	1.4	-	-
Carlsbad	98.7	1,500,000	15,201
Estero Bay	1.2	-	-
Los Angeles River	16.3	250,000	15,379
Otay	-	-	-
Pajaro River	-	-	-
Penasquitos	2.2	-	-
Pueblo San Diego	0.0	-	-
Salinas	106.4	500,000	4,700
San Diego	56.2	1,000,000	17,798
San Dieguito	89.8	1,500,000	16,701
San Gabriel River	0.0	-	-
San Juan	13.1	250,000	19,025
San Luis Rey	612.4	7,500,000	12,246
Santa Ana	1006.9	40,000,000	39,724
Santa Clara	0.3	-	-
Santa Margarita	684.7	10,000,000	14,605
Santa Monica Bay	0.3	-	-
Santa Ynez	-	-	-
South Coast	7.8	-	-
Sweetwater	5.7	-	-
Tijuana	41.1	1,500,000	36,496
Ventura River	117.4	7,500,000	63,909
TOTALS:	**2861.9**	**$71,500,000**	**$24,983**

Table 8-2. Estimated control costs by watershed within the study area for peak *Arundo* levels and current *Arundo* levels.

Watershed	PEAK Net Acres	Cost peak distribution			CURRENT Net Acres	Cost current infestation		
		Management: 5k	Implementation: 20k	Total		Management: 5k	Implementation: 20k	Total
Calleguas	229	1,145,750	4,583,000	5,728,750	228	1,138,539	4,554,155	5,692,693
Carlsbad	148	739,472	2,957,889	3,697,362	49	246,088	984,352	1,230,440
Estero Bay	10	48,828	195,310	244,138	9	42,953	171,811	214,764
Los Angeles	131	656,886	2,627,543	3,284,429	115	575,608	2,302,431	2,878,039
Otay	19	92,945	371,781	464,726	19	92,945	371,781	464,726
Pajaro River	8	40,681	162,723	203,404	8	40,681	162,723	203,404
Penasquitos	24	117,737	470,947	588,683	21	106,860	427,440	534,300
Pueblo S.Diego	15	75,009	300,035	375,043	15	74,834	299,336	374,170
Salinas	1,332	6,658,544	26,634,177	33,292,721	1,225	6,126,663	24,506,651	30,633,314
San Diego	149	747,328	2,989,310	3,736,638	93	466,390	1,865,559	2,331,949
San Dieguito	175	874,894	3,499,577	4,374,471	85	425,825	1,703,299	2,129,124
San Gabriel	44	221,535	886,141	1,107,677	44	221,465	885,858	1,107,323
San Juan	173	867,083	3,468,333	4,335,416	160	801,380	3,205,519	4,006,899
San Luis Rey	684	3,419,392	13,677,570	17,096,962	71	357,237	1,428,946	1,786,183
Santa Ana	2,534	12,668,913	50,675,651	63,344,563	1,527	7,634,222	30,536,887	38,171,109
Santa Clara	1,019	5,093,858	20,375,431	25,469,289	1,018	5,092,328	20,369,313	25,461,641
Santa Margarita	689	3,444,463	13,777,850	17,222,313	4	20,972	83,890	104,862
Santa Monica	18	92,430	369,722	462,152	18	90,964	363,857	454,821
Santa Ynez	6	30,104	120,414	150,518	6	30,104	120,414	150,518
South Coast	30	149,075	596,300	745,375	22	110,003	440,014	550,017
Sweetwater	42	208,866	835,464	1,044,330	36	180,474	721,897	902,371
Tijuana	131	653,115	2,612,459	3,265,574	90	447,615	1,790,459	2,238,074
Ventura River	250	1,249,462	4,997,848	6,247,311	133	662,691	2,650,762	3,313,453
TOTALS:	**7,859**	**$39,296,369**	**$157,185,475**	**$196,481,844**	**$4,997**	**$24,986,839**	**$99,947,355**	**$124,934,194**

8.2 Benefit

The CBA included six *Arundo* impact classes. Each of these impacts is a 'benefit' when the agent causing the impact (*Arundo*) is removed. The six classes are: fire, water use, sediment trapping, flood damage, habitat enhancement, and beach debris.

8.2.1 Reduced Fire Impacts (Benefit)

Benefits related to reduced fire impacts resulting from *Arundo* control are presented in Table 8-3. This information is generated from data presented in Chapter 6 on fires that were initiated in *Arundo* stands, as well as wildfire events that burned *Arundo*. *Arundo*-initiated fires have costs associated with fire suppression (Table 8-3). A conservative fire response and suppression cost of $50,000 per event was used in generating cost estimates. The number of events over a ten-year period was based on data for the San Luis Rey watershed. This was then extrapolated to all watersheds based on their acreage of *Arundo*. Fire suppression costs are related to the number of units responding, work hours spent suppressing the fire, equipment costs, and other support. Fires usually involve multiple units that frequently use air suppression and often have fire lines cut by crews and/or mechanized equipment. The impacts from the fire suppression activities indicate the level of effort exerted during the action (suppression disturbance impacts are outlined in Chapter 6). *Arundo*-initiated fire impacts to habitat are also included in the cost estimate. The value of burned *Arundo* riparian habitat is priced lower ($20,000 per acre) then the valuation of un-invaded riparian habitat that burns ($80,000 per acre). These per acre cost valuations are based on mitigation costs associated with restoring riparian habitat, excluding easements and land purchase. Both the actual fire acreage and fire suppression acreage are aggregated in the cost estimate.

Arundo-initiated fires were estimated to generate $74.6 million of impacts over 10 years at peak *Arundo* distribution, and $38.8 million over 10 years at current *Arundo* levels (Table 8-3).

Wildfires represent a potentially open-ended impact class in terms of cost. As discussed in Chapter 6, *Arundo* stands may be conveying fires across the landscape, linking upland areas and spreading fire into urbanized areas. This seems to have occurred in Santa Clara, where a smaller 8,474-acre fire spread across the river via *Arundo* stands to the southern mountain range where it burned 107,560 acres. Other fires such as the Freeway Complex fire in Orange/Riverside County and western portions of the Witch Fire in San Diego County may also have had increased fire conveyance as the fires burned through riparian zones containing *Arundo* surrounded by urbanized areas. Impact costs were hundreds of millions of dollars with large losses to both habitat and developed areas. These landscape-level wildfire costs are too complicated to include in this CBA, but they clearly constitute a significant unmeasured cost that should be partially applied to *Arundo*. Further documentation needs to occur to more clearly define the role *Arundo* is having in wildland fires.

Wildfires can burn riparian habitat, particularly in firestorm/Santa Ana type events. *Arundo*-invaded habitat burns during these events along with un-invaded habitat. The *Arundo*-invaded areas burn much hotter than native vegetation due to the large amount of biomass per acre and the high levels of fuel per unit of biomass (Chapter 6). This results in more intense and complete fires that have a greater impact on the habitat. Post-fire recovery of *Arundo* stands is rapid, typically resulting in further domination of *Arundo* in areas that have burned (Ambrose 2007). A valuation of *Arundo's* degradation of habitat during wildfire events was valued at $2,500 per acre of burned *Arundo*-invaded habitat. This is an

extremely conservative valuation of the impacts to habitat, and it specifically excludes valuation of the fire conveyance impacts that *Arundo* has during wildfire events.

Wildfires that burn *Arundo* stands were estimated to generate $17.6 million of impacts over 10 years at peak *Arundo* distribution and $10.4 million over 10 years at current *Arundo* levels (Table 8-3).

8.2.2 Reduced Water Use (Benefit)

Water use of *Arundo*-invaded habitat was estimated in Section 4.2. Specific adjustments were made for replacement vegetation. Water use and net water savings are exceedingly difficult to validate in field studies, but it seems clear from the high productivity of *Arundo* (i.e. the very high stand biomass, the high leaf area recorded in studies, and the high water use of C_3 plants in general) that it does indeed have substantially higher water use than native vegetation and/or open areas that would exist in post-control riverine sites. The calculated water savings generated are significant (Section 4.2). It is important to note that most of the areas where *Arundo* is present within the study area have water available throughout the year. Many watersheds have significant amounts of imported water that generate these year-round flows or, at a minimum, make water tables high enough to support *Arundo* throughout the growing season.

Putting a valuation on water 'saved' after *Arundo* removal is complicated. In a more comprehensive study, this value would vary by watershed and be based on the specific benefit that the saved water is generating. One key benefit may be the potential for an increase in groundwater recharge. This may benefit domestic use (Santa Ana, Santa Margarita) or heavy agricultural use (Salinas, Santa Clara) of groundwater in a system. For those watersheds (San Luis Rey, San Diego) that have only moderate use of groundwater, the focus may turn to other potential benefits. An increase of water in the riverine system can also benefit habitat and recreation. Longer baseline flows can be critical to several endangered species, particularly on systems with high levels of water management (dams and reservoirs). All of these benefits could be priced out at different rates. For this analysis, a single low value of $50 per acre-foot (ac-ft) of water was used in calculating benefit of water savings. This is a conservative valuation, particularly for southern California. A valuation of $50 per ac-ft of water was the lower end value in the Rio Grande *Arundo* water use CBA study, with the higher end coming in at $200 per ac-ft (Seawright 2009). Valuations for domestic water use are $527 per ac-ft (Metropolitan Water District) and for agricultural water range from $70 (Coachilla) to $482 per ac-ft (MWD). Much of the water is priced at highly subsidized rates. Nearly all watersheds in the study area import water at a high absolute cost. Additionally, water transfer and pumping costs range from $70–$200 ac-ft (MWD). Water recycling and conservation measures typically cost $70–$150 per ac-ft and are usually considered to be a net benefit.

The estimated valuation of water saved over 10 years by controlling *Arundo* is $78.2 million at its peak distribution and $49.6 million at current distribution level (Table 8-4).

Table 8-3. Estimated reduction of fire impacts (benefit).

Watershed	PEAK *ARUNDO* LEVELS					CURRENT *ARUNDO* LEVELS				
	Fire Started by *Arundo*				Wildfires	Fire started by *Arundo*				Wildfire
	50k per event	Habitat damage: *Arundo* $20K ac	Habitat damage: rip $80K ac	*Arundo* fires 10 yr total	Wildfire: 500K per 200 ac	50k per event	Habitat damage: *Arundo* $20K ac	Habitat damage: rip $80K ac	*Arundo* fires 10 yr total	Wildfire: 500K per 200 ac
Calleguas	115,742	401,857	2,129,655	2,647,254	578,711	115,000	395,814	2,149,120	2,659,934	575,000
Carlsbad	73,947	256,745	1,360,629	1,691,321	369,736	24,609	98,862	459,889	583,360	123,044
Los Angeles	66,394	230,518	1,221,641	1,518,553	331,968	57,561	202,254	1,075,696	1,335,510	287,804
Otay	9,322	32,365	171,519	213,205	46,608	9,295	32,278	173,696	215,268	46,473
Penasquitos	11,810	41,004	217,300	270,114	59,049	10,686	37,407	199,700	247,793	53,430
Salinas	1,003,061	348,263	1,845,632	3,196,956	501,000	100,000	223,336	1,744,000	2,067,336	501,000
San Diego	75,111	260,787	1,382,050	1,717,948	375,557	47,000	169,675	878,336	1,095,011	235,000
San Dieguito	87,491	303,768	1,609,833	2,001,092	437,455	42,582	160,061	795,781	998,425	212,912
San Gabriel	22,281	77,359	409,967	509,607	111,404	22,146	76,929	413,873	512,948	110,732
San Juan	87,575	304,061	1,611,385	2,003,022	437,876	80,138	280,262	1,497,619	1,858,019	400,690
San Luis Rey	341,939	1,187,213	6,291,682	7,820,834	1,709,696	35,724	207,323	667,604	910,651	178,618
Santa Ana	1,361,931	4,728,624	25,059,526	31,150,080	6,809,654	820,000	2,813,396	15,324,160	18,957,556	4,100,000
Santa Clara	540,629	1,877,065	9,947,580	12,365,274	2,703,147	540,500	1,776,596	10,100,864	12,417,960	2,702,500
S. Margarita	344,446	119,592	633,781	1,097,819	1,722,231	-	-	-	0	0
Santa Monica	9,314	32,340	171,385	213,038	46,572	9,096	31,642	169,994	210,732	45,482
South Coast	14,908	51,759	274,298	340,965	74,538	11,000	39,256	205,575	255,831	55,002
Sweetwater	21,172	73,510	389,567	484,249	105,861	18,047	63,511	337,270	418,828	90,237
Tijuana	67,785	235,350	1,247,246	1,550,381	338,926	47,250	161,674	883,008	1,091,932	236,250
Ventura	165,997	576,341	3,054,344	3,796,682	829,985	94,000	257,212	1,756,672	2,107,884	470,000
TOTALS:	**$4,420,856**	**$11,138,520**	**$59,029,021**	**$74,588,396**	**$17,589,972**	**$2,084,635**	**$7,027,490**	**$38,832,856**	**$47,944,981**	**$10,424,174**

Table 8-4. Estimated reduction of water use by *Arundo* (benefit).

Watershed	10 Year Water Use	
	Peak *Arundo* levels	Current *Arundo* levels
Calleguas	2,290,974	2,290,974
Carlsbad	1,478,605	492,060
Los Angeles River	1,313,470	1,150,950
Otay	185,848	185,848
Penasquitos	235,419	213,650
Salinas	13,314,032	12,250,510
San Diego	1,494,312	932,570
San Dieguito	1,749,387	851,450
San Gabriel River	442,969	442,969
San Juan	1,733,768	1,602,390
San Luis Rey	6,837,215	714,310
Santa Ana	25,332,010	15,264,940
Santa Clara	10,185,377	10,185,377
Santa Margarita	6,887,344	41,940
Santa Monica Bay	184,819	184,819
South Coast	298,082	219,960
Sweetwater	417,636	360,870
Tijuana	1,305,930	895,020
Ventura River	2,498,351	1,325,080
TOTALS:	**$78,185,547**	**$49,605,686**

8.2.3 Reduced Sediment Trapping (Benefit)

As outlined in Section 5.1, it is likely that *Arundo* has impacts to sediment transport, particularly in low gradient areas where *Arundo* cover is high (>40%). Many of these areas are highly urbanized, have large-scale agricultural operations, or have significant infrastructure present. Localized sediment trapping is likely occurring in portions of these highly invaded reaches, resulting in loss of flow conveyance. *Arundo* stands on their own, not even considering sediment trapping, were demonstrated to reduce flow conveyance by five feet where they occurred (Section 5.1). This is a significant loss of conveyance, likely larger than the sediment trapping effect. If these areas are managed for flood risk, agencies (particularly ACOE, municipalities, and counties) may be forced to undertake vegetation reduction or sediment removal to maintain flow conveyance. For example, levees on the San Luis Rey River were designed to contain flows up to a 120–year event. Vegetation and *Arundo* growth reduced this to a 90–year event capacity (ACOE pers. comm. 2009). This can result in areas being designated as 'high flood risk' (i.e. raising insurance costs) or being designated as uninsurable. Both of these scenarios result in lower property values. When sediment removal and vegetation clearing are not permitted or are considered too costly, the alternative is building new levees or increasing existing levee heights. Both

Santa Margarita and San Luis Rey have required either modification or installation of levee structures and/or vegetation reduction programs to maintain flow conveyance. The Salinas River has had channel maintenance activities to reduce flood risk and bank/bridge failure. Other riverine systems in the study area are likely to have had actions in the past and/or will require actions in the future. Cost of implementing vegetation reduction and or sediment removal is also very high. While costs include the removal work itself, this is often a small proportion of the total project cost. Projects typically require complicated regulatory clearance that can take years to obtain, as well as significant mitigation for habitat disturbance/impacts. No specific cost valuation data exist other than the authors' familiarity with actions carried out on various rivers and the high costs associated with programs undertaking these types of activities. Therefore, valuations assigned in the benefit analysis are again highly conservative. Alternative activities, such as increasing levee heights or constructing new levees are not included here, but these actions do occur and the costs associated with them are high, both in terms of construction cost, permitting and mitigation for permanent wetland loss. True costs of *Arundo* impacts could be one or two orders of magnitude greater than presented here.

The valuation of avoided sediment removal or vegetation reduction costs over 10 years by controlling *Arundo* was estimated to be $2,500,000 (Table 8-5).

Table 8-5. Estimated reduction of sediment trapping (benefit).

Watershed	Sediment Removal
Calleguas	$250,000
Carlsbad	
Los Angeles River	$250,000
Otay	
Penasquitos	
Salinas	$1,000,000
San Diego	
San Dieguito	
San Gabriel River	$250,000
San Juan	
San Luis Rey	$500,000
Santa Ana	$250,000
Santa Clara	
Santa Margarita	
Santa Monica Bay	
South Coast	
Sweetwater	
Tijuana	
Ventura River	
TOTALS:	**$2,500,000**

8.2.4 Reduced Flood Damage: Bridges (Benefit)

Arundo biomass mobilizes during high flow events. This material can contribute or cause loss of structures that cross or are located within (power poles, sewer, gas, and water lines) the river channel. The exact proportion of damage costs associated with the presence of *Arundo* is difficult to determine. The most easily verified flood damage events involving *Arundo* are related to massive amounts of *Arundo* debris that form dams against bridges (Section 5.2.5.1). Loss of bridges has occurred on numerous watersheds that have high levels of *Arundo* invasion. Not all bridges were observed at the time of failure, but observations of bridges that have been damaged and operations to clear bridges of *Arundo* during flow events demonstrate that *Arundo* is a factor. High flow events that mobilize *Arundo* biomass also move large woody material such as trees. This combination of material collects and backs up against bridge pylons, or if flows are high enough, against the bridge itself. Older bridges with narrow spans are at greater risk of failing. Smaller bridges are also at higher risk as they typically have low clearance and narrow spans. Each watershed was reviewed for bridges (road and rail) that cross over river habitat with significant levels of *Arundo* around or upstream of them. These bridges were classified into three groups and conservative replacement costs were applied: large ($5 million), medium ($1.5 million), and small ($500,000). These valuations are extremely conservative, as bridge construction often requires costly environmental review and mitigation. Results were multiplied by 20% to estimate the likelihood of bridge loss within the 10-year period and to account for a portion of cost that is due to large flood events taking out bridges regardless of whether *Arundo* material is in the system or not.

The valuation of avoided bridge losses at peak *Arundo* distribution was estimated to be $24.2 million over 10 years. Control programs have cleared *Arundo* around and above several bridges, reducing estimated projected impacts to $17.3 million over 10 years (Table 8-6).

8.2.5 Habitat Enhancement (Benefit)

As explored in multiple chapters within this report, *Arundo* has many abiotic and biotic impacts. Some of the most severe impacts to riparian systems are to abiotic processes that are nearly impossible to quantify monetarily in terms of their environmental consequences. Changes to geomorphic form and function, hydrology, water use, and other abiotic functions affect the entire system. Most of the valuations for these types of impacts in previous sections were limited to anthropogenic costs including infrastructure, water for urban and agriculture use, or flood damage. Environmental costs were not included. This CBA will limit valuation of environmental impacts to the degradation of habitat *Arundo* has invaded. The cost of controlling *Arundo* is used as a valuation of the habitat benefit (habitat restoration as well and threatened and endangered species' benefits). A valuation of $25,000 per acre is used to represent the benefit of habitat enhancement/restoration that occurs when *Arundo* is controlled. This is the same as the cost of the work as outlined in Section 8.1. The total cost is lower, however, reflecting the subtraction of *Arundo* acreage that was counted under the fire benefits evaluation. This avoids double counting benefits. The use of this valuation is corroborated by the common use of *Arundo* control as a form of mitigation for impacts to riparian habitat. This is still a slightly conservative valuation as many other forms of riparian 'mitigation' have higher costs per acre ($50,000 to $100,000) for restoration activities, even when land use restrictions (easements or land costs) are excluded from project costs.

The total 10 year benefit calculated for habitat restoration/enhancement was estimated to be $181 million at peak *Arundo* distribution and $110 million for current distribution levels (Table 8-7).

Table 8-6. Estimated reduction of bridge losses (benefit) by watershed at peak and current *Arundo* levels.

Watershed	Number of Bridges: Large, Medium, & Small	PEAK *ARUNDO* LEVELS		CURRENT *ARUNDO* LEVELS	
		Bridge loss or damage	Flood damage: Bridge 20%	Bridge loss or damage	Flood damage: Bridge 20%
Calleguas	Med: 8, Sm: 1	12,500,000	2,500,000	12,500,000	2,500,000
Carlsbad		0	0	0	0
Los Angeles River	Lg: 1	5,000,000	1,000,000	5,000,000	1,000,000
Otay		0	0	0	0
Penasquitos		0	0	0	0
Salinas	Lg: 4, Med: 2, Sm: 1	22,000,000	4,400,000	22,000,000	4,400,000
San Diego	Med: 1, Sm: 2	2,500,000	500,000	500,000	100,000
San Dieguito		0	0	0	0
San Gabriel River	Lg: 1	5,000,000	1,000,000	5,000,000	1,000,000
San Juan	Med: 1, Sm: 1	2,000,000	400,000	2,000,000	400,000
San Luis Rey	Med: 4	6,000,000	1,200,000	0	0
Santa Ana	Lg: 5	25,000,000	5,000,000	10,000,000	2,000,000
Santa Clara	Lg: 2, Med: 3	14,500,000	2,900,000	14,500,000	2,900,000
Santa Margarita	Lg: 2, Med: 1	11,500,000	2,300,000	0	0
Santa Monica Bay		0	0	0	0
South Coast		0	0	0	0
Sweetwater		0	0	0	0
Tijuana	Sm: 1	500,000	100,000	500,000	100,000
Ventura River	Lg: 2, Med: 2, Sm: 3	14,500,000	2,900,000	14,500,000	2,900,000
	TOTALS:	**$121,000,000**	**$24,200,000**	**$86,500,000**	**$17,300,000**

Table 8-7. Estimated habitat enhancement (benefit) by watershed at peak and current *Arundo* levels.

Watershed	Habitat benefit: 25K per ac	
	PEAK *ARUNDO* LEVELS	**CURRENT *ARUNDO* LEVELS**
Calleguas	5,226,429	5,190,372
Carlsbad	3,376,431	909,509
Los Angeles River	2,996,281	2,589,891
Otay	424,270	424,270
Penasquitos	537,429	483,046
Salinas	32,857,393	30,197,986
San Diego	3,410,654	2,005,966
San Dieguito	3,994,761	1,749,414
San Gabriel River	1,010,978	1,010,624
San Juan	3,955,339	3,626,822
San Luis Rey	15,612,946	302,166
Santa Ana	57,433,784	32,260,330
Santa Clara	23,122,958	23,115,310
Santa Margarita	17,222,313	104,862
Santa Monica Bay	421,728	414,396
South Coast	680,677	485,319
Sweetwater	952,443	810,484
Tijuana	2,971,387	1,943,887
Ventura River	5,526,884	2,593,026
TOTALS:	**$181,735,081**	**$110,217,679**

8.2.6 Reduced Beach Debris

Impacts from clearing *Arundo* debris from beaches in southern California was reviewed in Section 5.2.5.2. These costs are based on information collected from municipalities that remove biomass from beaches. Only watersheds that are near beaches and actively remove biomass were given benefit valuations. The estimated 10–year benefit of reduced *Arundo* biomass on beaches is $1.97 million (Tables 8-8&9).

8.2.7 Total Benefit

The total benefit of controlling *Arundo* at its peak distribution was estimated at $380 million (Table 8-8), and the benefit at its current distribution at $239 million (Table 8-9). This is a conservative

valuation because several types of impacts could not be estimated or quantified, and all evaluated impacts were conservatively valued.

8.3 Benefit to Cost Ratio

The benefit to cost ratio for peak *Arundo* distribution was 1.94 to 1 ($380,767,747 to $196,481,844). Current *Arundo* distribution generates a similar benefit to cost ratio of 1.91 to 1 ($239,461,270 to $124,934,194). A 2:1 return ratio on funds invested is a significant benefit, particularly considering the additional impacts that were not assessed (due to complex valuation), as well as the conservative valuation of factors that were included.

A more rigorous CBA carried out for either specific watersheds or the entire project area would likely generate higher benefit to cost ratios. Higher cost valuations of impacts could be documented and defended, and some of the more complicated impacts, which were not included in this CBA, could be explored and included.

Table 8-8. Estimated benefits at the peak level of *Arundo* distribution.

Watershed	Water use 10 yr	Sediment removal	Flood damage: bridge & levee	*Arundo* fires 10 yr total	Wildfire: 500K per 200 ac	Habitat rest 25K	Beach debris	10 year benefit
Calleguas	2,290,974	250,000	2,500,000	2,647,254	578,711	5,226,429	-	13,493,368
Carlsbad	1,478,605	-	0	1,691,321	369,736	3,376,431	-	6,916,093
Los Angeles	1,313,470	250,000	1,000,000	1,518,553	331,968	2,996,281	328,125	7,738,397
Otay	185,848	-	0	213,205	46,608	424,270	-	869,931
Penasquitos	235,419	-	0	270,114	59,049	537,429	-	1,102,011
Salinas	13,314,032	1,000,000	4,400,000	3,196,956	501,000	32,857,393	-	55,269,381
San Diego	1,494,312	-	500,000	1,717,948	375,557	3,410,654	-	7,498,471
San Dieguito	1,749,387	-	0	2,001,092	437,455	3,994,761	-	8,182,694
San Gabriel	442,969	250,000	1,000,000	509,607	111,404	1,010,978	328,125	3,653,083
San Juan	1,733,768	-	400,000	2,003,022	437,876	3,955,339	-	8,530,006
San Luis Rey	6,837,215	500,000	1,200,000	7,820,834	1,709,696	15,612,946	328,125	34,008,816
Santa Ana	25,332,010	250,000	5,000,000	31,150,080	6,809,654	57,433,784	-	125,975,527
Santa Clara	10,185,377	-	2,900,000	12,365,274	2,703,147	23,122,958	328,125	51,604,881
Santa Margarita	6,887,344	-	2,300,000	1,097,819	1,722,231	17,222,313	328,125	29,557,833
Santa Monica	184,819	-	0	213,038	46,572	421,728	-	866,157
South Coast	298,082	-	0	340,965	74,538	680,677	-	1,394,261
Sweetwater	417,636	-	0	484,249	105,861	952,443	-	1,960,188
Tijuana	1,305,930	-	100,000	1,550,381	338,926	2,971,387	-	6,266,624
Ventura River	2,498,351		2,900,000	3,796,682	829,985	5,526,884	328,125	15,880,026
TOTALS:	**$78,185,547**	**$2,500,000**	**$24,200,000**	**$74,588,396**	**$17,589,972**	**$181,735,081**	**$1,968,750**	**$380,767,747**

Table 8-9. Estimated benefits at current levels of *Arundo*.

Watershed	Water use 10 yr	Sediment removal	Flood damage: bridge & levee	*Arundo* fires 10 yr total	Wildfire: 500K per 200 ac	Habitat rest 25K	Beach debris	10 year benefit
Calleguas	2,290,974	250,000	2,500,000	2,659,934	575,000	5,190,372		13,466,280
Carlsbad	492,060		0	583,360	123,044	909,509		2,107,972
Los Angeles	1,150,950	250,000	1,000,000	1,335,510	287,804	2,589,891	328,125	6,942,280
Otay	185,848		0	215,268	46,473	424,270		871,858
Penasquitos	213,650		0	247,793	53,430	483,046		997,919
Salinas	12,250,510	1,000,000	4,400,000	2,067,336	501,000	30,197,986		50,416,832
San Diego	932,570		100,000	1,095,011	235,000	2,005,966		4,368,547
San Dieguito	851,450		0	998,425	212,912	1,749,414		3,812,201
San Gabriel	442,969	250,000	1,000,000	512,948	110,732	1,010,624	328,125	3,655,399
San Juan	1,602,390		400,000	1,858,019	400,690	3,626,822		7,887,921
San Luis Rey	714,310		0	910,651	178,618	302,166	328,125	2,433,870
Santa Ana	15,264,940	250,000	2,000,000	18,957,556	4,100,000	32,260,330		72,832,826
Santa Clara	10,185,377		2,900,000	12,417,960	2,702,500	23,115,310	328,125	51,649,272
Santa Margarita	41,940		0	0	0	104,862	328,125	474,927
Santa Monica	184,819		0	210,732	45,482	414,396		855,429
South Coast	219,960		0	255,831	55,002	485,319		1,016,111
Sweetwater	360,870		0	418,828	90,237	810,484		1,680,419
Tijuana	895,020		100,000	1,091,932	236,250	1,943,887		4,267,089
Ventura River	1,325,080		2,900,000	2,107,884	470,000	2,593,026	328,125	9,724,115
TOTALS:	**$49,605,686**	**$2,000,000**	**$17,300,000**	**$47,944,981**	**$10,424,174**	**$110,217,679**	**$1,968,750**	**$239,461,270**

9.0 WATERSHED BASED *ARUNDO* CONTROL PROGRAMS: RECOMMENDATIONS, STATUS, AND PRIORITIZATION

9.1 Recommendations and Status of Watershed Based *Arundo* Control Programs

Given *Arundo*'s dependence on asexual propagation (it only spreads from fragments of plant material), control programs that start at the top of watersheds are undoubtedly the most efficient and effective over the long-term. Most watershed-based programs start on the upper portions of rivers and tributaries and proceed downstream to the ocean outfall. Many programs do not control all scattered infestations, such as those occurring in urbanized areas, particularly if these properties are not directly connected to drainages, creeks, or rivers. More comprehensive programs do attempt to eradicate all *Arundo* within the watershed, as any material is potentially a propagule source. Yard waste that is disposed of improperly, such as dumped along roads or creeks, is a pathway of spread. Once a watershed has had all *Arundo* controlled there is still a need to remain alert for new introductions that can occur from other watersheds as: contaminated fill, yard waste, or intentional planting of *Arundo* (even though it is a CDFA listed Noxious Weed, B rated).

General goals of control programs should be the following, but there are site-specific exceptions to these statements:

- Control programs should attempt to achieve eradication on entire watersheds, as this is the most efficient use of limited resources.
- Control programs should start in upper watershed areas and proceed downstream. This is more important on large, highly invaded watersheds that may require 10–20 years to carry out implementation. Small watersheds, or those large watersheds with little acreage, can be treated in any 'order' as long as everything is treated over a reasonable time frame.
- Programs frequently implement control projects in defined sub-sections of the watershed. The program still proceeds from the upper, to the middle, and then the lower watershed as different sub-sections are completed. Within a section, control may occur 'out of order'. This can be beneficial (fuel breaks, creating a mosaic of age classes for restored areas, multiple classes of property ownership, etc.) and is often done intentionally.
- Programs should strive to achieve 100% control within project areas. This is a difficult objective and requires both long-term commitment and substantial tracking. Most *Arundo* is controlled after 5–10 years of work, but re-sprouts will occur, particularly if project areas are large. Areas need to be checked and re-treated for 20 years to assure 100% control. Control and surveying may occur at three-year intervals for older project areas.
- Some highly invaded watersheds may have high-value habitat areas that need or require restoration or *Arundo* control before the larger program has 'reached' the area. These activities may be warranted, even though significant untreated *Arundo* remains upstream. Projects should budget periodic treatment of new *Arundo* invasion onto the property. Re-invasion of a given property is difficult to predict and would be dependent on geomorphic position, amount of *Arundo* upstream, and periodic flow events that mobilize material. Historic review of systems indicates that invasion is very episodic for the most part, and that responding after very large events will be the primary task.
- Watersheds with active programs may prioritize areas for control that have burned. Fires temporarily clear biomass from a site, representing an excellent opportunity for inexpensive

control as biomass reduction or removal is often the most expensive component of a control project.

9.1.1 Entity/Group Leading Watershed Based Work

For a watershed-based control program to succeed it typically needs either a single lead entity or an organization that brings together multiple partners. Larger watersheds without a lead entity or formal coordination have been unable to implement meaningful watershed-based *Arundo* control. There are five main reasons why a program lead is needed: funding, permitting, contracting, permission through right-of-entry agreements (ROEs), and long-term presence. Groups that are unable to receive public funds, hold permits, obtain ROEs, and garner broad support among watershed stakeholders should not attempt to lead projects or programs. Control programs on watersheds with more than 50 acres of *Arundo* or *Arundo* on more than 100 properties will likely only succeed if a program with an identified lead entity exists.

Table 9-1 identifies the specific watershed program leads within the study area. Most larger watersheds with high levels of *Arundo* invasion have already formed watershed based groups to initiate work. There are multiple types of organizations that can function as a lead. Most groups are public entities such as County Departments, Resource Conservation Districts (RCDs), and Joint Power Authorities (JPAs). But it is possible for a non-profit to function as a watershed lead (Carlsbad: San Elijo Conservancy, Tijuana: SWIA). Appealing to a broad range of landowners is a strong benefit, particularly in areas with a mix of private and public landownership. Resource Conservation Districts (RCD's) are frequently leads (Mission, Monterey) or active participants in stakeholder groups (SAWA: RCD's and water districts). Weed Management Areas or WMAs (typically formed by County Agriculture Departments or RCDs) can also play an important role in implementing projects and building watershed control programs.

9.1.2 Status of Permitting Allowing Work to Occur

Watershed programs seeking to control *Arundo* are required to obtain regulatory clearance from multiple agencies. Permits and conditions are dependent on methods being used to control *Arundo*. Typically this includes:

- CEQA: generally Mitigated Negative Declaration, Negative Declaration, or Notice of Exemption. EIRs are rarely required. This can take anywhere from 1-12 months to process depending on the path taken.
- Department of Fish and Game Streambed Alteration Permit 1600: nearly always required. This process can take one month to over a year long and CEQA should be completed first.
- U.S. Fish and Wildlife Service: Section 7/10 or a Technical Assistance Letter may be required if federally listed species are present. If take or harassment is likely to occur, a Section 7/10 is required and this can take 6-12 months or longer. If endangered species are present but impacts can be avoided, a Technical Assistance Letter can be used to outline protective measures. This can be completed in one to three months.
- Two other agencies also regulate protected species: California Endangered Species Act (under CA Department of Fish and Game) may require concurrence with U.S. Fish and Wildlife Service agreements/protective measures and National Marine Fisheries Service (under the National Oceanic and Atmospheric Administration) may require consultation.

Table 9-1. *Arundo* control programs within the study area: program leads, status of permitting and work completed on each watershed.

Watershed Unit	Total net acres	Treated net acres	Percent treated	Group leading control program	Watershed-based permitting completed	Notes
Calleguas	229	2	1%	No clear lead, multiple partners	CEQA	Ventura RCD and County active, but few projects completed to date
Carlsbad HU	148	98	67%	San Elijo Lagoon Consrvncy, San Diego Co	CEQA, DFG 1600, FWS, ACOE	Well established program (2002), strong implementation
Estero Bay	10	1	12%	San Luis Obispo County Ag Dept.	Project based	Work is project by project
Los Angeles River	131	16	12%	None	Project based	Work is project by project
Otay	19		0%	None	None	
Pajaro River	8		0%	None	None	
Penasquitos	23	2	9%	None	Project based	Work is project by project
Pueblo San Diego	15		0%	None	Project based	Work is project by project
Salinas	1,332	106	8%	Monterey RCD	CEQA, DFG,&FWS in process (& existing project based)	Project based but moving toward formal watershed-based program
San Diego	150	56	38%	San Diego River Conservancy	CEQA, DFG 1600, FWS, ACOE 404, SWCB 401	Newer watershed-based program (2009), rapid implementation
San Dieguito	175	90	51%	San Dieguito JPA	CEQA, DFG 1600, FWS	Well established watershed-based program (2006), rapid implementation
San Gabriel River	44	8	19%	None	None	Work is project by project
San Juan	173	13	8%	County of Orange	CEQA, DFG 1600, FWS, ACOE 404, SWCB 401	Newer watershed based program (2009), little implementation to date
San Luis Rey	684	612	90%	Mission RCD	CEQA, DFG 1600, FWS, ACOE 404, SWCB 401	Well established program (2000), strong implementation
Santa Ana	2,534	1,007	40%	SAWA	CEQA, DFG 1600, FWS, ACOE 404, SWCB 401	Well established program (1992), strong implementation
Santa Clara	1,019	1	0%	No clear lead, multiple parties	Some permits for LA County, none for Ventura County	Poorly formed program, no clear lead, low levels of implementation

Watershed Unit	Total net acres	Treated net acres	Percent treated	Group leading control program	Watershed-based permitting completed	Notes
Santa Margarita	689	685	99%	Lower: USMCB Camp Pendleton, Middle: Mission RCD, Upper: none	Lower and middle: NEPA/CEQA, DFG 1600, FWS, ACOE 404, SWCB 401 Upper: none	Well established program (1995), strong implementation- but no clear upper watershed lead
Santa Monica Bay	19	1	2%	None	None	Work is project by project
Santa Ynez	6		0%	Santa Barbara County Ag Commissioner	In Process: CEQA, DFG 1600	Newly forming project (2010)
South Coast	30	8	26%	Multiple parties: County, Cities	Project based	Work is project by project: some watershed units far along, some just starting
Sweetwater	42	6	14%	Sweetwater Authority	Project based	Work is project by project
Tijuana	131	41	31%	Southwest Wetlands Interpretive Assoc. (SWIA)	Project based	Work is project by project- constrained by *Arundo* in Mexico, true watershed-based management may not be possible on lower watershed
Ventura River	250	117	47%	County of Ventura	CEQA, DFG 1600, FWS, ACOE 404, SWCB 401 (project based, but for large sections of watershed)	Well established watershed-based program (2008), rapid implementation
Totals:	**7,864**	**2,862**	**36.4%**			

- Army Corps of Engineers 404 permit may be required for larger control programs using heavy equipment. In Southern California (San Diego up to San Luis Obispo County), a Regional General Permit 41 has been issued for *Arundo* and other non-native plant control programs. This permit, when activated for a specific program or project, fulfills both ACOE 404 permitting requirements and SWCB 401 certification. Completion of the ACOE RGP 41 application process can occur in less than three months. ACOE 404 certification without use of RGP 41 is an open-ended process.
- State Water Control Board or Regional Water Quality Control Board 401 certification or discharge permits can be required for programs depending on methods and equipment used. If obtained under ACOE RGP 41, the process is fast (under a month). If obtained as a 401 certification or discharge permit, the process is open-ended.
- Coastal Commission Permit may be required for certain projects. Exemptions have been obtained for some programs deemed to be restoration. Permitting process is open-ended and typically is the last permit completed.
- Other permits: additional project or watershed-specific permits may be required. This may include California State Historic Office (notification and/or compliance) and municipal or county codes/permits.

The number and complexity of regulatory permits for carrying out *Arundo* control makes it imperative that program leads are familiar with navigating the permitting process and that efficient and competent management of programs and permitting requirements is occurring. Given the number of permits that are required for larger programs, it is of substantial benefit if watershed-based permits can be obtained. Each watershed is identified in Table 9-1 as to the type of permits that are held and programs in place (whether it is watershed or project based). Additionally, *Arundo* control is a long-term process, with projects lasting at least five years and control typically taking 10-15 years. Programs on larger systems may take 15-20 years to complete all initial control. For this reason, obtaining the longest duration permits (particularly for DFG 1600) is the most efficient use of resources, even though these permits cost more initially.

Funding agencies and mitigation programs frequently will not fund projects that have permitting 'in process' or projects that expect to obtain permits after being awarded funding. Having approved and active permits in place from all required regulatory agencies is a primary indicator of a program's ability to execute on a specific project.

9.1.3 Work Completed to Date

Experience and track record of a watershed control program are the best indicators of a specific group's ability to complete projects in a time-efficient and cost-effective manner. Program leads typically are in charge of selecting work areas, obtaining ROEs, obtaining and complying with permits, obtaining funding, and selecting and contracting with groups to carry out the work. These factors are usually well documented in grant and other funding applications, and it is beyond the scope of this report to evaluate successes and failures of specific programs. Table 9-1 does, however, indicate which watersheds have well-established programs, when they started, and the treated acreage. Many of these programs actively participate in sharing information on control methods, mapping methods, permitting approaches, public outreach and other information. The community of control programs across the state is, in general, open and supportive of each other.

9.1.4 Future Program Work

Programs should use mapping data to demonstrate that top-down control is occurring by indicating what has been controlled, what is proposed, and what is planned. Programs should also use high-resolution mapping of *Arundo* stands to calculate budgets presented in proposals and for tracking treated acreage in mitigation programs. The mapping completed for this study and presented in this report represents high-resolution data.

Some programs appear to be vastly over-inflating acreage of *Arundo* stands in their proposals, work plans and mitigation programs. This may not be intentional, but it is misleading, particularly when making comparisons between watersheds or even proposals within a watershed. One example of misrepresentation occurs when gross area is used in place of net area. For example, a 200 acre site that has 15 acres of *Arundo* stands scattered within it should not be characterized as '200 acres of *Arundo* control'. If there are large expanses of native vegetation within areas designated as '*Arundo* project acreage', it can be a clear indication of questionable mapping. This overestimation can easily be detected if the mapped elements are viewed over high-resolution aerial imagery.

Maps presenting project acreage with point and line data can also be particularly suspect, especially if *Arundo* acreage is high. Additionally, maps with large polygons covering long lengths of river from terrace to terrace are questionable. Even in the most invaded portions of highly invaded systems, *Arundo* rarely achieves cover greater than 50% for long lengths of river. The mapping data presented here allows general verification of mapping presented in proposals. Mapping with acreage levels that are within 20 to 30% of this study's acreage is most likely accurate. A large difference in *Arundo* acreage compared to this study's mapping may indicate that a different methodology was implemented (i.e. coarse mapping with low *Arundo* cover) or mapping protocols were of poor quality. Other clues to either a poor understanding of implementation costs ($10-30,000 per acre for a typical project), or mapping that is not accurately representing *Arundo* acreage, can appear in proposed project budgets. For example, projects outlining control of 100 acres of *Arundo* for five years cannot reasonably cost $150,000. It is recommended that future proposals and plans be evaluated to determine if they accurately represent *Arundo* acreage.

9.2 Priority Ranking of Watershed-Based *Arundo* Control

9.2.1 Factors Considered in Ranking: Impacts and Capacity

Ranking watershed programs is a complicated and potentially subjective exercise. Multiple impacts from *Arundo* invasion have been outlined in this report. Some impacts are directly tied to the level of invasion (geomorphology, flooding, fire and water use), while other impacts are tied to specific species co-occurring with *Arundo* (listed species). While different weightings could be used for each factor, this analysis will weigh all factors as equal. Active watershed groups are also assessed in terms of their ability to initiate and complete work (functioning lead entity, completed permits, past execution). A ranking or evaluation of each program's quality of execution was not performed for this assessment.

Watersheds with small amounts of *Arundo* will tend to rank low in the impact assessment, yet these areas may be among the most efficient to treat in terms of preventing future degradation. This will be discussed at the end of the section.

9.2.2 Control Priority

Overall there are three priority actions for funding of *Arundo* control:

1) Fund re-treatments of project areas that have already implemented watershed-based control. This protects the existing investment.
2) Fund control of *Arundo* on watersheds with low levels of invasion. It is more cost efficient to control *Arundo* before it becomes abundant.
3) Fund new control on invaded systems, but prioritize where watershed-based programs/ approaches are being used, and where benefit is greatest. Funding is finite, so efficient use of limited resources should occur.

Re-treatment of *Arundo* within established program areas is the highest priority. The fact that *Arundo* was abundant at these sites prior to control work indicates that these areas have the capacity to support re-establishment of large infestations if left unfinished. Over $70 million has been spent to date on well-established *Arundo* control programs within the coastal watersheds in the study area. Five watersheds have controlled a significant portion (>80%) of the *Arundo* found on their watersheds: Carlsbad HU, San Luis Rey, Santa Ana, Santa Margarita, and Ventura. Maintaining and completing *Arundo* control on the portions of these watersheds treated to date is highest priority. For the most part, funding and management agencies have recognized this and provided funding for re-treatments (years 5 to 20). Continued long-term funding support is needed for re-treatments to achieve true eradication of *Arundo* within these program areas.

Control of *Arundo* on watersheds with low levels of invasion is the next priority. Some watersheds have low levels of *Arundo*, most likely due to more recent introductions. Control of invasive plants early in the invasion process is always more cost effective than responding to a larger, more widespread invasion. Programs should be able to control *Arundo* on many of these smaller populations (Santa Ynez, Estero, Pajaro, and others) with less complicated permitting and low project implementation costs. Treated *Arundo* biomass can often be left standing if it is scattered, also greatly reducing treatment costs.

Funding *Arundo* control on more invaded watersheds should target watersheds experiencing the most severe impacts coupled with the highest likelihood of achieving success. These rankings are based on impacts caused by *Arundo* invasion (four classes) and program capacity (two classes, Table 9-2). This ranking approach is biased in that it selects for watersheds that have moderate to high levels of *Arundo*

invasion (due to correlation of impact level and invasion level). Watersheds with low levels of invasion have already been recognized as being of 'high value' for control, even though few impacts may currently be occurring. It should also be noted that the impact classes reflect the magnitude of *Arundo*'s effect on the watershed, not the importance of the impact issue. For example, groundwater recharge and water savings may be a significant issue on a watershed that scores a 0. This low ranking reflects the low *Arundo* acreage, and corresponding level of impact, but not the importance of water savings on the watershed. Table 9-2 provides guidance in assigning priority among the more invaded watersheds, which may be of use. High ranked watersheds are experiencing severe impacts and have the capacity to implement control. Watersheds with high acreage in the medium class may provide less return on investment in terms of impact reduction.

Programs/projects that do not fit into a watershed-based control program should be evaluated carefully. There are situations where control of *Arundo* at a downstream site can make sense. For instance, control may help protect structures and restore important habitat, or the entity owning the land may have the resources to initiate work. These sites are, however, at significant long-term risk of re-invasion. Funds should be set aside to respond to re-invasion, which is expected to be periodic and varying in intensity. Projects that merely reduce *Arundo* biomass or only carry out one treatment are not effective long-term control projects, and should not be presented as such.

Table 9-2. *Arundo* treatment priority ranking by watershed. Based on *Arundo* impacts and program capacity.

Watershed Unit	Total Net Acres	Percent treated	Group leading control program	*Arundo* Impacts				Capacity		Total	Priority ranking
				Water Use	Geo-morph	Fire	Listed species	Exp. lead	Per-mits		
Santa Ana	2,534	40%	SAWA	5	5	5	5	5	5	30	Very high
San Luis Rey	684	90%	Mission RCD	4	5	5	5	5	5	29	
Santa Margarita	689	99%	Lower: USMCB Camp Pendleton, Middle: Mission RCD, Upper: none	4	5	4	5	5	5	28	
San Dieguito	175	51%	San Dieguito JPA	5	2	4	4	5	5	25	
Ventura River	250	47%	County of Ventura	3	4	5	3	5	5	25	
Santa Clara	1,019	0%	No clear lead, multiple parties	5	4	5	5	1	3	23	High
San Diego	150	38%	San Diego River Conservancy	4	2	4	3	4	5	22	
Salinas	1,332	8%	Monterey RCD	5	5	2	3	3	3	21	
Carlsbad	148	70%	San Elijo Conservancy, S.Diego Co	2	2	2	3	5	5	19	
San Juan	173	8%	County of Orange	2	3	3	3	3	5	19	
Tijuana	131	31%	SWest Wetlands Interpretive Assoc.	2	2	2	2	4	4	16	Medium
Calleguas	229	1%	None	3	3	4	2	1	2	15	
Los Angeles	131	12%	None	2	1	3	4	2	2	14	
Calleguas	229	1%	None	3	3	4	2	1	0	13	
Santa Ynez	6	0%	Santa Barbara County Ag Dept	0	1	1	3	5	3	13	
Sweetwater	42	14%	Sweetwater Authority	1	2	2	3	3	2	13	
San Gabriel	44	8%	None	1	1	2	4	2	2	12	
South Coast	30	26%	Santa Barbara County Ag Dept	0	1	2	3	3	3	12	
Santa Monica	19	2%	None	0	1	2	4	2	2	11	
Otay	19	0%	None	0	1	2	2	3	2	10	
Estero Bay	10	12%	None	0	0	0	2	3	3	8	Low
Penasquitos	23	9%	None	0	1	2	3	1	0	7	
Pueblo San Diego	15	0%	None	0	1	2	1	0	0	4	
Pajaro River	8	0%	None	0	0	0	2	0	0	2	
Totals:	**7,864**	**36.4%**									

10.0 SUMMARY OF DATA FOR *ARUNDO*: PHYSICAL CHARACTERISTICS, DISTRIBUTION, ABUNDANCE, IMPACTS, AND WATERHSHED CONTROL PROGRAMS' STATUS AND PRIORITY

Conclusions from this impact report are presented below and based on collected data and observations for the greater study area: coastal watersheds in California from Monterey to San Diego (Figure 3-1).

Physical Characteristics and Biology

- Mature stands are taller than what has been typically reported in the literature: 6.5 m mean, range of 2.6 – 9.9 m. (Section 2.3)
- Adjustments need to be made when scaling up from cane-specific data to stand data due to canes not emerging within all areas of *Arundo* canopy. Areas along edges and gaps within stands have zero to few canes. (Section 2.3)
- Biomass per unit area is very high for mature *Arundo* stands and it is in general agreement with the literature: 15.5 kg/m^2. (Section 2.4)
- Leaf area of secondary branches is the primary photosynthetic area for older canes, and this constitutes the majority of the mature stand leaf area (75%). This has not been clearly recorded in the literature. (Section 4.1)
- Measurements of leaf area (LAI) in mature *Arundo* stands are very high (15.8 LAI). This is in general agreement with the literature. (Section 4.1)
- Additional studies examining LAI and stand structure would further establish that mature *Arundo* stands have very high LAI. Examination of native riparian vegetation LAI may also be beneficial.
- Reviewed literature demonstrates that *Arundo* spreads through asexual propagation (fragments of rhizomes and infrequently canes). Seeds are not viable. This makes *Arundo* spread dependent on flood action or anthropogenic disturbance. (Section 2.5)
- Review of historic aerial photography indicates that spread of *Arundo* within a watershed is very episodic- large magnitude (50 to 100–year) events are necessary for the plant to actively invade significant new areas in a riparian system, particularly floodplains and terraces. (Section 2.6.4)

These observations are important in that they characterize *Arundo* stands within the study area. These baseline attributes are used to quantify and explore multiple impacts associated with *Arundo* in later sections.

***Arundo* Impacts: Transpiration and Water use**

- Due to high leaf area of mature stands, stand-based transpiration is very high (E_{stand} 40 mm/day). There are two other studies evaluating stand-based *Arundo* transpiration. One study on the Santa Clara watershed (within this project's study area) is in agreement (41.1 mm/day). The other study on the Rio Grande River is lower (9.1 mm/day). (Section 4.1).
- Stand-based transpiration rates of *Arundo*, when used to calculate total water over larger areas, indicate very high levels of water use: 48 ac-ft/ac per year. (Section 4.2)
- Net water savings for areas after *Arundo* removal are high (20 ac-ft/yr), even when *Arundo* water use is lowered 24 ac-ft/ac per yr to reflect levels that may be closer to physiological water transpiration limits. (Section 4.2)

- New studies using different approaches to measure stand-based water use of *Arundo* are needed to corroborate and refine stand-based water use found in this and other studies. New studies need to be on mature stands of *Arundo*. Stands under treatment or in post-fire or flood recovery should be excluded, as these are not representative of the majority of *Arundo* stands within the study area. (Section 4.2)

Water use by *Arundo* appears to be a significant impact on invaded systems. Water use by vegetation is difficult to measure. Additional baseline and comparative studies are needed.

Distribution and Abundance

- *Arundo* mapping documented a total (gross) of 8,907 acres of *Arundo*. Net acreage, adjusted for *Arundo* cover, was 7,864 acres. This represents the peak distribution of *Arundo* in the study area prior to control activities. (Section 3.2)
- Over 3,000 gross acres of *Arundo* have been treated to date within the study area. This is 34% of the *Arundo* occurring within the study area. (Section 3.2)
- Three large, contiguous watershed units have the highest levels of *Arundo* control observed in the study area: Santa Margarita at 99%, San Luis Rey at 90% and Carlsbad at 70%. (Section 3.2)
- Most other invaded watersheds in the study area with more than 100 acres of *Arundo* have had at least 30% of their *Arundo* treated. Noted exceptions to this are Calleguas, Salinas and Santa Clara watersheds, which have less than 10% of their *Arundo* acreage under treatment. (Section 3.2)
- *Arundo* is most abundant in broad, low-gradient riparian areas where it averages 13% cover. (Section 5.2)
- *Arundo* cover can be very high for large sections (reaches > 0.5 mi long). *Arundo* was observed occurring at >40% cover on specific reaches on all three watersheds that were examined in detail: Santa Margarita, San Luis Rey and Santa Ana. (Section 5.1)

Distribution and abundance data is extremely valuable because it quantifies past and current levels of invasion on watersheds, allows detailed examination and quantification of impacts, and facilitates watershed-based control. Programs can use the spatial data to implement watershed-based control, develop proposals and budgets, and manage control programs.

***Arundo* Impacts: Hydrology and Geomorphology**

- Mature *Arundo* stands, due to high cane density, functionally raise the elevation profile by 5 feet, lowering flow capacity. (Section 5.1.4.6)
- *Arundo* stands occur predominantly in floodplain and terrace portions of the river and are nearly absent from the low flow and active channel areas. (Sections 5.1 & 5.2)
- *Arundo* stands on floodplains adjacent to the active channel function as a wall or levee, focusing flows within channel areas. Over time this results in a deepening of the channel and a transformation of the system from a braided unstable channel form to a laterally stable single-thread channel form. (Section 5.1.4.6)
- Floodplain areas (floodplains and low terraces) have become much more vegetated on most systems over the last eighty years. This vegetation is both native woody vegetation and *Arundo*. Mature *Arundo* stands, however, have much higher stem density and biomass per unit area, generating the observed effects noted above. (Section 5.2.3)

- Active channel areas (low flow and bar channel areas with little vegetation) have significantly declined over time on most systems. (Section 5.2.2)
- The over-vegetated floodplains and narrow stable deep channels result in modifications of sediment transport and stream power during flow events. (Section 5.1.4.7)
- Most riverine systems have become significantly compressed (narrower) over time as terrace and floodplain areas have been permanently separated from the river system with levees that protect both urbanization and agricultural land use. (Section 5.2)
- Most riverine systems in the study area have converted from: broad riparian systems with little vegetation cover and channels that were laterally unstable (braided) to narrow riparian systems with highly vegetated floodplains that have a single deep channel. (Section 5.2)
- Most *Arundo* has been removed from the Santa Margarita River for 13 years. The geomorphic response to large flow events in that time has been a significant widening of the low flow and bar channel area (38% increase). Flows also actively pass through floodplain areas; this is a major change in function and process. Moderately-sized events (15 year) now flow through significant portions of channel, bar, and floodplain areas. Before *Arundo* was removed, flows were restricted to channel and bar areas. (Section 5.2.4)
- Loss of flow capacity and presence of *Arundo* biomass is likely contributing to overbank flows and bridge loss and damage. (Section 5.2.5.1)
- Flow events mobilize large amounts of *Arundo* biomass. Part of this biomass load ends up on coastal beaches where it is frequently removed by public agencies and carries an estimated annual cost of $197,000. This does not include impacts on habitat quality. (Section 5.2.5.2)

Hydro-geomorphic impacts are significant. This has ramifications to both the ecosystem and infrastructure in and around invaded rivers. Watershed-based analysis on sediment movement and impacts should be explored in greater detail to further document and quantify relationships.

Arundo Impacts: Fires

- *Arundo* stands are highly flammable throughout the year with large amounts of fuel (15.5 kg/m^2 of biomass), a large amount of energy (287.1 MJ/m^2), and a tall well-ventilated structure with dry fuels distributed throughout the height profile. (Section 6.1)
- Fires frequently start in *Arundo* stands. The primary ignition sources are transient encampments and discarded cigarettes from highway overpasses. (Section 6.1)
- *Arundo* stands strongly attract transient use (dense cover and shelter). This was documented throughout the study area with numerous high use locations noted in both urban and agricultural areas. (Section 6.3.1)
- Fires initiated in *Arundo* stands occur due to fuel and ignition source occurring at the same location. This is a newly defined class of fire events. (Section 6.4.1)
- Fires that are initiated in *Arundo* burn both *Arundo* stands and native riparian areas. In addition, suppression of fires also impacts riparian habitat. Impacts were calculated for all watersheds using San Luis Rey as a case study. Over a ten-year period for the study area, *Arundo*-initiated fire events are estimated to have burned 513 acres of *Arundo* and 706 acres of native riparian habitat. Fire suppression over a ten-year period has impacted 44 acres of *Arundo* and 32 acres of native riparian vegetation. (Section 6.5)
- Wildfires burn a significant acreage of *Arundo* stands. Over ten years, 6.1% of *Arundo* stands (544 acres) burned within the study area. (Section 6.5)
- Due to high fuel load and stand structure, areas with *Arundo* burn hotter and more completely then native vegetation during wildfire events. (Section 6.4.2)

- *Arundo* stands appear to be conveying fires across riparian zones- linking upland vegetation areas that would have been separated by less flammable riparian vegetation. This can have catastrophic impacts like those observed in the 2008 Simi fire. The 8,474-acre fire crossed the Santa Clara River and then burned an additional 107,560 acres. (Section 6.4.2)
- *Arundo* fires accelerate the dominance of *Arundo* in invaded areas due to rapid re-growth and low mortality of *Arundo*. (Section 6.5.1)
- *Arundo* fire events lead to both direct mortality of wildlife and plants (some of which are sensitive) as well as a longer-term quality reduction of burned riparian areas (post-fire recovery of vegetation and structure). (Section 6.5.2)
- Emergency actions tied to *Arundo* fire suppression also result in impacts (disturbance of both *Arundo* and riparian vegetation) that degrade riparian habitat and/or may result in mortality of species. (Section 6.5.4)

Documentation and separation of *Arundo*-initiated fires from wildland fires that burn *Arundo* is an important finding. Impacts from *Arundo*-initiated fires are common and are the result of *Arundo* invasion. Harboring ignition sources in combination with combustible fuels year round creates this unique fire risk and impact. This needs to be further studied and documented. If validated, impacts to wildfire spread could be the greatest single impact.

Arundo Impacts: Federally Endangered and Threatened Species

- *Arundo* impacts to 22 federally endangered and threatened species from five taxonomic groups varied from: very severe (score of 10) to very low/improbable (score of 1). (Section 7.3.1)
- Documented and potential abiotic and biotic impacts from *Arundo* are described for each species. Abitoic impacts include modification of geomorphology, hydrology, flood disturbance, fire disturbance, water use, and nutrient budgets. Biotic impacts include alteration of vegetation/community structure (displacement of native vegetation), filling in 'open' un-vegetated portions of habitat, creating physical structure that impedes movement, creation of structure in estuaries that facilitates predation, biomass debris that degrades breeding areas, stand structure that is of low value for nesting, and biomass that is of low forage value for both insects and animals. (Section 7.2)
- *Arundo* co-occurs with sensitive species on many watersheds in the study area. This overlap in distribution was evaluated using the *Arundo* mapping data and sensitive species occurrence data (Appendix B). Interaction between *Arundo* and each species was scored. *Arundo* present upstream of sensitive species was specifically accounted for as impacts occur to downstream areas from alteration of sediment loads, geomorphic forms, biomass discharge and other factors. (Section 7.2)
- A cumulative impact score was calculated using the species' specific impact score and the overlap score. This allows each species and each watershed to be evaluated for magnitude of impact. Least Bell's Vireo and Arroyo toad ranked as the most 'severely impacted'. Three species ranked 'very high', four species ranked 'high', ten species were 'moderate', and three species were 'low'. (Section 7.2)
- Several fish species ranked very high on the cumulative impact scoring. This is a group of species that have not been closely associated with *Arundo* impacts prior to this study. Most fish species had impacts related to modification of channel form (single versus braided), channel depth (shallow versus deep), sediment transport, and potential biomass/debris impacts. (Section 7.2)

- Estuaries and beaches were shown to have moderate impacts resulting from both *Arundo* stands, which create physical structure that facilitates predation, and *Arundo* debris that covers open sandy areas required by ground-nesting avian species. (Section 7.2)
- Watershed rankings of *Arundo* impacts on sensitive species shows that there are four watersheds designated as 'severely impacted', two as 'highly impacted', eight as 'moderately impacted', and five as 'lowly impacted'. (Section 7.2)
- Three of the four 'severely impacted' watersheds have well-developed watershed-based *Arundo* control programs in place. (Section 7.2)

Impacts to habitat are significant. *Arundo*'s overlapping distribution with sensitive species creates pressures on a wide range of species. Impacts range from abiotic to direct biotic interaction. The most significant impacts relate to abiotic modification of the system (water, fire, geomorphic form), but these are the most difficult to document and quantify due to their scale. Additional research and documentation are needed to increase our understanding of how *Arundo* modifies ecosystem-regulating processes.

Cost to Benefit Analysis

- Cost of *Arundo* control is $25K per acre, as documented by $70 million of work completed on control programs within the study area over the past 20 years. (Section 8.1)
- This would total $196 million in control costs at the study area's peak *Arundo* distribution and $124 million at current *Arundo* distribution levels. (Section 8.1)
- Benefits from control and reduction of impacts was calculated for fire, water use, sediment trapping, flood damage (bridges), habitat, and beach debris. Analysis was conservative. (Section 8.2)
- Benefits: $380 million at peak *Arundo* distribution and $239 million at current *Arundo* distribution levels. (Section 8.2)
- Benefit to cost ratio of 1.9:1. (Section 8.2)

Arundo control is of substantial net benefit. Many impacts were not included in the analysis, and benefits were valued conservatively. The actual benefit of *Arundo* control is likely much higher than calculated.

Watershed Programs

- Watershed-based control is a priority and is facilitated by a strong lead entity that manages the program. Effective programs must have the capacity to manage project funds, obtain right of entry agreements, and hold regulatory permits. (Section 9.1)
- Permitting is complicated and expensive, but required. Programs with broad and active permits are able to implement programs more effectively and quickly. (Section 9.1)
- Watershed programs should use accurate and standardized mapping to represent *Arundo* acreage. This allows better management of programs, facilitates comparison of projects, and increases accountability. (Section 9.1)
- A significant amount of *Arundo* control has already occurred within the study area and many watershed-based control programs have already formed. (Section 9.1)
- Priorities for *Arundo* control are: (Section 9.2)
    - Long term re-treatment of program areas that have already had initial control: this protects the investment already made.

- Control *Arundo* on watersheds with low levels of invasion: this eradicates populations before they become abundant, which is more cost effective and avoids future impacts.
- Treat watersheds with significant *Arundo* invasion based on: level of impacts and capacity of groups proposing work.

Watershed-based management of *Arundo* is greatly facilitated by the establishment of a program lead. Programs with tracking systems for work completed, in addition to long-term stability, have the greatest ability of completing true watershed based control (eradication).

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APPENDIX A. Detailed Maps of *Arundo* Distribution Within the Study Area

***Arundo* distribution data from Monterey to San Diego, CA**
(see Chapter 3 for information on mapping methodology)

Spatial data set (GIS geo database) are available for download at:

http://www.cal-ipc.org/ip/research/arundo/index.php

or

http://www.cal-ipc.org/ip/mapping/arundo/index.php

The spatial data set is also viewable at the DFG BIOS web site:

http://bios.dfg.ca.gov/

Project data sets are named:
Invasive Plants (Species) - Central_So. Cal Coastal Watersheds [ds645]
Invasive Plants (Prct Cover) - Central_So. Cal Coastal Watersheds [ds646]

APPENDIX B. Occurrence Data and Critical Habitat Areas for Federally Listed Species and Distribution of *Arundo*.

Spatial data for federally listed species includes:

- **Critical habitat areas designated by USFWS**
- **Occurrence data compiled by the Ventura USFWS Office**
- **Occurrence data from the California Natural Diversity Database (CNDDB: CA DFG)**
- **Additional occurrence data from USGS, SANDAG, and other sources**

Spatial data set (GIS geo database) are available for download at:

http://www.cal-ipc.org/ip/research/arundo/index.php

or

http://www.cal-ipc.org/ip/mapping/arundo/index.php

The spatial data set is also viewable at the DFG BIOS web site:

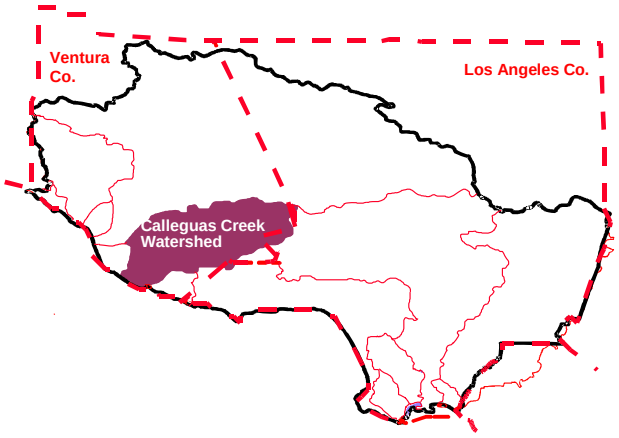
http://bios.dfg.ca.gov/

Project data sets are named:
Invasive Plants (Species) - Central_So. Cal Coastal Watersheds [ds645]
Invasive Plants (Prct Cover) - Central_So. Cal Coastal Watersheds [ds646]

2.10 CALLEGUAS CREEK WATERSHED

This watershed will be targeted in FY2011/2012.

Overview of Watershed



Calleguas Creek and its major tributaries, Revolon Slough, Conejo Creek, Arroyo Conejo, Arroyo Santa Rosa, and Arroyo Simi drain an area of 343 square miles in southern Ventura County and a small portion of western Los Angeles County. This watershed, which is elongated along an east-west axis, is about 30 miles long and 14 miles wide. The northern boundary of the watershed is formed by the Santa Susana Mountains, South Mountain, and Oak Ridge; the southern boundary is formed by the Simi Hills and Santa Monica Mountains.

Land uses vary throughout the watershed. Urban developments are generally restricted to the city limits of Simi Valley, Moorpark, Thousand Oaks, and Camarillo. Although some residential development has occurred along the slopes of the watershed, most upland areas are still open space; however, golf courses are becoming increasingly popular to locate in these open areas. Agricultural activities, primarily cultivation of orchards and row crops, are spread out along valleys and on the Oxnard Plain as shown in the figure below.

Source: California Invasive Plant Council

URL of this page: http://www.cal-ipc.org/ip/management/ipcw/acknowledgements.php

Invasive Plants of California's Wildland

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Foreword >

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Invasive Plants of California's Wildland

Foreword

The heart of this book is the species accounts, which provide detailed information about the biology and control of seventy-eight non-native plant species that are listed as Exotic Invasive Plants of Greatest Ecological Concern as of 1996 by the California Exotic Pest Plant Council (Cal-IPC). We decided to cover only the species on this list because it is the best effort to date1 to determine which of the non-native plants already growing wild in California cause or have the potential to cause serious damage in the state's parks, preserves, and other wildlands. We are convinced that non-native invasive plants pose one of worst threats, perhaps the worst of all, to the state's remaining populations and communities of native species. We hope the information on the pages that follow will be used to help promote the survival and growth of native plants and animals threatened by these invaders.

Cal-IPC was established in 1992 in response to growing concern about invasive non-native plants in the state's wildlands. In 1994 Cal-IPC canvassed its members and other land managers and researchers around the state for information about non-native plants that invade California's preserves, parks, and other wildlands. This information was used to develop a list of Exotic Invasive Plants of Greatest Ecological Concern in California. The species were grouped into several categories to indicate how severe and/or widespread they are. List A-1 includes the most invasive and damaging species that are widespread in the state. List A-2 includes highly damaging species that are invasive in fewer than five of the geographic subdivisions designated in The Jepson Manual: Higher Plants of California. List B includes less invasive species that move into and degrade wildlands. The Red Alert List includes species whose ranges in California currently are small but that are believed to have the potential to spread explosively and become major pests. Species for which there was insufficient information to determine their ability to invade and degrade natural areas were placed on a Need More Information list and only a few for whom strong evidence is mounting are included in this book. As the list was being compiled and categorized it was reviewed, re-reviewed, and finally approved by a group of respected researchers. In 1996 the Cal-IPC list was updated based on new information and expanded to include a total of seventy-eight species.

We begin this book with a brief overview of the impacts of invasive plants and what we know about the characteristics of plant species most likely to invade and the habitats and communities most likely to be invaded. This is followed by a discussion of strategies and methods appropriate for the control of invasive plants in parks, preserves, and other wildlands. The remainder of the book consists of species accounts for seventy-eight invasive non-native species. Each account helps readers to identify the species and understand important aspects of its biology and lists specific control methods that are regarded as relatively effective, as well as some found to be ineffective.

[1] We acknowledge that several non-native invaders that have caused severe damage to wildlands in California are not on the 1996 edition of the list, as does Cal-IPC. As we write this Cal-IPC is preparing an updated version of the list, but it will not be ready in time for us to include newly listed species.

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Invasive Plants of California's Wildland

California Wildland Invasive Plants

John M. Randall and Marc C. Hoshovsky

The focus of this book is non-native plants that invade parks, preserves, and other wildlands in California, but our real concern is the survival and growth of the native plants and animals these invaders threaten. Unfortunately, some non-native invasive plant species inflict so much damage that, unless they are controlled, it will be impossible to preserve viable populations of many native species or many of the state's natural communities and ecosystems.

The good news is that many plant invasions can be halted or slowed, and, in certain situations, even badly infested areas can be restored to relatively healthy communities dominated by native species. Weed control and restoration are now widely regarded as necessary in many wildlands across the state and around the world. We hope this book will help land managers, volunteer stewards, and others to recognize some of California's most damaging wildland in vad ers, to better understand their impacts, and to minimize the damage they do to native biological diversity.

Invasive species are now widely recognized worldwide as posing threats to biological diversity second only to direct habitat loss and fragmentation (Pimm and Gilpin 1989, Scott and Wilcove 1998). In fact, when biological invasion by all types of organisms is considered as a single phenomenon, it is clear that to date it has had greater impacts on the world's biota than have more notorious aspects of global environmental change such as rising CO2 concentrations, climate change, and decreasing stratospheric ozone levels (Vitousek et al. 1996). Compared to other threats to biological diversity, invasive non-native plants present a complex problem that is difficult to manage and has long-lasting effects. Even when exotics are no longer actively introduced, these plants continue to spread and invade new areas. Effective control will require awareness and active participation of the public as well as natural resource managers and specialists.

California's invasive plant problems are widespread and severe. The state's varied topography, geology, and climates have helped to give rise to the state's extraordinary native biological diversity and high levels of endemism. However, these varied conditions also provide suitable habitat for a wide variety of non-native plant species, many of which have readily established and rapidly spread in the state. Fewer than ten percent of the 1,045 non-native plant species that have established in California are recognized as serious threats (Randall et al. 1998), but these have dramatically changed California's ecological landscape. They alter ecosystem functions such as nutrient cycles, hydrology, and wildfire frequency, outcompete and exclude native plants and animals, harbor dangerous animal invaders, and hybridize with native species. Some spread into national parks, preserves, and other wildlands and reduce or eliminate the species and communities these sites were set aside to protect.

Rare species appear to be particularly vulnerable to the changes wrought by non-native invaders. For example, the California Natural Diversity Database indicates that 181 of the state's rare plant species are experiencing threats from invasive weeds (California Department of Fish and Game, Natural Heritage Division). Habitats for rare animals such as the San Clemente sage sparrow and the Palos Verde blue butterfly are also being invaded. Even more common species could be driven to rarity or near extinction by particularly disruptive invaders, as evidenced by the fate of the American chestnut (Castanea dentata) in the eastern hardwood forest following introduction of chestnut blight, Cryphonectria parasitica (National Academy of Science 1975).

IMPACTS OF INVASIVE PLANTS ON WILDLANDS

Non-native plant invasions can have a variety of effects on wildlands, including alteration of ecosystem processes; displacement of native species; support of non-na tive animals, fungi, or microbes; and alteration of gene pools through hybridization with native species.

Ecosystem Effects

The invasive species that cause the greatest damage are those that alter ecosystem processes such as nutrient cycling, intensity and frequency of fire, hydrological cycles, sediment deposition, and erosion (D'Antonio and Vitousek 1992, Vitousek 1986, Vitousek and Walker 1989, Vitousek et al. 1987, Whisenant 1990). These invaders change the rules of the game of survival and growth, placing many native species at a severe disadvantage (Vitousek et al. 1996). Cheat grass (Bromus tectorum) is a well studied example of an invader that has altered ecosystem processes. This annual grass has invaded millions of acres of rangeland in the Great Basin, leading to widespread increases in fire frequency from once every sixty to 110 years to once every three to five years (Billings 1990, Whisenant 1990). Native shrubs do not recover well from more frequent fires and have been eliminated or reduced to minor components in many of these areas (Mack 1981).

Some invaders alter soil chemistry, making it difficult for native species to survive and reproduce. For example, iceplant (Mesembryanthemum crystallinum) accumulates large quantities of salt, which is released after the plant dies. The increased salinity prevents native vegetation from reestablishing (Vivrette and Muller 1977, Kloot 1983). Scotch broom (Cytisus scoparius) and gorse (Ulex europaea) can increase the content of nitrogen in soil. Although this increases soil fertility and overall plant growth, it gives a competitive advantage to non-native species that thrive in nitrogen-rich soil. Researchers have found that the nitrogen-fixing firetree (Myrica faya) increases soil fertility and consequently alters succession in Hawaii (Vitousek and Walker 1989).

Wetland and riparian invaders can alter hydrology and sedimentation rates. Tamarisks (Tamarix chinensis, T. ramosissima, T. pentandra, T. parviflora) invade wetland and riparian areas in southern and central California and throughout the Southwest, and are believed to be responsible for lowering water tables at some sites. This may reduce or eliminate surface water habitats that native plants and animals need to survive (Brotherson and Field 1987, Neill 1983). For example, tamarisk invaded Eagle Borax Spring in Death Valley in the 1930s or 1940s. By the late 1960s the large marsh had dried up, with no visible surface water. When managers removed tamarisk from the site, surface water reappeared, and the spring and its associated plants and animals recovered (Neill 1983). Tamarisk infestations also can trap more sediment than stands of native vegetation and thus alter the shape, carrying capacity, and flooding cycle of rivers, streams, and washes (Blackburn et al. 1982). Interestingly, the only species of Tamarix established in California that is not generally regarded as invasive (athel, or T. aphylla) is regarded as a major riparian invader in arid central Australia.

Other wetland and riparian invaders and a variety of beach and dune invaders dramatically alter rates of sedimentation and erosion. One example is saltmarsh cordgrass (Spartina alterniflora), native to the Atlantic and Gulf coasts and introduced to the Pacific Coast, where it invades intertidal habitats. Sedimentation rates may increase dramatically in infested areas, while nearby mudflats deprived of sediment erode and become areas of open water (Sayce 1988). The net result is a sharp reduction in open intertidal areas where many migrant and resident waterfowl feed.

Coastal dunes along the Pacific Coast from central California to British Columbia have been invaded and altered by European beachgrass (Ammophila arenaria). Dunes in infested areas are generally steeper and oriented roughly parallel to the coast rather than nearly perpendicular to it as they are in areas dominated by Leymus mollis, L. pacificus, and other natives (Barbour and Johnson 1988). European beachgrass eliminates habitats for rare native species such as Antioch Dunes evening-primrose (Oenothera deltoides ssp. howellii) and Menzies' wallflower (Erysimum menziesii ssp. menziesii). Species richness on foredunes dominated by European beachgrass may be half that on adjacent dunes dominated by Leymus species (Barbour et al. 1976). Changes in the shape and orientation of the dunes also alter the hydrology and microclimate of the swales and other habitats behind the dunes, affecting species in these areas.

Some upland invaders also alter erosion rates. For example, runoff and sediment yield under simulated rainfall were fifty-six percent and 192 percent higher on plots in western Montana dominated by spotted knapweed (Centaurea maculosa) than on plots dominated by native bunchgrasses (Lacey et al 1989). This species is already established in northern California and the southern Peninsular Range and recently was found on an inholding within Yosemite National Park (Hrusa pers. comm.).

Some invasive plants completely alter the structure of the vegetation they invade. For example, the punk tree (Melaleuca quinquenervia) invades marshes in southern Florida's Everglades that are dominated by sedges, grasses, and other herbaceous species, rapidly converting them to swamp forest with little or no herbaceous understory (LaRoche 1994, Schmitz et al. 1997). Such wholesale changes in community structure may be expected to be followed by changes in ecosystem function.

HABITAT DOMINANCE AND DISPLACEMENT OF NATIVE SPECIES

Invaders that move into and dominate habitats without obviously altering ecosystem properties can nevertheless cause grave damage. They may outcompete native species, suppress native species recruitment, alter community structure, degrade or eliminate habitat for native animals, and provide food and cover for undesirable non-native animals. For example, edible fig (Ficus carica) is invading riparian forests in the Central Valley and surrounding foothills and can become a canopy dominant. Invasive vines are troublesome in forested areas across the continent. In California, cape ivy (Delairea odorata) blankets riparian forests along the coast from San Diego north to the Oregon border (Elliott 1994).

Non-native sub-canopy trees and shrubs invade forest understories, particularly in the Sierra Nevada and Coast Ranges. Scotch broom (Cytisus scoparius), French broom (Genista monspessulana), and gorse (Ulex europaea) are especially troublesome invaders of forests and adjacent openings and of coastal grasslands (Bossard 1991a, Mountjoy 1979). Herbaceous species can colonize and dominate grasslands or the ground layer in forests. Eupatory (Ageratina adenophora) invades and dominates riparian forest understories along California's southern and central coast. Impacts of these ground-layer invaders have not been well studied, but it is suspected that they displace native herbs and perhaps suppress recruitment of trees.

Annual grasses and forbs native to the Mediterranean region have replaced most of California's native grasslands. Invasion by these species was so rapid and complete that we do not know what the dominant native species were on vast areas of bunchgrasses in the Central Valley and other valleys and foothills

around the state. The invasion continues today as medusa-head (Taeniatherum caput-medusae) and yellow starthistle (Centaurea solstitialis) spread to sites already dominated by other non-natives. Yellow starthistle is an annual that produces large numbers of seeds and grows rapidly as a seedling. It is favored by soil disturbance, but invades areas that show no sign of being disturbed by humans or livestock for years and has colonized several relatively pristine preserves in California, Oregon, and Idaho (Randall 1996b).

In some situations invasive, non-native weeds can prevent reestablishment of na tive species following natural or human-caused disturbance, altering natural suc ces sion. Ryegrass (Lolium multiflorum), which is used to reseed burned areas in southern California, interferes with herb establishment (Keeley et al. 1981) and, at least in the short term, with chaparral recovery (Schultz et al. 1955, Gautier 1982, Zedler et al. 1983).

Hybridization with Native Species

Some non-native plants hybridize with natives and could, in time, effectively eliminate native genotypes. The non-native Spartina alterniflora hybridizes with the native S. foliosa where they occur together. In some Spartina populations in salt marshes around south San Francisco Bay, all individual plants tested had non-native genes (Ayres et al. in press).

Promotion of Non-Native Animals

Many non-native plants facilitate invasions by non-native animals and vice versa. Myrica faya invasions of volcanic soils in Hawaii promote populations of non-native earthworms, which increase rates of nitrogen burial and accentuate the impacts these nitrogen-fixing trees have on soil nutrient cycles (Aplet 1990). M. faya is aided by the non-native bird, Japanese white-eye (Zosterops japonica), perhaps the most active of the many native and non-native species that consume its fruits and disperse its seeds to intact forest (Vitousek and Walker 1989).

EARLY INVASIONS BY NON-NATIVE PLANTS

The first recorded visit by European explorers to the territory now called California occurred in 1524, but people of Old World ancestry did not begin to settle here until 1769. Available evidence indicates that the vast majority of non-native plants now established in California were introduced after this time. There is compelling evidence that red-stem filaree (Erodium cicutarium), and perhaps a few other species, may have established even earlier, perhaps after being carried to the territory by roaming animals or by way of trading networks that connected Indian communities to Spanish settlements in Mexico (Hendry 1931, Hendry and Kelley 1925, Mensing and Byrne 1998). Once settlers began to arrive, they brought non-native plants accidentally in ship ballast and as contaminants of grain shipments and intentionally for food, fiber, medicine, and ornamental uses (Frenkel 1970, Gerlach 1998).

The number of non-native species established in California rose from sixteen during the period of Spanish colonization (1769-1824) to seventy-nine during the period of Mexican occupation (1825-1848) to 134 by 1860 following American pioneer settlement (Frenkel 1970). Jepson's A Manual of the Flowering Plants of California (1925), the first comprehensive flora covering the entire state, recognized 292 established non-native species. Rejmnek and Randall (1994) accounted for taxonomic inconsistencies between the 1993 Jepson Manual and earlier floras and found that Munz and Keck's 1959 A Flora of California included 725 non-native plants species and their 1968 A California Flora and Supplement included 975. The 1993 Jepson Manual recorded 1,023 non-natives, and subseqent reports in the literature have brought the number up

to 1,045 (Randall et al. 1998). Rejmnek and Randall (1994) remarked that, although non-native species continue to establish in California, the rate of increase in their number appears to be slowing after roughly 150 years of rapid growth.

Most non-native plants introduced to California in earlier times first established at coastal sites near ports and around missions and other settlements. In recent times, first reports of new non-native species have come from every major geographic subdivision of the state (Rejmnek and Randall 1994). Apparently, the great speed and reach of modern transportation systems and the increasing global trade in plants and other commodities have enabled non-natives to spread to sites throughout the state. A variety of human activities continue to introduce new species to California and to spread those that have established populations in only a few areas. For example, land managers still introduce non-native species to control erosion or provide forage for livestock. New ornamental plants and seeds are imported and sold. Movement of bulk commodities such as gravel, roadfill, feed grain, straw, and mulch transport invasive plant propagules from infested to uninfested areas (OTA 1993). The rate of spread is often alarming. For example, within California, yellow starthistle has expanded its range at an exponential rate since the late 1950s, increasing from 1.2 to 7.9 million acres by 1991 (Maddox et al. 1996, Thomsen et al. 1993).

Problems caused by invasive plants in California were recognized by Frederick Law Olmsted in 1865 in a report he filed on the newly set-aside Yosemite Valley, noting that, unless actions were taken, its vegetation likely would be diminished by common weeds from Europe. The report pointed out that this had already happened in large districts of the Atlantic States. Botanists and other students of natural history noted the establishment of non-native species in the state in published papers, and by the 1930s natural area managers in Yosemite and scattered parks and preserves around the state began controlling invading non-native species that were recognized as agricultural pests (Randall 1991). The issue was brought into mainstream ecology in the late 1950s with the publication of Charles Elton's book, The Ecology of Invasions by Animals and Plants (1958). Concern and interest among both land managers and researchers have grown since that time, particularly since the mid-1980s.

SPECIES MOST LIKELY TO BE INVASIVE

Many people have wondered if certain traits distinguish species that become invasive. Despite a great deal of study, no single answer presents itself, and researchers have been surprised by the success of some species and the failure of others. Studies conducted in 1980 in central California on Peruvian pepper (Schinus molle) and its close relative Brazilian pepper (Schinus terebinthifolius) failed to determine why the former was spreading in California (Nilsen and Muller 1980a, 1980b). Instead the studies suggested Brazilian pepper was the more invasive species. Recently, Brazilian pepper has been found to be invasive in southern California, so perhaps studies of this type do have some predictive power.

Despite these puzzling cases, recent work has pointed to several factors that may help to predict which species are likely to be invasive. In two studies the best predictor was whether a species was invasive elsewhere (Panetta 1993, Reichard and Hamilton 1997). For example, if a species native to Spain is invasive in Western Australia, it is likely to be invasive in California and South Africa as well. Rejmnek and Richardson (1996) analyzed characteristics of twenty species of pines and found that the invasive species were those that produce many small seeds and that begin reproducing within their first few years. When they extended the analysis to a group of flowering trees, these same characters usually discriminated between invasive and non-invasive species. This study and several others also found plants with animal-dispersed seeds, such as bush honeysuckles or ligustrums, are much more likely to be invasive in forested communities (Reichard 1997, Reichard and Hamilton 1997). It has also been suggested that species capable of reproducing both by seed and by vegetative growth have a better chance of spreading in a new land (Reichard 1997).

Self-compatible species, with individuals that can fertilize themselves, have been thought more likely to invade, since a single plant of this type could initiate an invasion (Baker 1965). However, many self-incompatible species are successful invaders, including some with male and female flowers on separate plants. It is also thought that plants dependent on one or a few other species for pollination, fruit dispersal, or the uptake of nutrients from the soil are less likely to invade new areas unless these organisms are introduced at the same time. As a group, figs may be relatively poor invaders because, with few exceptions, each species is pollinated by a distinctive species of wasp that is in turn dependent on that species of fig. However, the edible fig's pollinator was introduced to promote fruit production, and now the species is invasive in parts of California. Other plant invasions may be promoted by introduced animals as well. For example, honeybees boost seed production of invaders whose flowers they favor (Barthell pers. comm.). In Hawaii feral pigs promote the spread of banana poka (Passiflora mollissima) and other species by feeding voraciously on their fruits and distributing them in their scat, often in soil they have disturbed while rooting for food.

It has also been suggested that species with relatively low DNA contents in their cell nuclei are more likely to be invasive in disturbed habitats (Rejmnek 1996). Under certain conditions, cells with low DNA contents can divide and multiply more quickly, and consequently these plants grow more rapidly than species with higher cellular DNA content. Plants that germinate and grow rapidly can quickly occupy such areas and exclude other plants following disturbance.

It is generally agreed that a species is most likely to invade an area with a climate similar to that of its native range, but some non-native species now thrive in novel conditions. An analysis of the distribution of non-native herbs of the sunflower and grass families in North America indicated that species with a larger native range in Europe and Asia are more likely to become established and to have a larger range here than species with small native ranges (Rejmnek 1995). It is thought that species with large native ranges are adapted to a variety of climate and soil conditions and are more likely to find suitable habitat in a new area. This ability to cope with different conditions can be attributed in part to genetic plasticity (genetic differences among individuals of a species) or to phenotypic plasticity (the ability of any given individual of some species to cope with a variety of conditions). Another factor that may help to determine whether a plant will invade a site is whether it is closely related to a native species (e.g., in the same genus). Plants without close relatives appear more likely to become established (Rejmnek 1996).

A species may be more likely to become established if many individuals are introduced at once or if they are introduced repeatedly. Introductions of many individuals may help to ensure that they will mate and produce offspring and that there will be sufficient genetic variability in the population for the species to cope with a wider variety of conditions. In addition, if sites where the species can successfully germinate and grow are limited in number, the chance that at least one seed scattered at random will land on an appropriate site increases with the number of seeds dispersed. Chance may be important in other ways. For example, species that happen to be introduced at the beginning of a drought may be doomed to fail, although they might easily establish following a return to normal rainfall. An early introduction may by chance include no individuals with the genetic makeup to thrive in an area, while a later introduction may include several.

There is often a time lag of many decades between the first introduction of a plant and its rapid spread. In fact, some species that rarely spread today may turn out to be troublesome forty, fifty, or more years from now. This makes it all the more urgent that we find some way of determining which species are most likely to become invasive so that we can control them while their populations are still small.

HABITATS AND COMMUNITIES MOST LIKELY TO BE INVADED

Another question that has long intrigued ecologists is why some areas appear more prone to invasion than others. Again, many hypotheses have been advanced, but we have few solid answers. There is even some question about which areas have suffered the highest numbers of invasions, since this may differ depending on the type of organism considered and which species are regarded as firmly established. A given area may be highly susceptible to invasion by one type of organism and highly resistant to another, while the situation might be reversed in other areas.

It is generally agreed that areas where the vegetation and soil have been disturbed by humans or domestic animals are more susceptible to invasion. In North America disturbed sites are commonly invaded by species native to the Mediterranean region and the fertile crescent of the Old World where the plants had millennia to adapt to agricultural disturbances. Changes in stream flows, the frequency of wildfires, or other environmental factors caused by dam building, firefighting, and other human activities may also hinder survival of native plants and promote invasion by non-natives. Nonetheless, reserves and protected areas are not safe from exotic species. In a 1996 poll, sixty-one percent of National Park Service supervisors throughout the United States reported that non-native plant invasions are moderate to major problems within their parks. In more than half (fifty-nine percent) of The Nature Conservancy's 1,500 preserves exotic plants are considered one of the most important management problems (TNC 1996a, 1997).

It is also safe to say that remote islands in temperate and tropical areas appear to be highly susceptible to invasions by non-native plants and animals. For example, nearly half (forty-nine percent) of the flowering plant species found in the wild in Hawaii are non-native as are twenty-five percent of plants on California's Santa Cruz Island (Junak et al. 1995). Most remote islands had no large native herbivores, so pigs, cattle, sheep, and other grazers introduced by humans found the native plants unprotected by spines or foul-tasting chemicals. Introduced grazers often denuded large areas of native vegetation, leaving them open to colonization by introduced species adapted to grazing. There is also speculation that islands, peninsulas such as southern Florida, and other areas with low numbers of native species or without any representative or distinctive groups are more prone to invasion. For example, there are no rapidly growing woody vines native to the Hawaiian Islands, where several introduced vines have become pests. Some researchers theorize that where such gaps exist, certain resources are used inefficiently if at all. Such open niches are vulnerable to invasion by non-native species capable of exploiting these resources. Other researchers reject this concept, maintaining that open niches are impossible to identify in advance and that when new species move in they do not slip into unoccupied slots but instead use resources that would have been used by organisms already present.

History likely also plays a large role in determining the susceptibility of a site to invasion. Busy seaports, railroad terminals, and military supply depots are exposed to multiple introductions. People from some cultures are more likely to introduce plants from their homelands when they migrate to new regions. In fact, colonization of much of the Americas, Australia, and other areas of the world by western Europeans and the plants and animals from their homelands may go hand in hand, the success of one species promoting the success of others. European colonists were followed, sometimes preceded, by animals and plants with which they were familiar and that they knew how to exploit. The plants and animals benefited in turn when these people cleared native vegetation and plowed the soil.

DEFINITIONS OF TERMS USED IN THIS BOOK

Native plants are those growing within their natural range and dispersal potential. They are species or subspecies that are within the range they could occupy without direct or indirect introduction and/or care by humans. Most species can be easily classed as either native or non-native using this definition, but

there are some gray areas. Natural ranges should not be confused with political or administrative boundaries. Bush lupine (Lupinus arboreus), for example, may be thought of as a California native, but its native range is only along the central and southern coasts of the state. It is not native along the north coast, where it was intentionally planted outside its natural range (Miller 1988, Pickart this volume). All hybrids between introduced or domesticated species and native species are also non-native.

Non-native plants are those species growing beyond their natural range or natural zone of potential dispersal, including all domesticated and feral species and all hybrids involving at least one non-native parent species. Other terms that are often used as synonyms for non-native include alien, exotic, introduced, adventive, non-indigenous, non-aboriginal, and naturalized. With rare exceptions, conservation programs are dedicated to the preservation of native species and communities. The addition of non-native species rarely contributes positively to this unless these plants alter the environment in ways that favor native species as do some grazers and biological control agents.

Natural areas are lands and waters set aside specifically to protect and preserve undomesticated organisms, biological communities, and/or ecosystems. Examples include most national parks, state and federally designated wilderness areas, and preserves held by private organizations such as The Nature Conservancy and the National Audubon Society.

Wildlands include natural areas and other lands managed at least in part to promote game and/or non-game animals or populations of native plants and other organisms. Examples include federal wildlife refuges, some national and state forests, portions of Bureau of Land Management holdings, including some areas used for grazing, and some lands held by private landowners.

Pest plant and weed are used interchangeably in this book to refer to species, populations, and individual plants that are unwanted because they interfere with management goals and objectives. Plants regarded as pests in some wildlands may not be troublesome elsewhere. For example, the empress tree (Paulownia tomentosa) is a pest in deciduous forests of the eastern United States, particularly in the southern Appalachians, but it is not known to escape from cultivation in California, where it is used as an ornamental landscape tree. Some species that are troublesome in agricultural or urban areas rarely, if ever, become wildland weeds. The term environmental weeds is used by many Australians (Groves 1991, Humphries et al. 1991b) to refer to wildland weeds, but few North American land managers or researchers use this term.

Invasive species are those that spread into areas where they are not native, according to Rejmnek (1995), while other authors define as invasives only species that displace natives or bring about changes in species composition, community structure, or ecosystem function (Cronk and Fuller 1995, White et al. 1993). Most wildland weeds are both invasive and non-native, but not all non-native plants are invasive. In fact, only a small minority of the thousands of species introduced to California have escaped cultivation, and a minority of those that have escaped spread into wildlands.

Management of Invasive Species >

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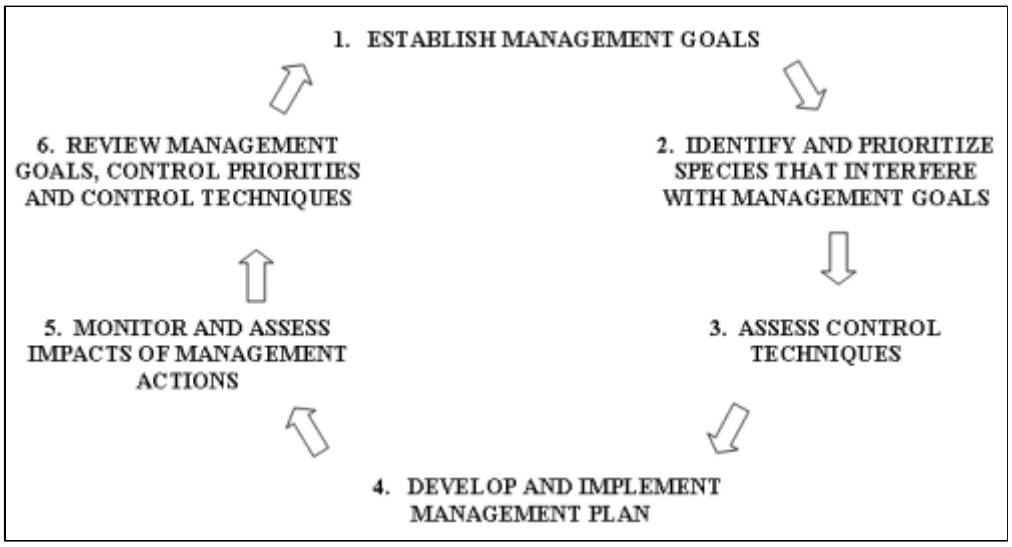
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Invasive Plants of California's Wildland

Management of Invasive Species

Marc C. Hoshovsk and John M. Randall

Before embarking on a weed management program, it is important to develop a straightfor-ward rationale for the actions you plan to take. We believe this is best accomplished using an adaptive management approach as follows: (1) establish management goals and objectives for the site; (2) determine which plant species or populations, if any, block or have potential to block attainment of management goals and objectives; (3) determine which methods are available to control the weed(s); (4) develop and implement a management plan designed to move conditions toward management goals and objectives; (5) monitor and assess the impacts of management actions in terms of effectiveness in moving toward goals and objectives; and (6) reevaluate, modify, and start the cycle again (Figure 1). Note that control activities are not begun until the first three steps have been taken.



It is vital to establish management goals before embarking on any management activities. What is it you want to protect or manage? Is your objective to protect or enhance a certain species or community, preserve a vignette of pre-Columbian America, preserve certain ecosystem attributes, or preserve a functioning ecosystem? A weed control program is best viewed as part of an overall restoration program, so focus on what you want in place of the weed, rather than simply eliminating the weed. Keep in mind that the ultimate purpose of a weed control program is to further the goal of preserving a species, community, or functioning ecosystem.

In many cases it will be easy to identify species that degrade the site or threaten to do so. If impacts of a

species are not clear, you may need to monitor its abundance and effects on the natural community. Set priorities to minimize your total, long-term workload. This often means assigning highest priority to preventing new invasions and to quickly detecting and eliminating any new invasions that occur. High priority should also be assigned to the species with the most damaging impacts, to infestations that are expanding rapidly, and to infestations that affect highly valued areas of the site. Also consider the difficulty of control. It is of little use to spend time and resources to attack an infestation you have little hope of controlling.

Consider all control options available: manual, mechanical, encouraging competition from native plants, grazing, biocontrol, herbicides, prescribed fire, solarization, flooding, and other, more novel techniques. Each of these methods has advantages and disadvantages, and often the best approach is to use a combination of methods. Frequently, one or more methods will not be appropriate for a given situation because they do not work well, their use is objectionable to people in the area, or they are too costly. Herbicides may kill important non-target plants. Mechanical methods often disturb soil and destroy vegetation, providing ideal conditions for establishment of weedy species. It will often be best to employ two or more methods. For example, cutting and herbicides or prescribed fire and herbicides have been used successfully in combination in many weed control programs.

Biological control can be an extremely selective control tool, but there is some risk that control agents may attack desirable species. The best known example of a biocontrol agent attacking desirable species is that of Rhinocyllus conicus, a beetle first released to control non-native thistles in North America in the 1960s that was recently found attacking native thistles and reducing their populations at some sites (Louda et al. 1997).

Some native animals use invasive non-native species for food and cover and may have difficulty finding replacements if infestations are removed and not replaced with non-invasive native or introduced species. For example, huge numbers of monarch butterflies (Danaus plexippus) roost in some groves of Eucalyptus globulus in coastal California. In addition, elimination of plants in a natural area can be alarming to some people, particularly when herbicides are used, so it is important to explain the threats posed by the pest and the reasons why you chose the methods you did.

There is much room for improvement in control methods for many of the species described in this book. Readers may want to experiment with methods that may more effectively and efficiently control these invaders and promote native species.

The Bradley Method is a sensible approach to weed management (Bradley 1988, Fuller and Barbe 1985). In this approach, weed control is begun in portions of the site with the best stands of desirable native vegetation (those with few weeds) and proceeds slowly to areas with progressively worse weed infestations. This is similar to Moody and Mack's (1988) advice to attack outlying satellite weed populations first rather than larger, denser source populations. They based this advice on modeling work that indicated that the rate of spread of small satellite poplations is generally significantly higher than that of older, larger populations and that containing or eliminating the outliers saves time and effort in the long run. The Bradley Method dictates that the area under control should expand at a rate that allows previously treated areas to be monitored and kept in satisfactory condition. It also advocates the use of techniques that minimize damage to native plants and disturbance to the soil so that the natives can thrive and defend against reinvasion. This approach is particularly promising for small preserves or sites with access to large pools of volunteer labor. More detailed information on the Bradley Method is contained in Fuller and Barbe (1985).

PREVENTION

The most effective and efficient weed control strategies are preventing invasions by new plants species and quickly detecting invasions that occur so weeds can be eradicated or contained before they spread. The California Department of Food and Agriculture (CDFA) has long recognized this, and the state's Noxious Weed List gives highest priority to species that either are not yet established in the state or whose populations are not yet widespread. The state's native species will be better protected if new invaders are detected quickly and word of their discovery is communicated to those who can take action to prevent their spread, such as the staff at the CDFA Control and Eradication Branch or Plant Pest Diagnostics Branch.

There are already at least 1,045 non-native plant species established in California (Randall et al.1998), and more continue to arrive and become established. If allowed to spread, some of these new species could impact native species and communities as severely as yellow starthistle and tamarisk do now. Preventing or stopping just one new invasive weed would be of greater conservation benefit in the long run than far more costly and difficult efforts to control an already widespread pest.

Taking precautions in normal resource management activities can halt or slow the establishment and spread of weeds in a given area. Wise precautions include: removing seed sources from roads, trails, rights-of-way, watercourses, and other dispersal routes; closing unnecessary roads and trails where possible; planning work projects to minimize soil disturbance and reestablish vegetation as quickly as possible where disturbance does occur; limiting the use of construction materials such as gravel, fill, mulch, straw, and seed mixes that may carry weeds or buying from suppliers who guarantee their products are weed-free; washing vehicles and equipment to remove weed seeds and other propagules before they are used in another area; follow-up monitoring of work sites to detect new weed populations while they are still small and easily controlled; and public education and outreach regarding the importance of weed detection and prevention of invasion.

ERADICATION

Eradication is the complete elimination of a species from a given area. The great appeal of eradicating a weed is, of course, that once the project achieves success no more work is required and the species cannot spread unless it is re-introduced. Unfortunately, it is rarely possible to eradicate an established weed from a large area. In fact, the history of CDFA's eradication projects indicates that there is little likelihood of eradicating a species from California once it has spread to a few tens of acres in the state.

It may be possible to eradicate a weed from a given area, such as a preserve or national park if it has not yet become widespread there, but it is likely to re-invade from adjacent lands unless there is some barrier that will prevent it from doing so. Eradication is most likely when the species has just begun to establish in a new area, which underscores the importance of efforts to detect new invaders at national, state, and local levels.

PHYSICAL CONTROL

Physical methods of weed control generally are labor intensive and often are used for small populations or where other control methods are inappropriate, such as near sensitive water supplies. Nonetheless, physical methods have been used successfully by volunteer groups and paid workers to control weed infestations on several large sites in California (e.g., Pickart and Sawyer 1998). Physical methods can be highly selective, targeting only the pest species, but they can also disturb the soil or damage nearby vegetation, thereby promoting germination and establishment of weedy species. Physical control methods may also produce large amounts of debris, disposal of which is sometimes difficult.

Physical control methods range from manual hand pulling of weeds to the use of hand and power tools to uproot, girdle, or cut plants. Two companies produce tools specifically for pulling shrubs such as scotch broom, tamarisk, and Russian olive. The Weed Wrench (see Resources section) and the Root Jack (see Resources section) are lever arms with a pincher or clamp at the bottom that grips the plant stem. Once the stem is secured, the user leans back, tightening the clamp in the process. After a little rocking, the entire plant comes up, roots included (Hanson 1996). Other tools for weed control, including girdling knives, axes, machetes, loppers, clippers, chainsaws, and brush cutters, are available from hardware stores and gardening and forestry supply companies. Various attachments are available for bulldozers and tractors to clear and uproot woody plants. Brush rakes or blades may be mounted on the front of the bulldozer, and brushland disks or root plows may be pulled behind. Mowing can prevent seed formation on tall annual and perennial weeds and deplete food reserves of shoots and roots. Unfortunately, repeated mowing can favor low-growing weeds or damage desirable native species (Ashton and Monaco 1991).

Prescribed Fire

Fire can be an effective means of reducing weed infestations, particularly for shrub by weeds and in native communities that evolved with fire. Fire may sometimes be the only element necessary to give native species a chance to recover. Fire may also be used to eliminate old vegetation and litter in areas infested with perennial herbs such as fennel (Foeniculum vulgare) or leafy spurge (Euphorbia esula) prior to treating the area with herbicide. This allows more herbicide to reach the living leaves and stems of target plants, potentially enhancing its effectiveness. Fire can also be used to induce seeds of some species to germinate so the seedbank can be flushed and the resulting seedlings can then be killed with another fire or some other method (e.g., Bossard 1993).

Conducting a prescribed burn is not a simple or risk-free operation. Managers considering prescribed burning should be trained and certified and should work close ly with the local office of the California Department of Forestry and Fire Protection to ensure safe, effective, and legal burns. Good logistical planning, coordination of work teams, careful timing with respect to weather (winds, moisture conditions), co or di na tion with air quality agencies, and attention to other details are required to carry out an effective and safe burn. In most parts of California it is necessary to address air quality concerns and to obtain permission from the regional air quality board. Escaped fires are costly and can be disastrous.

Prescribed fires may promote certain invasive, non-native species, and so should be used with caution. Non-native annual and biennial species, such as cheat grass (Bromus tectorum) and bull thistle (Cirsium vulgare), are most likely to be favored in the years immediately following a burn and in repeatedly burned areas. Hot fires can also sterilize the soil, volatilizing important nutrients and killing microorganisms on which native plants rely. Removal of vegetation by fire can also increase soil erosion and stream sedimentation. Construction of firebreaks and associated soil disturbance can increase erosion and provide a seedbed for invasive weeds.

Blowtorches and flamethrowers can also be used to burn individual plants or small areas. This method has been used with some success on thistles in several areas. Flamethrowers have also been used to heat-girdle the lower stems of shrubs such as scotch broom (Cytisus scoparius). This technique has the advantages of being less costly than basal and stem herbicide treatments and suitable for use during wet weather. On the other hand, it is time-consuming and not viable in areas where wildfire is a danger.

Flooding and Draining

Prolonged flooding can kill plants that infest impoundments, irrigated pastures, or other areas where water

levels can be controlled. This method may be even more effective if plants are mowed or burned before flooding. Spotted knapweed (Centaurea maculosa) is sensitive to flood ing, and its populations can be reduced by flood irrigation in pastures. Flooding may also help to control non-natives by promoting the growth and competitive ability of certain native species in some situations. Unfortunately, flood ing will not kill the seeds of many target species.

Draining water from ponds and irrigation canals may control aquatic weeds such as reed canary grass (Phalaris arundinacea) (Schlesselman et al. 1989). Drainage can be conducted in different ways, including seasonal, intermittent (within-season), or par tial draw downs (McNabb and Anderson 1989).

Mulching

Mulching excludes light from weeds and prevents them from photosynthesizing. Commonly used mulches are hay, manure, grass clippings, straw, sawdust, wood chips, rice hulls, black paper, and black plastic film. The most effective mulches are black paper or plastic because of their uni form coverage. Particle mulches cannot prevent all weeds from breaking through (Schlesselman et al. 1989). Mulch materials and application can be expensive and may be suitable only for small infestations. Particle mulches should be weed-free to avoid introduction of other weeds.

Soil Solarization

Soil solarization is a technique for killing weed seeds that have not yet germinated. A clear polyethylene plastic sheet is placed over moist soil and kept in place for a month or more. The incoming solar radiation creates a greenhouse effect under the plastic, increasing soil temperatures. High temperatures kill some seeds outright and weaken others, making them more susceptible to attack by pathogens (Schlesselman et al. 1989).

BIOLOGICAL CONTROL

Biological control, or biocontrol, involves the use of animals, fungi, or other mi crobes that prey upon, consume, or parasitize a target species. Target species are fre quent ly non-natives whose success in new environments may be due in part to the absence of their natural predators and pathogens.

Classical biological control involves careful selection and introduction of one or more natural enemies to the target species' new habitat to reduce target populations. Successful control programs of this kind result in permanent establishment of the control agent or agents and permanent reduction in target species populations. Such programs are not designed to eliminate the target species completely, and it may take repeated releases to ensure the establishment of an agent. It may take years or decades before their effects are obvious. Some of the greatest strengths of classical biological control are that once an agent is established it will last indefinitely and it may spread on its own to cover most or all of the area infested by the weed, generally without additional costs. On the other hand, these strengths can become liabilities if the agent begins to attack desirable species as well as the pest it was introduced to control. Biocontrol researchers take great pains to locate and use agents that are highly specific to the targeted weed. This contributes to the high cost and long time required for development and approval of new biological control agents. Several of the species covered in this book are the subjects of ongoing classical biological control programs.

As opposed to classical biocontrol, inundative or augmentative biocontrol involves mass releases of pathogens whose effects on the target are normally limited by their inability to reproduce and spread. Inundative biocontrol agents that are non-native and/or not target-specific may be sterilized or otherwise

rendered incapable of establishing permanent populations before they are released. Because they do not become established, they must be reared and released again each time weed populations erupt. There have, however, been instances in which mistakes or back mutations allowed some of these species to establish permanent wild populations.

The USDA must approve biocontrol agents for use. Approved biological control agents have been studied, and their host specificity determined. Accidentally introduced species have unknown host species, are not permitted for distribution, and should not be redistributed. If you have questions about any potential biocontrol agents, contact the CDFA Biological Control Program (see Resources section).

Competition and Restoration

The use of native plants to outcompete alien weeds is a frequently overlooked but potentially powerful technique. Sometimes the natives must be planted into the habitat and given some care until they are well established. This may be appropriate where a native forest community is to be reestablished in an old field currently occupied by a thick cover of alien grasses and forbs. Reseeding with native species also works well in some grasslands. In other cases all that may be required is time; the native community may reestablish itself once human-caused disturbance ceases. Even in these cases, it may be important to locate and remove certain weeds capable of hindering succession. You can also enhance other weed control methods by encouraging competition from native species.

Ideally, seeds or cuttings used in restoration should be collected on the site or from adjacent properties. Unfortunately, in many cases the only available or affordable seeds and plants are from distant or unidentified populations. Potential impacts of using seeds and plants collected at distant sites include project failure if genotypes used are unable to survive conditions on the site, introduction of diseases, and loss of genetic diversity through overwhelming or contaminating locally adapted genotypes.

Grazing

Grazing animals may be used to selectively control or suppress weeds, but grazing is also known to promote certain invaders in some circumstances. Cattle, sheep, goats, geese, chickens, and grass carp have been used to graze undesirable species at sites around the nation. Often grazing must be continued until the weed's seedbank is gone, as the suppressed plants may otherwise quickly regain dominance. Another drawback to using grazing animals is that they sometimes spread weed seeds in their droppings.

CHEMICAL CONTROL

Herbicides are chemicals that kill or inhibit plant growth. They can be extremely effective tools when used to eliminate certain species. They can also be dangerous and should be used only after careful consideration of other options and only with extreme care. Each species treatment in this book provides specific information on the herbicides, rates, and times that have been found most effective against that species. However, the effectiveness of a given treatment may vary with climate and environmental conditions, and some populations of a given species may be more tolerant of, or even resistant to, a particular herbicide than other populations of the same species. It may be necessary to conduct trials to identify the most effective techniques for controlling a particular problem species.

The most important safety rule for herbicide use is to read the label and follow the directions. Applicators must wear all protective gear required on the label of the herbicide they are using. It is also important to adopt or develop protocols for storing, mixing, transporting, cleaning up, and disposing of herbicides and for dealing with medical emergencies and spills.

California's programs to regulate pesticides and pesticide applicators are regarded as the most stringent in the nation and as such are the standard against which many other states measure their programs. California's Department of Pesticide Regulation reviews health effects of pesticides independently of the federal Environmental Protection Agency and has more stringent registration requirements. California also has the most stringent pesticide use reporting requirements. Agricultural pesticide use is broadly defined and includes applications made in nature preserves, parks, golf courses, and cemeteries and along roadsides. Such applications are regulated by the CDFA, and county agricultural commissioners' offices enforce the regulations. Pest control businesses, agricultural pest control advisors, and pest control aircraft pilots must register in each county where they operate. Anyone who wants to buy a restricted pesticide must have a permit from the commissioner's office. All agricultural pesticide use must be reported monthly to the commissioner's office. Home-use pesticides (those purchased over-the-counter in small volumes) are exempt. There are also more detailed requirements for applicator training and protective gear. Inspectors from county commissioners' offices conduct thousands of compliance inspections every year and have the authority to halt pesticide applications if they believe an applicator's safety is in danger or the pesticide is likely to drift off-site. Contact your county agriculture commissioner's office for details on training and other regulations before purchasing or applying herbicides. County agricultural agents can answer questions about both wildland and agricultural uses of herbicides, as can certified herbicide applicators.

Environmental risks posed by herbicide use include drift, volatilization, persistence in the environment, groundwater contamination, and harmful effects on animals. Drift and resulting death or damage to non-target plants may occur when herbicides are applied as a spray; chances of drift increase with decreasing size of spray droplets and increase with increasing wind speeds. Volatilization and subsequent condensation on non-target plants resulting in their death or damage is another risk of herbicide use. Some herbicides are much more likely to volatilize than others, and likelihood of volatilization increases with increasing temperature. Some herbicides are more persistent in the environment and thus have a greater opportunity for harmful effects. Most herbicides will decompose more rapidly with increasing temperature and soil moisture, and some are decomposed by ultra-violet light. Chances of groundwater contamination generally increase with increasing solubility and persistence of the herbicide, increasing porosity of the soil, and decreasing depth to the water table. Herbicides with potential to cause direct harm to animals (e.g., diquat) are rarely used in natural areas. Animals may, however suffer from indirect impacts if, for example, their food plants are killed.

In order to minimize these environmental risks, look for compounds that can be used selectively (to kill one or a few species); that degrade rapidly under conditions found at the site; that are immobilized on soil particles and unlikely to reach groundwater; that are non-toxic to animals; and that are not easily volatilized.

Also choose an application method that minimizes risks of harming non-target plants and environmental damage. Possible application methods include: spraying on intact, green leaves (foliar spray); spot application (usually from backpack or handheld sprayer); wick application; boom application (from a boom mounted on a vehicle or aircraft); single spot or around the circumference of the trunk on intact bark (basal bark); cuts in the stem (frill or hack and squirt); injected into the inner bark; cut stems and stumps (cut stump); spread in pellet form at the plant's base; and sprayed on the soil before seeds germinate and emerge (pre-emergent).

Mix a dye with the herbicide so applicators can see which plants have been treated and if they have gotten any on themselves or their equipment. Some pre-mixed herbicides include a dye (e.g., Pathfinder II® includes the active ingredient triclopyr, a surfactant and a dye). Ester-based herbicides such as Garlon4® require oil-soluble dyes such as colorfast purple, colorfast red, and basoil red (for use in basal bark

treatments), which are sold by agricultural chemical and forestry supply companies. Clothing dyes such as those produced by Rit® will work in water-soluble herbicides such as Garlon3A®, and they are inexpensive and available at most supermarkets and drugstores.

Detailed information on herbicides is available in the *Weed Science Society of America's Herbicide Handbook* (Ahrens 1994) and *Supplement* (Hatzios 1998). This publication gives information on nomenclature, chemical and physical properties, uses and modes of action, precautions, physiological and biochemical behavior, behavior in or on soils, and toxicological properties for several hundred chemicals (see Resources section). Critical reviews of several common herbicides are available at a small charge from the Northwest Coalition for Alternatives to Pesticides (see Resources section).

Beyond this book, additional information and training on weeds and their control can be found by contacting local universities, extension agents, county weed and pest supervisors, and the California Department of Food and Agriculture. The California Exotic Pest Plant Council can direct readers to other local experts on weeds. The Bureau of Land Management offers an Integrated Pest Management and Pesticide Certification course in Denver, Colorado, and the Western Society of Weed Science offers a Noxious Weed Management Short Course in Bozeman, Montana.

View plant list by:
[Scientific Name] [Common Name] [Authors] [Category]

Authors >

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SOUTHERN CALIFORNIA COAST STEELHEAD RECOVERY PLANNING AREA

CONSERVATION ACTION PLANNING (CAP) WORKBOOKS
THREATS ASSESSMENT SUMMARY



Matilija Creek, Ventura River watershed, Ventura County

Prepared for:

NOAA-NMFS
Southwest Region
735 State Street, Suite 616
Santa Barbara, CA 93101

Contact: Mark Capelli
(805) 963-6478

Prepared by:

Hunt & Associates Biological Consulting Services
5290 Overpass Rd, Suite 108
Santa Barbara, CA 93111

Contact: Lawrence E. Hunt
(805) 967-8512

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Southern California Coast ESU
Steelhead Threats Assessment Methodology

Introduction. The Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service (NMFS) contracted with Lawrence E. Hunt of Hunt & Associates Biological Consulting Services to provide technical support in developing Recovery Plans for steelhead (*Oncorhynchus mykiss*) populations in the South-Central California Coast Steelhead Evolutionarily Significant Unit (ESU) and the Southern California Coast Steelhead ESU. Specifically, Hunt & Associates was tasked with reviewing existing information on steelhead habitat conditions and assessing the magnitude and extent of threats to steelhead and their habitats and developing recovery planning actions across these two ESUs. This document summarizes the results of an assessment of threats and sources of threats to steelhead in the Southern California Coast Steelhead ESU, which includes coastal steelhead populations in the Santa Maria River system in Santa Barbara County southward to the Tijuana River watershed (U.S. portion only) along the United States-Mexico border. Recovery action matrices for each watershed in both ESUs are provided in a separate document.

Methods. Thirty-two coastal basins, representing 46 drainages, were selected for threats assessment analysis and recovery planning actions in this ESU (see Table 1 in Threats Assessment Summary section). Boughton et al. (2006) identified these watersheds as supporting historical and extant steelhead populations. Information on existing steelhead habitat conditions in the project area was gathered from a broad range of books, peer-reviewed scientific publications, technical reports, federal, state, and local environmental documents, EIR/EISs, management plans, passage barrier assessments, habitat evaluations, and field surveys, as well as specific information given by stakeholders and other interested parties at a series of public workshops held throughout both ESUs in 2007. These sources are listed in the bibliography in this document.

A separate CAP Workbook was established for each of the 46 component watersheds analyzed in this ESU. The reader is directed to any of these workbooks for the following discussion:

The Conservation Action Planning (CAP) Workbook, a relational database developed by The Nature Conservancy to identify conservation targets, assess existing habitat conditions, and identify management issues was used to organize and evaluate the large amount of information on current steelhead habitat conditions and threats to steelhead in these watersheds, as gleaned from widely disparate sources. The CAP Workbook methodology provides a number of benefits in assessing the magnitude and extent of threats to steelhead and their habitats:

- It can use quantitative and qualitative (i.e., professional judgment) measures of existing habitat conditions;
- It provides an objective, consistent means for determining changes in the status of each conservation target (steelhead life history stage) over time;

- It provides an objective, consistent way to compare the status of a specific target between watersheds;
- It provides an overall assessment of a watershed's "health" or viability and allows objective comparisons to other watersheds;
- It focuses recovery actions by identifying past, current, and potential threats to steelhead and their habitats;
- It provides a central repository for documenting current knowledge and assumptions about existing conditions;
- It can be continually updated as information on the target's biology and/or existing conditions within watersheds change, and;
- It creates the foundation upon which recovery actions can be monitored and updated, based on changing current conditions.

The CAP Workbook process uses available information on the target's biology in an explicit, objective, consistent, credible, and transparent assessment of current habitat conditions. Assessing threats to particular or multiple life stages does not require "perfect" information. Rather, the CAP Workbook allows the user to input quantitative as well as qualitative (professional judgment) information in order to determine what existing conditions are and what healthy targets should look like. The Workbook is flexible, iterative, and adaptable—it uses the best available knowledge at the time, and can be updated as additional information becomes available.

CAP Methodology—Conservation Targets. The user identifies specific "conservation targets" for analysis. The conservation targets in this case are steelhead life history stages: egg, fry, smolt, and adult. In an effort to balance the specificity inherent in a life history stage approach, a more general conservation target, "Multiple Life Stages", also was established to allow landscape-scale land use and habitat assessment, based on information derived from GIS=based analysis of entire watersheds (see section below describing relationship between Kier Associates' and Hunt & Associates' CAP Workbook analyses).

CAP Methodology—KEAs. Assessing the "viability" or "health" of a particular conservation target (life history stage) begins with identifying "Key Ecological Attributes" (KEA) for each target. KEAs are aspects of the conservation target's biology or ecology such that if missing or severely degraded, would result in loss of that target over time. KEAs, such as substrate quality, non-native species, food availability, road density, water quality, etc., were identified for each target and measurable indicators, such as turbidity, water temperature, aquatic invertebrate species richness, presence or absence of non-native predators, miles of road/square mile of watershed, etc., were identified in order to characterize existing conditions in the component watersheds. KEAs were grouped into three categories, based roughly on spatial scale:

- *Size*: target abundance (i.e., number of adult steelhead);

- *Condition*: a measure of the biological composition, structure, and biotic interactions that characterize the target's occurrence (i.e., generally a local measure of habitat quality or composition), and;
- *Landscape Context*: an assessment of the target's environment (i.e., landscape-scale processes, such as connectivity, accessibility of spawning habitat; hydrology).

CAP Methodology—Current Indicators. The range of variation found in each indicator is subdivided into four more or less subjective, but discrete, categories: "Poor", "Fair", "Good", or "Very Good". The current condition of a specific indicator, taken from a field measurement, literature source, or professional judgment, is assigned to one of these four discrete rating categories (see the description of indicators used in the CAP steelhead analyses and the justification for these discrete indicator categories in Kier Associates and National Marine Fisheries Service (2008)). Functionally however, there are essentially two states for the indicator as it relates to the species: "poor-fair", in which the indicator exceeds or barely meets the requirements for species survival and the population is in danger of extirpation, and "good-very good", where habitat conditions are favorable for species persistence.

The CAP Workbook can use local-, regional-, and landscape-scale indicators. For example, land use indicators, such as density of roads per square mile of watershed, has been widely employed as a landscape-scale metric of watershed "health" for salmonids throughout the western United States (see discussion in Kier Associates and NMFS, 2008). These types of landscape-scale metrics were used in the present document to overcome logistical and analytical problems inherent in local-scale metrics of steelhead habitat quality, e.g, water temperature, that exhibit extreme spatial and temporal variation.

The conceptual goal of establishing measurable and objective indicators sometimes exceeded current knowledge of existing habitat conditions in the component watersheds. For example, turbidity is an important steelhead habitat indicator. For the steelhead fry life stage, turbidity was defined as the "number of days turbidity exceeded 25 NTUs" and the "poor" category was defined as "> 30 days during fry development period", while "very good" was defined as "< 10 days during fry development period", with "fair" and "good" conditions intermediate between these boundaries. Currently, there is little or no systematic and widespread collection of turbidity data in most of the subject watersheds drainages to permit a useful analysis. In these instances, subjective information, such as observations of mass wasting of slopes, descriptions of point and non-point sediment inputs, etc., were used to qualitatively assess a current condition and rating for this indicator. A key feature of the CAP Workbook process is its ability to use quantitative information as well as professional judgment to assess current habitat conditions. Because the CAP Workbook analysis is iterative, results can be improved as better quantitative information becomes available.

CAP Methodology—Stresses and Sources of Stress (Threats). The next step in the CAP Workbook analysis is identifying a series of stresses to each steelhead life history stage. These stresses are basically altered KEAs and, ideally, should directly affect the life stage, e.g., degraded hydrologic function, increased turbidity, presence of non-native predators, increased substrate embeddedness). In this CAP Workbook analysis however, the GIS-based surrogate variables used for the "Multiple Life Stages" conservation target actually are sources of stress, not direct stressors on steelhead life stages (e.g., increased road density (a source of stress) contributes indirectly to increased turbidity (a direct stressor). This resulted in some level of redundancy in the analyses. The user assesses the severity (very high, high, medium, or low) and geographic scope (very high, high, medium, and low) of each stress, then the CAP Workbook assigns an overall stress rank (very high, high, medium, or low) to that stress.

The CAP Workbook automatically inputs the overall rank of each stress into a table that relates the stress to a series of anthropogenic sources of stress (also called Threats) that have been identified by the user as relevant to that watershed (e.g., roads, grazing practices, logging, recreational facilities, agricultural conversion of watershed lands, dams, groundwater extraction, in-channel mining, etc.). The user ranks each threat on the basis of its relative "contribution" (very high, high, medium, or low) and "irreversibility" (very high, high, medium, or low) to each stress (e.g., increased turbidity). The CAP Workbook then ranks the threat (source of stress) as "Very High', "High", "Medium", or "Low" and inputs that rank into the next step of the analysis. This process was repeated for each conservation target (steelhead life history stage--egg, fry, juvenile, smolt, and adult), as well as the "Multiple Life Stages" conservation target.

CAP Methodology—Summary of Threats. The CAP Workbook ranks the threat sources for the various conservation targets (life history stages) from the previous analysis into a "Summary of Threats" table that lists all the threat sources for all life history stages and assigns a composite "Overall Threat Rank" to each threat source (e.g., dams and surface water diversions), as well as an overall threat rank to that watershed for all threat sources combined. The Workbook derives a second table ("Stress Matrix") that shows the rank of each stress on each life history stage. The final step in the steelhead CAP analysis was the derivation of a third table entitled, "Overall Viability Summary", that ranks the viability of each life history stage and KEA category (size, condition, and landscape context) by calculating a composite rank of the current habitat indicators from the "Viability" page of the workbook, as well as an overall "Project Biodiversity Health Rank", which is a measure of watershed "health" based on current habitat conditions. The first and third summary tables proved most useful in analyzing stresses and sources of stress to steelhead in the South-Central California Coast and Southern California Coast steelhead ESUs.

Data Gaps. The pages in the CAP Workbooks for the present study have many blank cells. Blank cells indicate a lack of available information. Watersheds that have been intensively studied have fewer blank cells than watersheds with few studies. In general, the level of available information on current watersheds conditions, with a few notable

exceptions, increased dramatically south of the Santa Monica Mountains (e.g., the Mojave Rim Biogeographic Population Group watersheds and most of the Orange and San Diego county watersheds). As previously stated, a feature of the CAP Workbook methodology is the ability to update the analyses as information becomes available.

Relationship between CAP Workbook analyses developed by Hunt & Associates and Kier Associates. The CAP Workbooks analyses prepared by Kier Associates are meant to complement, not duplicate, those prepared by Hunt & Associates. During the initial stages of CAP Workbook analyses by Hunt & Associates, it was determined that, in some cases, surrogate indicators covering regional spatial scales and derived from GIS-based watershed analysis, might be useful in overcoming the spatial and temporal problems associated with habitat indicators that rely on point measurements, such as water temperature, turbidity, riparian corridor width and composition, etc. A separate conservation target category "Multiple Life Stages" was developed for the CAP Workbook analyses that used GIS-based surrogate indicators as input. Surrogate indicators, such as density of roads per square mile of watershed, density of roads within 300 feet of streams per square mile of watershed, human population density, percent of watershed converted to agriculture; percent of watershed converted to impervious surfaces, percent of watershed burned in past 25 years, and others provided a general measure of existing watershed conditions as they affect multiple steelhead life history stages. For example, road density, especially riparian road density, and percent of watershed as impervious surface, has strong predictive power of general habitat conditions for steelhead because paved surfaces have manifold effects on habitat quality, water quality, and hydrology of streams.

Kier Associates was subsequently contracted by NOAA-NMFS to provide GIS-based metrics and values for individual watersheds as support for the CAP Workbook analyses in-progress by Hunt & Associates. Kier Associates analyzed 54 watersheds across both steelhead ESUs (23 in the South-Central California Coast Steelhead ESU and 31 in the Southern California Coast Steelhead ESU), using the GIS-based regional indicators. Their workbooks also include information on a small number of point-based measurements, such as dissolved oxygen, water temperature, etc.

The Kier Associates' workbooks supplement those prepared by Hunt & Associates. Hunt & Associates' workbooks are based on review of a large number and broad range of ground-based steelhead surveys, habitat and barrier assessments, and other fieldwork, as well as the GIS-based indicators for the "Multiple Life History" target category developed by Kier Associates. Hunt & Associates developed CAP Workbooks for 73 watersheds across both steelhead ESUs (27 in the South-Central California Coast Steelhead ESU and 46 in the Southern California Coast Steelhead ESU).

Kier Associates' workbooks are provided as a separate document (Kier Associates and NMFS, 2008). In order to avoid confusion and explain discrepancies in the overall assessment of steelhead habitat conditions in watersheds found in the present document and Kier Associates' document, Table 1 compares the results of the two documents for

watersheds in the Southern California Coast Steelhead ESU. It should be noted that the difference between a "poor" and "fair" habitat rating or a "good" and "very good" rating is often a matter of professional judgment and does not represent important differences in habitat quality. Of real concern, are habitat differences between the "poor-fair" and "good-very good" indicator categories. Table 1 explains discrepancies between "poor-fair" and "good-very good" categories between the Hunt & Associates and Kier Associates CAP Workbook analyses.

Table 1. Assessment of Overall Habitat Conditions for Steelhead in Component Watersheds in the Southern California Coast Steelhead ESU Between Two CAP Workbook Analyses*

Watershed	Steelhead Habitat Rating		Reasons for Discrepancy**
	Hunt & Associates	Kier Associates	
Santa Maria River			
Santa Ynez River			
Ventura River			
Santa Clara River			
Gaviota Creek			
Arroyo Hondo			**Hunt & Associates rates passage barrier at Highway 101 as severe, but being re-designed for fish passage. Override function used to rate this relatively undisturbed watershed as "good"**
Tecolote Creek			
Goleta Slough			
Mission Creek			
Montecito Creek			
Carpinteria Creek			
Rincon Creek			
Big Sycamore Creek			
Arroyo Sequit			

Malibu Creek			
Las Flores Canyon Creek			
Topanga Canyon Creek			
Los Angeles River			
San Gabriel River			
Santa Ana River			
San Juan/Trabuco Creek			
San Mateo Creek			
San Onofre Creek			
Santa Margarita River			
San Luis Rey River			
San Dieguito River			
San Diego River			
Sweetwater River			
Otay River			
Tijuana River			

*** Overall habitat condition rating taken from "Project Biodiversity Health Rank" rating in "Overall Viability Summary" table in Summary section of individual CAP Workbooks (composite rating of habitat conditions for all steelhead life history stages combined). Watersheds analyzed only by Hunt & Associates are not shown.**

**** Pervasive discrepancies between Hunt * Associates vs Kier Associates "poor" and "fair" categories here due to fewer number of indicators used in the latter analyses.**

Key: dark green = very good conditions; light green = good conditions; yellow = fair conditions; red = poor conditions.

The results of the two analyses closely agree. There are four discrepancies (bolded table entries) that can be explained by the type (point measurements) and lower number of indicators used in each analysis by Kier Associates. This is a consistent difference between Kier Associates' and Hunt & Associates' workbooks. As the number of indicators decreases, the relative weight given to each indicator in the analysis correspondingly increases, and if these indicators are based on point measurements, such as water temperature or dissolved oxygen, that exhibit extreme spatial and temporal variation, then different results can be obtained. Despite these differences, again, the results closely agree.

Southern California Coast Steelhead Recovery Planning Area
Threats Assessment Summary

Location and Component Watersheds. The Southern California Coast Steelhead Environmentally Significant Unit (ESU) encompasses five Biogeographic Population Groups (BPGs) that extend from the southern end of the Santa Lucia Mountains southward through the Transverse and Peninsular ranges to the Mexican border, and includes portions of San Luis Obispo, Santa Barbara, Kern, Ventura, Los Angeles, Riverside, San Bernardino, Orange, and San Diego counties. These BPGs vary greatly in size, from the Santa Monica Mountains BPG at about 107,500 acres to the Monte Arido Highlands BPG, which encompasses over 2.95 million acres. The component watersheds of the five BPGs analyzed in this document are listed in Table 1 and the results of the Conservation Action Planning (CAP) Workbook analyses are presented in individual summaries for each BPG.

Table 1. Southern California Coast Steelhead ESU Component Biogeographic Population Groups, Watersheds, and Corresponding CAP Workbooks.

Biogeographic Population Group	Watershed	CAP Workbook
Monte Arido Highlands	Santa Maria River	Main stem Santa Maria River
		Cuyama River
		Sisquoc River
	Santa Ynez River	Main stem Santa Ynez River (lower, middle, and upper reaches)
	Ventura River	Main stem Ventura River
		Coyote Creek
		Main stem Matilija Creek
		North Fork Matilija Creek
		San Antonio Creek
	Santa Clara River	Main stem Santa Clara River
		Santa Paula Creek
		Sespe Creek
		Piru Creek
Conception Coast	Jalama Creek	Jalama Creek
	Canada de Santa Anita	Canada de Santa Anita
	Gaviota Creek	Gaviota Creek
	Arroyo Hondo Creek	Arroyo Hondo Creek
	Tecolote Creek	Tecolote Creek
	Goleta Slough	San Jose, Atascadero, San Pedro, and Maria Ygnacio creeks
	Mission Creek	Mission Creek
	Montecito Creek	Montecito Creek
	Carpinteria Creek	Carpinteria Creek
	Rincon Creek	Rincon Creek
Santa Monica Mountains	Big Sycamore Canyon Creek	Big Sycamore Canyon Creek
	Arroyo Sequit	Arroyo Sequit
	Malibu Creek	Malibu Creek
	Las Flores Canyon Creek	Las Flores Canyon Creek
	Topanga Canyon Creek	Topanga Canyon Creek
Mojave Rim	Los Angeles River	Main stem Los Angeles River
		Arroyo Seco
	San Gabriel River	Main stem San Gabriel River
		East Fork San Gabriel River
		West Fork San Gabriel River

	Santa Ana River	Main stem Santa Ana River
		Lytle Creek
		Mill Creek
Santa Catalina Gulf Coast	San Juan River	San Juan River/Trabuco Creek
	San Mateo Creek	San Mateo Creek
	San Onofre Creek	San Onofre Creek
	Santa Margarita River	Santa Margarita River
	San Luis Rey River	San Luis Rey River
	San Dieguito River	San Dieguito River
	San Diego River	San Diego River
	Sweetwater River	Sweetwater River
	Otay River	Otay River
	Tijuana River	Tijuana River

Land Use. Public ownership of lands in the Southern California Coast Steelhead ESU varies widely between watersheds but generally decreases southward. Although public ownership of these watersheds (National Forest and BLM lands, military reservations, etc.) can be extensive, public lands are concentrated in the upper watersheds leaving the middle and lower watersheds subject to private development. Population centers in this BPG are concentrated on the coastal terraces, plains, and basins. Population density varies widely between watersheds (Fig. 1; Table 2). Average population density is very high in the Mojave Rim BPG because it includes the very large metropolitan areas of the Los Angeles Basin. Although the Santa Catalina Gulf Coast BPG includes the San Diego metropolitan area, the Conception Coast BPG has the second highest population density because the watersheds in the latter are very small relative to those in the former. Regardless, population density is a relative measure of intensity of land use and impacts to individual watersheds.

Urban and suburban conversion of watershed lands in some parts of this ESU is very high, but again, varies greatly between BPGs, depending on human population density (Table 2). For example, 50% to 60% of the area of the San Gabriel River and Los Angeles River watersheds, respectively, in the Mojave Rim BPG is classified as urban, compared to less than 1% of the Big Sycamore Canyon Creek watershed in the Santa Monica Mountains BPG. Population densities in this ESU are generally highest in the Santa Barbara/Goleta region of the Conception Coast BPG, the Malibu Creek region of the Santa Monica Mountains BPG, the Los Angels Basin portion of the Mojave Rim BPG watersheds, and the northern and southern portions of the Santa Catalina Gulf Coast BPG (Table 2).

Table 2. Human population density of component watersheds in the Southern California Coast Steelhead ESU (data from CDFFP Census 2000 block data (migrated), 2003).

Watershed (north to south)	Human Population Density (# / square mile)
Monte Arido Highlands BPG	
Santa Maria River *	66
Santa Ynez River	83
Ventura River	196
Santa Clara River	216

Conception Coast BPG	
Jalama Creek	2
Canada de Santa Anita	5
Gaviota Creek	2
Arroyo Hondo	< 1
Tecolote Creek	57
Goleta Slough **	1,201
Mission Creek	3,491
Montecito Creek	409
Carpinteria Creek	205
Rincon Creek	22
Santa Monica Mountains BPG	
Big Sycamore Canyon Creek	1
Arroyo Sequit	31
Malibu Creek	678
Las Flores Canyon Creek	229
Topanga Canyon Creek	278
Mojave Rim BPG	
Los Angeles River	5,237
San Gabriel River	3,343
Santa Ana River	1,744
Santa Catalina Gulf Coast BPG	
San Juan River/Trabuco Creek	1,079
San Mateo Creek	30
San Onofre Creek	84
Santa Margarita River	246
San Luis Rey River	257
San Dieguito River	371
San Diego River	1,140
Sweetwater River	1,119
Otay River	838
Tijuana River ***	159

* includes the Santa Maria River, Cuyama River, and Sisquoc River watersheds
** includes the San Pedro, Atascadero, San Jose, and Maria Ygnacio watersheds
*** includes only the U.S. portion of the watershed

Some of these watersheds have been extensively developed for agriculture, which typically utilizes floodplain land first. The upland slopes in several of the watersheds in the Conception Coast BPG and Santa Catalina Gulf Coast BPG are extensively planted in orchard crops. The spatial configuration and intensity of land use within these watersheds generally determines the type and magnitude of impacts to steelhead and their habitats. A relatively small amount of urban or agricultural development can have disproportionately large impacts on instream and riparian conditions for steelhead. The typical pattern of urban and agricultural development focuses on the flatter portions of a watershed, typically within the floodplain and usually along the main stem of the drainage and one or more tributaries, thereby magnifying potential impacts to steelhead even if most of the watershed remains undeveloped.

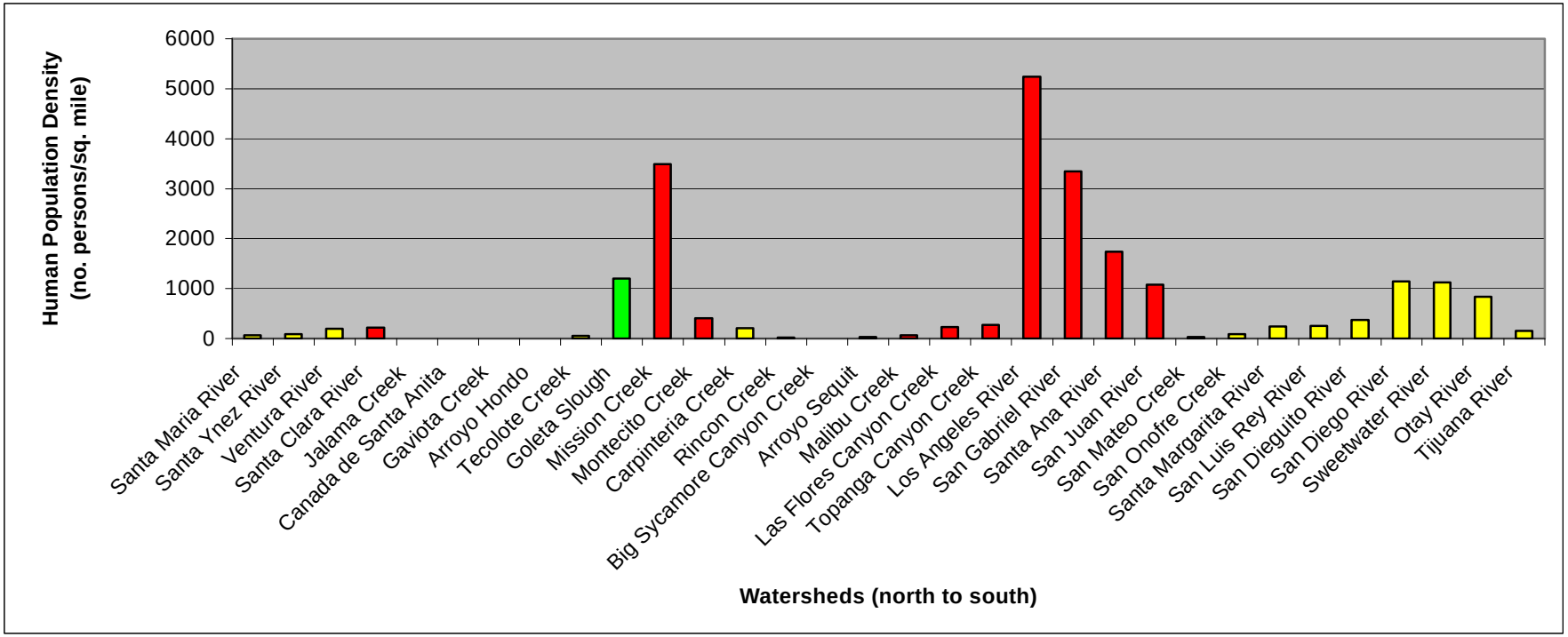


Figure 1. Habitat conditions for steelhead versus human population density in component watersheds of the Southern California Coast Steelhead ESU (densities are listed in Table 2; histogram color code is same as for indicator ratings in individual BPG summaries). Note scale of Y-axis relative to Fig. 1 in the South-Central California Coast Steelhead ESU threats summary.

Threats. Each of the watersheds in the Southern California Coast Steelhead ESU is impacted by a variety of anthropogenic factors, but the most frequent source of threats arises from agricultural and urban development, specifically water management activities. Dams, surface water diversions, groundwater extraction are common across this ESU, especially on the larger rivers, such as the Santa Maria, Santa Ynez, Ventura, Santa Clara (tributaries), San Gabriel, and Santa Ana rivers, some of which contain three major dams on the main stem alone. Fourteen of the 47 watersheds listed in Table 1 are sub-watersheds that depend on the main stem of the river to maintain connectivity to the estuary and ocean. Loss of surface flows or other passage impediments along the main stem of the river indirectly degrades these tributaries as spawning and rearing habitat even if the tributaries themselves remain undisturbed. Re-establishing or maintaining connections between the ocean and upper watersheds expands access to historically important spawning and rearing habitats, and significantly improve habitat conditions in these watersheds for steelhead, as well as the existing populations of native rainbow trout that currently are isolated above dams and reservoirs.

Urban and agricultural conversion of floodplain lands flanking the main stem of these rivers and creeks typically requires levees or other structures to protect these lands from flooding. The urban and agricultural reaches of all of the watersheds in this ESU have been subjected to some degree of channelization and/or levee construction with the resulting loss or degradation of the riparian corridor and/or streambed. Habitat impairments for steelhead may range from increased water temperature, incision of the streambed and loss of structural complexity and instream refugia (meanders, pools, undercut banks, etc.), complete loss of bed and bank habitat, increased sedimentation, turbidity, and substrate embeddedness, and nutrient loading.

Estuaries are used by steelhead as rearing areas for juveniles and smolt as well as staging areas for smolt acclimating to saline conditions in preparation for entering the ocean and adults acclimating to freshwater in preparation for spawning. Approximately 75% of estuarine habitats across this ESU have been lost (Table 3), and the remaining 25% are constrained by agricultural and urban development, levees, and transportation corridors (highways and railroads). Estuarine habitat loss varies widely across BPGs, with the Santa Maria River and Santa Ynez River estuaries being the most physically intact, though they are impaired by reduced freshwater inflows and point and non-point waste discharges from both municipal and agricultural sources.

Table 3. Estuarine habitat loss in component watersheds in the Southern California Coast Steelhead ESU.

Watershed (north to south)	Remaining Estuarine Habitat as Percentage of Historic Habitat
Monte Arido Highlands BPG	
Santa Maria River	81
Santa Ynez River	94
Ventura River	32
Santa Clara River	15
	Average = 56% remaining

Conception Coast BPG	
Gaviota Creek	25
Arroyo Hondo	5
Tecolote Creek	25
Goleta Slough	31
Mission Creek	10
Montecito Creek	5
Carpinteria Creek	20
Rincon Creek	5
	Average = 16% remaining
Santa Monica Mountains BPG	
Big Sycamore Canyon Creek	10
Arroyo Sequit	10
Malibu Creek	34
Las Flores Canyon Creek	3
Topanga Canyon Creek	30
	Average = 17% remaining
Mojave Rim BPG	
Los Angeles River	0
San Gabriel River	2
Santa Ana River	3
	Average = 2% remaining
Santa Catalina Gulf Coast BPG	
San Juan River	10
San Mateo Creek	76
San Onofre Creek	20
Santa Margarita River	41
San Luis Rey River	10
San Dieguito River	43
San Diego River	9
Sweetwater River	5
Otay River	14
Tijuana River	52
	Average = 28% remaining

Summary. The overall condition of component major watersheds within this ESU was rated as "Fair" to "Poor" (Fig. 1; see CAP Workbook summaries for more detailed information). Only four of the 45 watersheds analyzed in this ESU were rated overall as "Good" or "Very Good" in the CAP Workbook analyses: San Antonio Creek and Santa Paula Creek in the Monte Arido Highlands BPG, Arroyo Hondo in the Conception Coast BPG, and Topanga Canyon Creek in the Santa Monica Mountains BPG (see attached Overall Viability Summary in attachments for details). However, many of the watersheds in this BPG support high-quality steelhead spawning and rearing habitat but are compromised by one or more anthropogenic factors (e.g., Matilija Creek (dam), North Fork Matilija Creek (other passage barriers), and Sespe Creek (excessive groundwater extraction in the lower reaches) in the Monte Arido Highlands BPG). The overall low rating of watersheds in this ESU, specifically, the middle and lower reaches, reflects generally high to very high population density across portions of this ESU (Table 2; Fig. 1). Whereas in the South-Central Steelhead ESU where watershed health was directly related to population density, population density and development pressures are generally

so high in most of the watersheds in the Southern California ESU as to preclude this relationship. Even watersheds that have relatively low population densities, such as the Santa Maria River, Santa Ynez River and Tijuana River watersheds, support one or more major dams that severely degrade overall habitat conditions for steelhead by reducing and completely limiting flows necessary for fish passage, and blocking access to a majority of the prime spawning and rearing habitats in the upper reaches of these watersheds.

Table 4. Severe or Very Severe Threat Sources in the Southern California Coast Steelhead ESU*.

Threat Source	Biogeographic Population Group				
	Monte Arido Highlands	Conception Coast	Santa Monica Mountains	Mojave Rim	Santa Catalina Gulf Coast
Urban Development	X	X	X	X	X
Flood Control	X	X	X	X	X
Other Passage Barriers	X	X	X	X	X
Non-Native Wildlife	X	X	X	X	X
Roads	X	X	X	X	X
Dams and Surface Water Diversions	X		X	X	X
Groundwater Extraction	X	X		X	X
Agricultural Development	X	X		X	X
Levees and Channelization	X	X		X	X
Wildfires	X	X	X		
Non-Point Pollution			X	X	X
Mining and Quarrying	X	X			
Agricultural Effluents	X				X
Urban Effluents	X				
Non-Native Species	X				

*** These are the "severe" (yellow) and "very severe" (red) threat sources taken from the top five threat sources identified by the CAP Workbook analyses. See individual BPG Threat Summaries for more information.**

Because different threat sources can produce similar proximal stresses on steelhead and steelhead habitat, the severe and very severe sources of threats listed in Table 4 grouped into the following categories:

- Urban development (road density; culverts and stream/river crossings; non-point pollution; floodplain encroachment; levees and channelization, wastewater effluents; channel maintenance; non-native vegetation);
- Agricultural development (floodplain encroachment; levees and channelization; agricultural effluents; channel maintenance; non-native vegetation);

- Water management (dams, surface water diversions, and groundwater extraction to serve urban and agricultural development; non-native vegetation);
- Mining and quarrying (floodplain encroachment; passage barriers);
- Recreation (fisheries) development (non-native wildlife);
- Wildland fire (sedimentation; altered hydrograph; non-native vegetation).

These sources of threats are not mutually exclusive—they can create a number of primary and secondary sources of threats, which in turn degrade steelhead habitat and/or directly stress one or more steelhead life stages. Urban and agricultural development creates a cascading series of sources of threats to steelhead, e.g., dam construction creates passage barriers to spawning and rearing habitat and negatively affects the hydrology, sediment transport processes, and geomorphology of the affected drainages, but frequently includes recreational development of reservoirs for fishing and camping, which can introduce non-native predators and/or competitors to steelhead (e.g., largemouth bass, crayfish, western mosquitofish) as well as promote trampling of the active channel, which can lead to direct loss of redds.

A widespread trend observed in this ESU is severe to very severe degradation of habitat conditions along the main stem of impaired watersheds, while the upper main stem and tributaries retain relatively high habitat values for steelhead. Because the main stem of these drainages is the conduit that connects steelhead spawning and rearing habitat with the ocean, recovery actions in watersheds impaired in this manner should focus on reducing the severity of anthropogenic impacts along the main stem resulting from encroachment into riparian areas and related flood control activities in order to promote connectivity between the ocean and estuarine habitats. Additionally, degraded estuarine conditions stemming from filling, artificial sandbar manipulation, and both point and non-point waste discharges should be further evaluated and addressed as part of any recovery strategy for this ESU (see threats summaries and recovery action matrices for individual BPGs for more specific threats and recovery actions).

Threats Assessment for the Monte Arido Highlands Biogeographic Population Group

Location and Physical Characteristics. The Monte Arido Highlands BPG region encompasses four moderate-sized to large coastal watersheds and eight sub-watersheds that drain the western half of the Transverse Range in southern San Luis Obispo, Santa Barbara, Ventura, and eastern Los Angeles counties. The Santa Maria River watershed proper is a small, coastal drainage formed by the confluence of two large interior watersheds: the Cuyama River and the Sisquoc River, which together drain most of the Sierra San Rafael, Sierra Madre, and Caliente ranges. The Santa Ynez River drains the south-facing slopes of the Sierra San Rafael and north-facing slopes of the Santa Ynez Mountains. Together the Santa Maria and Santa Ynez rivers also drain the Santa Maria Basin, a coastal subsidence basin formed by crustal elongation and clockwise rotation of the Santa Ynez Mountains. The Ventura River drains the coastal slopes of the eastern end of the Santa Ynez Mountains and the western end of the Transverse Range. The Santa Clara River drains much of the western Transverse Range, including the northern slopes of the San Gabriel Mountains. The main stems of the Santa Maria River and Santa Ynez rivers are oriented to the west and discharge to the Pacific Ocean in western Santa Barbara County. The Ventura and Santa Clara watersheds abut the upper watersheds of the former two, but their main stems flow south and southwesterly into the Pacific Ocean in southern Ventura County (Fig. 2).

These watersheds are highly disparate in slope, aspect, and size, but share one common feature: the interior portions are mountainous and include high peak elevations, ranging between 5,700 and 8,600 feet above sea level. Each of these watersheds flows across a coastal terrace, but the Santa Maria, Santa Ynez, and Santa Clara rivers traverse broad coastal plains before entering the Pacific Ocean. Overall, stream lengths tend to be very long, owing to high topographic relief in the interior watersheds. The Santa Maria River watershed (Cuyama River sub-watershed) extends the furthest inland—almost 90 miles between the mouth and the limits of the upper watershed.

Average annual precipitation in the Santa Maria River and Santa Clara River watersheds is much lower than the other two because the former include extensive arid interior regions. Although rainfall amounts increase dramatically with increasing elevation, the orographic effect is enhanced in the coastal mountainous portions of these watersheds because much of their interiors lie in “rain shadows” formed by more coastal portions of the same watersheds. For example, Old Man Mountain at 5,500 feet above sea level in the Ventura River watershed not only receives five to ten times the amount of precipitation that falls on coastal locations only a few miles away in the same watershed, but also receives much more rainfall than interior peaks of comparable elevation in this region. The drainages in these watersheds exhibit “flashy” flow patterns during and after storm events and peak winter and summer base flows can vary by several orders of magnitude. Extensive portions of the main stems of all four major watersheds exhibit intermittent flows (with isolated pools) in summer because of a combination of strong seasonal variation in rainfall and anthropogenic factors.

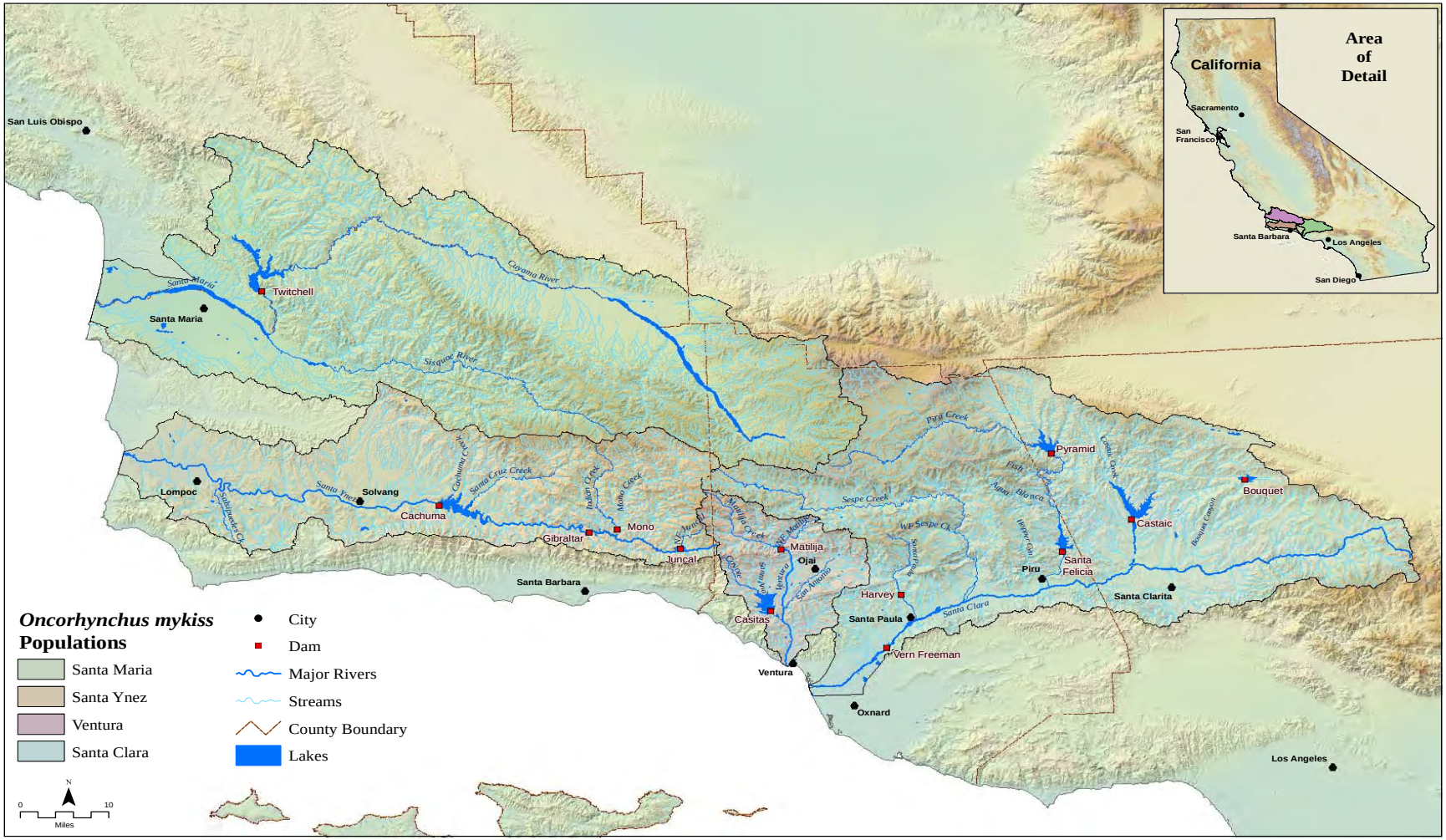


Figure 2. The Monte Arido Highlands Biogeographic Population Group region. Thirteen steelhead populations/watersheds were analyzed in this region: three in the Santa Maria River watershed; one in the Santa Ynez River watershed, five in the Ventura River watershed, and four in the Santa Clara River watershed.

Table 5. Physical and Land Use Characteristics of Watersheds in the Monte Arido Highlands BPG.

Physical Characteristics				Land Use				
Watershed (north to south)	**Area (acres/miles^2)[1]**	**Stream Length[2] (miles)**	**Average Annual Rainfall[3] (in.)**	**Total Human Population[4]**	**Public Ownership***	**Urban Area[5]**	**Agriculture/ Barren[5]**	**Open Space[5]**
Santa Maria River**	1,187,491/1,855	2,941	17.2	123,043	49%	10%	3%	87%
Santa Ynez River	576,717/901	1,543	18.3	74,900	39%	7%	3%	90%
Ventura River	144,967/227	409	18.8	44,550	48%	6%	9%	85%
Santa Clara River	1,040,223/1,625	2,485	16.7	350,363	54%	6%	7%	87%
Total/Average	**2,949,398/4,608**	**7,378**	**17.7**	**592,856**	**48%**	**7%**	**6%**	**87%**

Sources: 1. CDFFP CalWater 2.2 Watershed delineation, 1999 (www.ca.nrcs.usda.gov/features/calwater/)
2. CDFG 1:1,000,000 Routed stream network, 2003 (www.calfish.org/)
3. USGS Hydrologic landscape regions of the U.S., 2003 (1 km grid cells)
4. CDFFP Census 2000 block data (migrated), 2003
5. CDFFP Multi-source land cover data (v02_2), 2002 (100 m grid cells) (http://frap.cdf.ca.gov/data/frapgisdata/select.asp)

* National Forest Lands only; does not include State or County Parks or Military Reservations (http://old.casil.ucdavis.edu/casil/gis.ca.gov/teale/govtowna/)
** The Santa Maria River watershed includes the Cuyama River and Sisquoc River sub-watersheds.

Land Use. Table 5 summarizes land use and population density in this region. The coastal terrace and floodplains of these watersheds receive the most intensive land use. The interiors are largely uninhabited and include several federally-designated wilderness areas within the Los Padres National Forest: San Rafael, Dick Smith, Matilija, Chumash, and Sespe. Additionally, there are two federally-designated Wild and Scenic rivers within the Los Padres National Forest: Sisquoc River (Wild) in the Santa Maria River watershed, and Sespe Creek (Wild and Scenic), in the Santa Clara River watershed. Human population density increases steadily to the south, and averages about 129 persons/square mile over the BPG. The Santa Maria River watershed has the lowest population density (66 persons/square mile), while the Santa Clara River watershed, which extends into northeastern Los Angeles County, has the highest (216 persons/square mile). Population densities in individual watersheds vary widely across this region.

In most of these watersheds, the first land use change was livestock ranching and dry farming, followed by irrigated row crop agriculture. Urbanization followed this trend on the coastal plain, with current coastal population centers at Santa Maria, Lompoc, Buellton, Ventura, and Oxnard. More recently, interior portions of the floodplain of the Santa Clara River that were converted to agriculture (primarily orchards) decades ago, have experience strong urban growth and now include population centers at Santa Paula, Fillmore, and, most recently, the Santa Clarita-Castaic-Newhall area in Los Angeles County. The upper watersheds throughout this region are in the Los Padres and Angeles national forests; the coastal and middle watersheds are mostly privately owned. Semi-developed rural land, used for livestock ranching and orchard production covers extensive portions of the coastal and middle portions of these watersheds.

Agriculture (orchard production, row crops, and livestock ranching), are important land uses that directly or indirectly impact watershed processes throughout these watersheds, especially the lower Santa Maria, Santa Ynez, and Santa Clara River watersheds, which traverse broad coastal basins or plains that have mostly converted to agriculture. The Santa Ynez River and the Ventura River watersheds have been transformed by a series of dams constructed to serve municipal water needs for the cities of Goleta, Santa Barbara, Montecito, Summerland, Carpinteria, and Ventura. A major diversion on the lower main stem and three large dams in the upper watershed on Piru and Castaic creeks has similarly affected steelhead and their habitats in the Santa Clara River drainage. Municipal and agricultural water sources also include a number of groundwater wells located throughout the floodplains of these watersheds.

Current Watershed Conditions. Watershed conditions were assessed for the main stems of the four major rivers and for eight sub-watersheds. The relative ratings of current habitat and land use conditions (indicators) used to assess the viability of watersheds to support steelhead in the BPG are presented in Figure 3. The number of indicators used in the evaluations ranged from 17 for the Matilija Creek main stem watershed to 38 for the Santa Maria River watershed. The main stem and major tributaries of most of the drainages in this BPG offer fair to poor habitat conditions for steelhead in otherwise high rated tributaries to the Santa Maria River (Sisquoc River), Ventura River (Matilija Creek), and the Santa Clara River (Sespe Creek). Indicator ratings were typically downgraded because of passage barriers (see Threat Sources section below). Good- to excellent-quality steelhead habitat is generally found in the upper watersheds above these barriers, particularly in the Sisquoc River, Matilija Creek main stem, North Fork Matilija Creek, San Antonio Creek, Santa Paula Creek, and Sespe Creek drainages (Fig. 3). Sespe Creek probably supports the highest-quality and most extensive steelhead spawning and rearing habitat in this BPG, but is frequently isolated from the estuary and ocean by water management activities elsewhere in the watershed that reduce or eliminate surface flows along extensive reaches of the main stem.

Threats and Threat Sources. Varying numbers and intensity of habitat impairments (sources of threats) were identified in the CAP Workbooks analyses, ranging from seven sources in the North Fork Matilija Creek watershed to 21 in the Cuyama River watershed (Fig. 4). "Severe" and "Very Severe" sources of threats involving passage barriers created by dams and lack of surface flows caused by groundwater extraction or surface flow diversions disproportionately affect habitat conditions in all of the watersheds in this BPG. For example, Sespe Creek, although largely uninhabited and supporting some of the best steelhead spawning habitat in the BPG, is severely threatened by urban development occurring along the main stem of the Santa Clara River watershed, such as water management activities, that interrupt the connection between this sub-watershed, the main stem, estuary, and ocean.

Fifteen anthropogenic activities ranked as the top five sources of stress to steelhead in the Monte Arido BPG and are strongly associated with urban and agricultural development and recreation (Table 6).

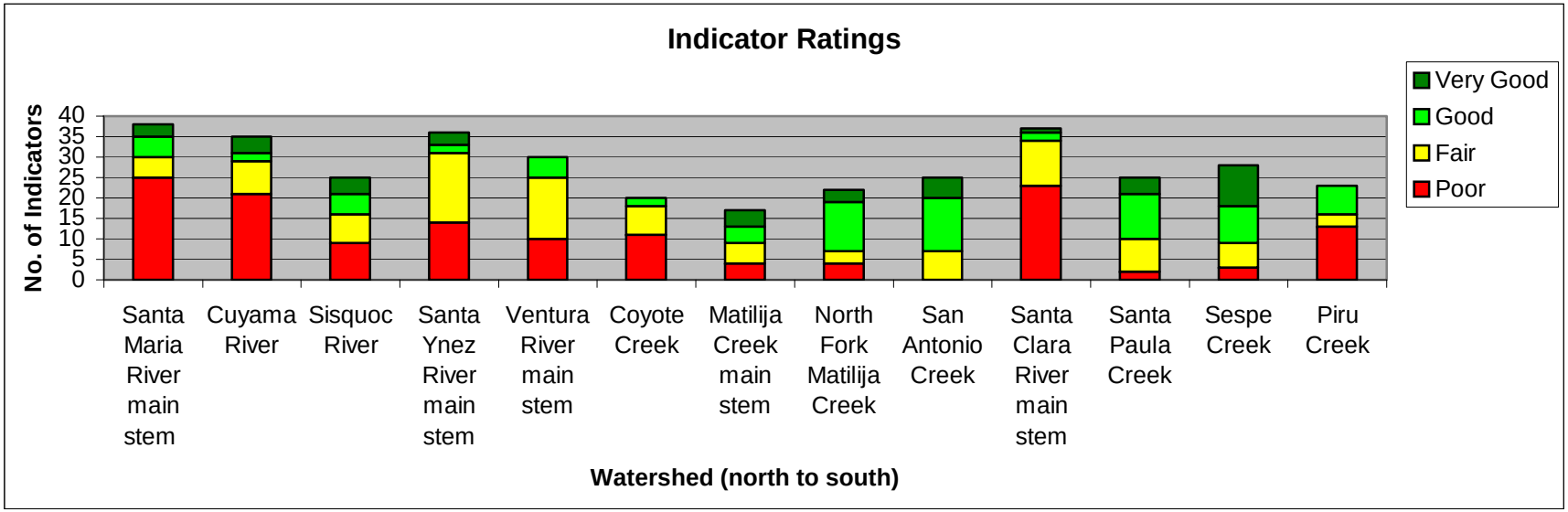


Figure. 3. Relative frequency of indicator ratings for watersheds in the Monte Arido Highlands BPG. Indicators are rated as "Very Good", "Good", etc., on the basis of the current condition of landscape, habitat, or population variables. The relative distribution of rankings provides a general picture of existing conditions for steelhead and their habitats within and between watersheds (see CAP Workbooks for details).

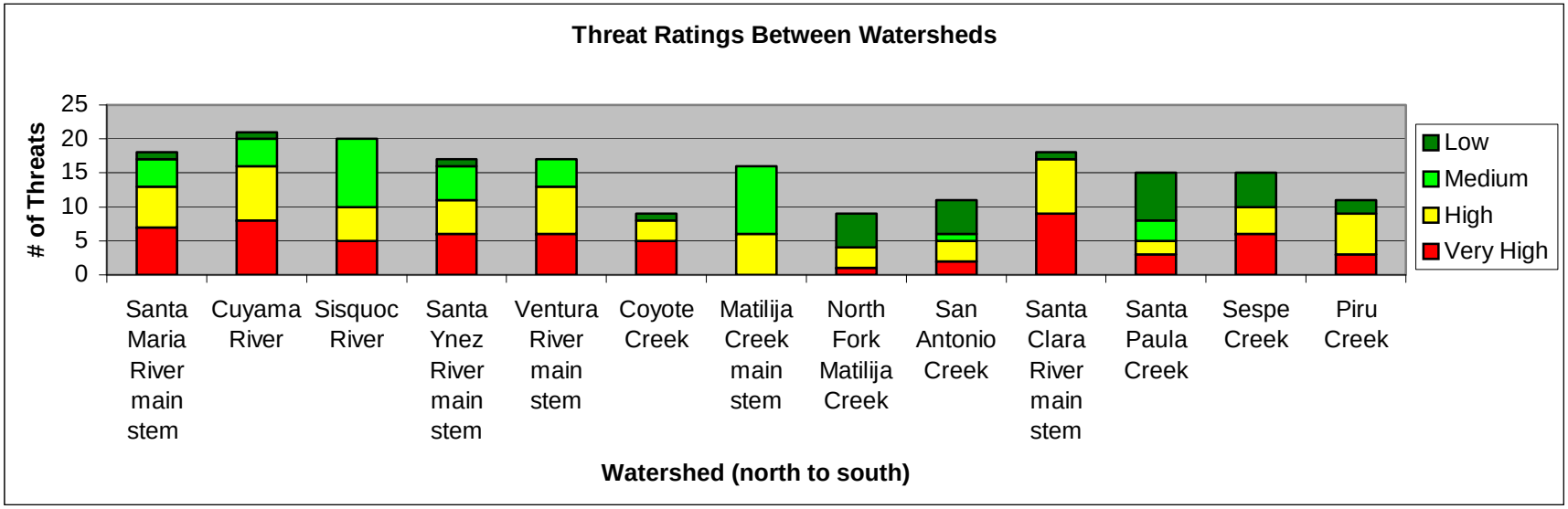


Figure 4. Relative frequency of threat source ratings in watersheds in the Monte Arido Highlands BPG, as identified by the CAP Workbook analyses.

Table 6. The top five sources of stress to steelhead and their habitats in the Monte Arido Highlands BPG (see CAP Workbooks for details).

Threat Sources	Component Watersheds (north to south)												
	Santa Maria River	Cuyama River	Sisquoc River	Santa Ynez River	Ventura River	Coyote Creek	Matilija Creek main stem	North Fork Matilija Creek	San Antonio Creek	Santa Clara River	Santa Paula Creek	Sespe Creek	Piru Creek
Dams and Surface Water Diversions													
Groundwater Extraction													
Agricultural Development													
Urban Development													
Recreational Facilities													
Non-Native Species													
Levees and Channelization													
Flood Control													
Wildfires													
Mining and Quarrying													
Roads													

Urban Effluents													
Agricultural Effluents													
Other Passage Barriers													

Key: Threat cell colors represent threat rating from CAP Workbook:
Red = Very High threat
Yellow = High threat
Light green = Medium threat
Dark green = Low threat

Agricultural and urban development has driven water management projects that conflict with steelhead habitat requirements. Dams, surface water diversions, and groundwater extraction have severely reduced or eliminated surface flows along extensive reaches of the main stems of the Santa Maria, Santa Ynez, Ventura, and Santa Clara rivers. Twitchell Dam on the Cuyama River is located close to the Sisquoc River confluence and blocks steelhead passage to the very large Cuyama River watershed, including several tributaries (e.g., Pine Creek). Surface flows in the Cuyama River disappear for most of the year because of excessive groundwater pumping throughout the arid Cuyama Valley to water row crops that have been extensively planted on the floodplain. Steelhead access to the equally large Sisquoc River watershed is severely limited because Twitchell Dam is managed for aquifer recharge in the Santa Maria Valley with the aim of minimizing surface flows to the ocean. Consequently, the Santa Maria River, which is the steelhead access corridor for both the Cuyama and Sisquoc rivers, is dry most of the year in most years. Bradbury, Gibraltar, Juncal, and Mono Debris Basin dams on the middle and upper main stem of the Santa Ynez River block access to at least 50% of their respective watersheds and the most extensive and productive spawning and rearing habitat. Matilija and Casitas dams on the main stem of Matilija Creek and Coyote Creek, respectively, have eliminated access to the most extensive and highest quality spawning habitat in the Ventura River watershed. Piru Dam and Pyramid Lake Dam on Piru Creek effectively eliminate this major tributary of the Santa Clara River as spawning and rearing habitat for steelhead, and access to all of the major tributaries is severely limited by loss of surface flows in the main stem of the Santa Clara River and to the estuary. Watersheds or portions of watersheds isolated by water management activities from the estuary and ocean continue to support high-quality steelhead spawning and rearing habitat. Moreover, all of the drainages in this BPG have native rainbow trout populations in their upper watersheds that would likely be anadromous if connectivity were restored.

Most or all of the reservoirs formed by these dams support sport fishing that have intentionally or accidentally introduced non-native predators or competitors on or with steelhead. These species have moved out of the reservoirs into the main stem and tributaries, including reaches below the dams and established reproducing populations (e.g., crayfish, largemouth bass, sunfish, catfish, carp, western mosquitofish, bullfrogs, etc.). Bullfrogs and carp are common throughout the main stem of the Santa Ynez and Ventura rivers. The African clawed frog (*Xenopus laevis*), a significant predator of native amphibians and fish, infests much of the main stem of the Santa Clara River from the estuary upstream to Fillmore, including large tributaries such as Santa Paula Creek and Hopper Canyon Creek.

The estuaries at the mouth of the Santa Maria and Santa Ynez rivers are relatively physically intact, retaining 81% to 94% of their historic size, respectively, although both are impacted by agricultural and urban effluent discharge. The Ventura River estuary has lost approximately 68% of its former size because of urban and agricultural encroachment (e.g., Ventura County Fairgrounds, Emma Wood State Beach, Union Pacific Railroad bridge, Highway 101 bridge). The Santa Clara River estuary has lost approximately 85% of its former size to agricultural encroachment and levee construction. Because estuaries are the gateway used by both immigrating adults and

emigrating juveniles moving between the marine and freshwater environments, estuarine loss affects steelhead throughout in the entire watershed. The remaining estuarine habitats are subject to degradation from urban, agricultural, and/or recreational development and loss of freshwater inflows. Surface flows diverted from the main stem for urban and agricultural use adversely affect both water quality and the seasonal breaching pattern of the sandbar at the mouth of the estuary.

Agricultural and urban development has severely constrained floodplain connectivity on the floodplains of the Santa Maria, lower Sisquoc, Santa Ynez, Ventura, San Antonio Creek, Santa Clara River, and lower Sespe Creek. Levees, channelization, and other flood control structures and activities, including related flood control activities (levee and vegetation management, etc.), constrict the floodplain and affect hydrology, sediment transport processes, and geomorphology, which limit instream habitat diversity and riparian corridor structure.

Fire is an important factor in slope erosion and sediment inputs to watersheds throughout this region. The Sisquoc River, North Fork Matilija Creek, and Piru Creek watersheds were identified as potentially severely threatened by mass wasting of slopes and loss of riparian canopy cover due to fires that occurred in 2006 and 2007 that covered most of their watersheds, but substantial portions of each of these watersheds have burned in the past 50 years.

The remaining anthropogenic factors listed in Table 6 are generally restricted to single watersheds. For example, the North Fork of Matilija Creek supports high-quality spawning and rearing habitat for steelhead but a landslide caused by on-going quarrying operations near the confluence with the main stem of Matilija Creek has blocked passage to and from this watershed. Passage barriers also have been created on this drainage by Highway 33, which closely parallels and crosses it for most of its length. Matilija Dam on the main stem of Matilija Creek creates ideal conditions for giant reed (*Arundo donax*) and this invasive grass has completely replaced native riparian vegetation along extensive portions of the lower reaches. A large-scale project to remove this species, and other invasive, non-native plants, from the Ventura River watershed began in 2007 and is part of an on-going project to improve habitat conditions for steelhead in the Matilija Creek and Ventura River watersheds. Runoff from agricultural fields that drain directly into the lower Santa Maria River is the source for nutrient loading, herbicides, and other agricultural chemicals in the lower river and estuary. The lower reaches of the main stem of Matilija Creek

Despite widespread and varied impacts to the coastal and middle portions of the watersheds in this region, steelhead continue to spawn in each of the watersheds in this BPG and native rainbow trout populations, which would be anadromous if barriers were removed, inhabit the high-quality habitat found in the upper watersheds above dams, reservoirs, and dry stream reaches. When connectivity through the main stem to the estuary and ocean is periodically re-established in years of adequate rainfall, steelhead spawn in many of these drainages.

Improving conditions for steelhead passage, spawning, and/or rearing in these watersheds will require multiple, long-term, measures, while conditions in others can be substantially improved with focused restoration projects that target fish passage barriers. The most effective improvement would be to maintain adequate surface flows to ensure passage between the ocean/estuary and upstream tributaries, as well as maintain suitable upstream spawning and rearing habitat conditions for steelhead within the Santa Maria, Santa Ynez, Ventura, and Santa Clara River systems.

The threat sources discussed in this section should be the focus of a variety of recovery actions to address specific stresses to steelhead viability associated with these threats. Spatial and temporal data acquired on specific indicators associated with sources of threats or stresses, such as water temperature, pH, nutrients, etc., are generally inadequate to be the target of specific recovery actions. This type of data acquisition should be the subject of site-specific investigations in order to refine the primary recovery actions or to target additional recovery actions. Impediments to fish passage stemming from the construction and operation of dams and groundwater extraction, modification of channel morphology and adjacent riparian habitats through flood control, instream activities such as sand and gravel mining, and loss of estuarine functions caused by filling and point and non-point waste discharges from agricultural and other anthropogenic activities should be further evaluated and addressed as part of any recovery strategy for the Monte Arido Highlands BPG (see recovery action matrices for more specific recovery actions).

ATTACHMENT. SUMMARY TABLES FOR STRESSES AND THREATS, STRESS MATRIX, AND OVERALL VIABILITY SUMMARY FOR THE MONTE ARIDO HIGHLANDS BPG

Threats Assessment for the Conception Coast Biogeographic Population Group

Location and Physical Characteristics. The Conception Coast BPG region encompasses eight small, coastal watersheds that drain a 50-mile long stretch of the south-facing slopes of the Santa Ynez Mountains in southern Santa Barbara County and extreme southwestern Ventura County (Fig. 5). The Santa Ynez Mountains are an east-west trending spur of the Transverse Range and create some of the steepest watersheds in any of the five BPG regions in the Southern California Coast Steelhead ESU. Peak elevations reach 4,300 feet just 5.5 air miles from the Pacific Ocean. These watersheds are relatively homogeneous in slope, aspect, and size, with steep upper watersheds with lower watersheds that cut across a relatively narrow coastal terrace. Stream lengths are short. The Gaviota Creek watershed penetrates the furthest inland (about seven air miles). Goleta Slough, the largest estuary in this BPG, is formed by the confluence of several sub-watersheds: Tecolotito Creek, Los Carneros Creek, San Pedro Creek, Las Vegas Creek, Maria Ygnacio Creek, San Jose Creek, and Atascadero Creek. Of these, the latter three watersheds were evaluated using the CAP analyses. The second largest estuary in this BPG, Carpinteria Slough, is formed by a synclinal basin fed by Santa Monica Creek and several minor drainages that are not included in the watersheds covered in the Conception Coast BPG.

Precipitation shows a strong increase in rainfall amounts with increasing elevation. Rainfall amounts in the upper watershed can be five to six times higher than on the coastal terrace portion of the watershed during the same storm event and the steep topography in these watersheds creates extremely "flashy" flows.

Table 7. Physical and Land Use Characteristics of Watersheds in the Conception Coast BPG region.

Physical Characteristics				Land Use				
Watershed (west to east)	**Area (acre/mi^2)[1]**	**Stream Length[2] (miles)**	**Average Annual Rainfall[3] (in.)**	**Total Human Population[4]**	**Public Ownership***	**Urban Area[5]**	**Agriculture/ Barren[5]**	**Open Space[5]**
Jalama Creek	15,800/25	45	17.4	59			< 1%	
Canada de Santa Anita	2,067/3	5	17.4	16			< 1%	
Gaviota Creek	12,912/20	39	17.5	40			1%	
Arroyo Hondo	2,796/4	6	17.8	1			< 1%	
Tecolote Creek	3,726/6	11	19.0	339			18%	
Goleta Slough**	30,410/48	92	19.2	57,664			16%	
Mission Creek	7,760/12	16	19.6	41,890			3%	
Montecito Creek	3,970/6	11	19.5	2,453			< 1%	
Carpinteria Creek	10,712/17	25	19.8	3,493			20%	
Rincon Creek	9,422/15	25	19.3	324			23%	
Total/Average	**213,099/333**	**560*** **	**18.6**	**201,459*** **		**16%**	**8%**	**74%**

Sources: 1. CDFFP CalWater 2.2 Watershed delineation, 1999
2. CDFG 1:1,000,000 Routed stream network, 2003
3. USGS Hydrologic landscape regions of the U.S., 2003 (1 km grid cells)
4. CDFFP Census 2000 block data (2003)

5. 5. CDFFP Multi-source land cover data (2002); 100m grid cells

* National Forest Lands only; does not include State or County Parks
** "Goleta Slough" includes analyses only for San Jose, San Pedro, Maria Ygnacio, and Atascadero creeks.
*** Total for entire BPG area, not component watersheds.

Land Use. Table 7 summarizes land use and population density in this region. The coastal terrace and middle portions of these watersheds receive the most intensive land use. Human population density varies widely between the component watersheds, averaging about 605 persons/square mile over the BPG. The western half of this BPG region has very low population density (one to 59 persons/square mile), while the Goleta Slough and Mission Creek watersheds average 1,201 and 3,491 persons/square mile, respectively (see Table 2 in the ESU Summary for details).

In most of these watersheds, the first land use change was livestock ranching and dry farming, followed by irrigated row crop agriculture, especially orchard crops, such as avocados, lemons, and walnuts. Most recently, the steep slopes in the middle reaches of some watersheds have been developed with avocado and other orchard crops. Urbanization followed this trend on the coastal plain in the eastern half of this BPG region then moved up into the montane portions of these watersheds as cities grew in size. The upper watersheds throughout this region are in the Los Padres National Forest; the coastal and middle watersheds are mostly privately owned. Semi-developed rural land and orchards cover extensive portions of the coastal and middle portions of the western watersheds. Most of the Arroyo Hondo watershed has recently been put under a conservation easement and is managed by the Land Trust of Santa Barbara County.

A number of coastal areas in this region have been developed as County and State Parks, including Gaviota State Beach (Gaviota Creek), Refugio State Beach (Refugio Creek), El Capitan State Beach (El Capitan Creek), Goleta Beach County Park (mouth of Goleta Slough), Arroyo Burro Beach County Park (Arroyo Burro Creek), City of Santa Barbara beaches (east and west of mouth of Mission Creek), Carpinteria State Beach (Carpinteria Creek), and Rincon Beach County Park (Rincon Creek). Each of these parks is located around the mouth of these drainages, including the estuary.

Agriculture (orchard cultivation and livestock ranching), are important land uses that directly or indirectly impact watershed processes throughout these watersheds. Most of the municipal water for Goleta, Santa Barbara, Montecito, Summerland, and Carpinteria is supplied by reservoirs on the middle and upper main stem of the Santa Ynez River on the north side of the Santa Ynez Range. This municipal water source is supplemented by groundwater wells located throughout the coastal terrace. The ranches that support irrigated orchard crops in these watersheds also depend heavily on groundwater as their source for agricultural water. Some large ranches have diversions and dams on their property to create reservoirs for agricultural use (e.g., Glen Annie Canyon, unnamed tributary of Dos Pueblos Creek, and Gato Creek).

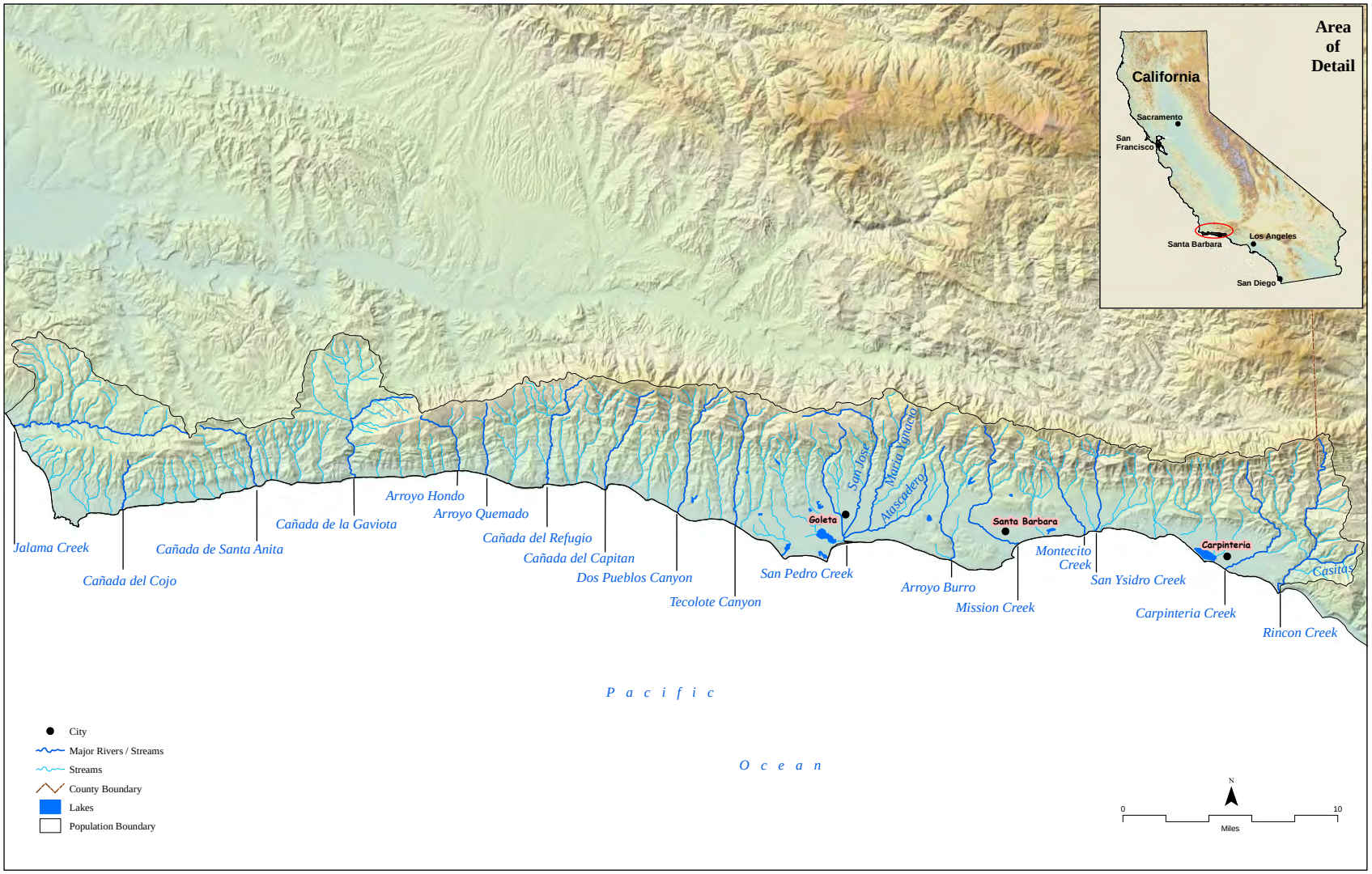


Figure 5. The Conception Coast Biogeographic Population Group region. Ten steelhead populations/watersheds were analyzed in this region.

Some of these reservoirs support small populations of bullfrogs and non-native predatory fish (e.g., Dos Pueblos Creek tributary reservoir), but the majority of the drainages in these watersheds are relatively free from these steelhead predators. Non-native crayfish and western mosquitofish, which may prey on steelhead eggs, occur in many urbanized drainages. Tecolotito Creek in the Goleta Slough watershed supports a reproducing population of African clawed frogs (*Xenopus laevis*), which may be a predator on certain steelhead life stages.

Current Watershed Conditions. The relative ratings of current habitat and land use conditions (indicators) used to assess the viability of watersheds to support steelhead in the BPG are presented in Figure 6. The number of available indicators used in the CAP Workbook analyses ranged from 16 for the Canada de Santa Anita to 33 in the Carpinteria Creek watershed.

In general, instream, riparian, and floodplain conditions for steelhead in watersheds in this BPG are rated "Fair" or "Good", but conditions vary widely within and between watersheds, depending on land use. The upper watersheds consistently support good to excellent quality steelhead spawning and rearing habitat. Conditions in each of these watersheds deteriorate downstream on the coastal plain. Highway 101 and the Union Pacific Railroad tracks traverse the main stem of each of these watersheds at or in close proximity to their mouths, which has damaged estuarine habitat and created passage impediments for steelhead. Agriculture-related activities, such as groundwater extraction, have reduced surface flows and degraded habitat conditions in the lower and middle portions of these watersheds. Urban development dominates the lower reaches of the Goleta Slough, Mission Creek, Montecito Creek, and Carpinteria Creek watersheds. Most of these watersheds also exhibit high road densities. The Arroyo Hondo watershed provides the least disturbed conditions for steelhead in this BPG because of low-intensity land use and its inclusion in a natural reserve system managed by the Land Trust of Santa Barbara County. The Goleta Slough watershed (San Jose, San Pedro, Maria Ygnacio, and Atascadero creeks) and the Mission Creek and Rincon Creek watersheds exhibit the least favorable conditions for steelhead, however, their upper watersheds sustain reproducing populations of native rainbow trout and, occasionally, steelhead despite urbanization, channelization, channel maintenance, and other urban creek land uses throughout their lower reaches.

Threats and Sources of Threats. Varying numbers and intensity of habitat impairments (sources of threats) were identified in the CAP Workbooks analyses, ranging from 10 in the Gaviota Creek and Arroyo Hondo watersheds to 17 in the Rincon Creek watershed (Figure 7). "Severe" and "Very Severe" sources of threats exist in all of the watersheds in this BPG, but the Arroyo Hondo watershed has the least number and severity of threats for steelhead. Threat sources are concentrated in the middle and lower portions of the watersheds and are associated with urban and agricultural development. The number and severity of threats generally diminishes in the upper, undeveloped portion of these watersheds. Steelhead and resident rainbow trout spawn in the upper reaches of most, and even in the degraded lower reaches of some of these drainages, such as Maria Ygnacio, Mission, and Carpinteria creeks.

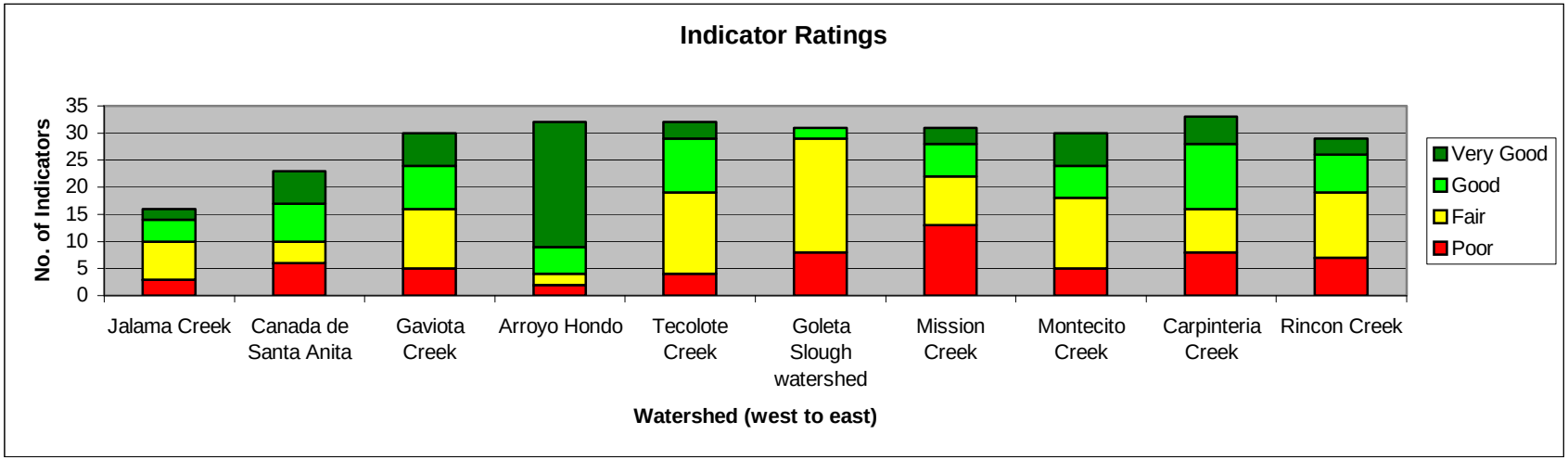


Figure 6. Relative frequency of indicator ratings for watersheds in the Conception Coast BPG. The relative ranking of indicators provides a general picture of existing conditions for steelhead and their habitats within and across watersheds in this BPG (see CAP Workbooks for more information).

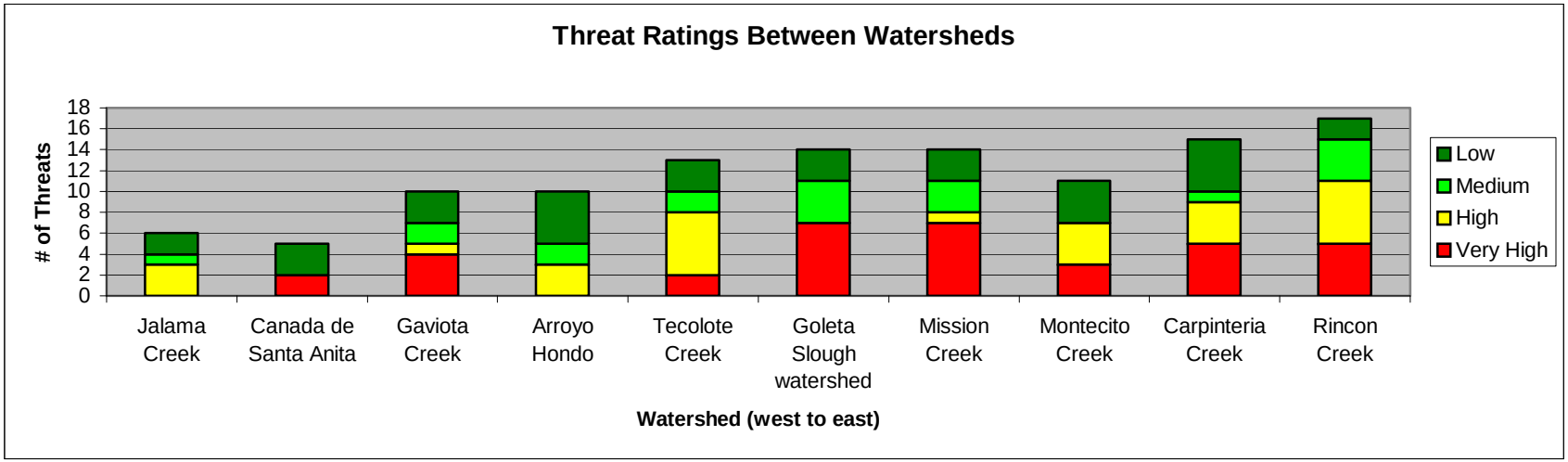


Figure 7. Relative frequency of sources of threats to steelhead and their habitats in watersheds in the Conception Coast BPG, as identified by the CAP Workbook analyses.

Thirteen anthropogenic activities, all strongly associated with urban and agricultural development, ranked as the top five sources of stress to steelhead in the Conception Coast BPG watersheds (Table 8). Road density, including roads in close proximity to stream riparian zones, and passage barriers associated with transportation corridors, consistently ranked as "Severe" to "Very Severe" source of threats to steelhead and their habitats. Proximal stressors associated with increased road density, especially roads near the drainage, include increased non-point pollution, sedimentation, substrate embeddedness, floodplain encroachment and constriction, channel incision, and loss of channel structural complexity.

Increased road density also leads to increased frequency of road crossings, culverts, and other structures that can form passage barriers, preventing steelhead from accessing spawning and rearing habitat. As previously stated, Highway 101 and the Union Pacific Railroad tracks cross the main stem of each of these watersheds near their mouths and, in most cases, the drainage passes through culverts at these points. Highway 101 and the railroad tracks typically crossed these drainages by filling the streambed with an earth berm and forcing the stream to flow through a culvert of varying lengths. In some cases, construction of these transportation corridors reduced the extent of estuarine habitat. The Highway 101 culvert on Rincon Creek and a number of other creeks is an impassable barrier preventing steelhead from reaching spawning and rearing habitat and isolating formerly anadromous populations in the upper watershed.

Groundwater extraction for municipal and agricultural use also is a pervasive threat source among these watersheds. Widespread pumping of groundwater routinely eliminates surface flows and de-waters pools in portions of most of these drainages; the magnitude of loss of surface flows and severity of passage barriers is exacerbated during years of below-average precipitation. These effects negatively impact on particular life-stages (e.g., egg incubation, alevins, fry, and parr development).

Increasing urbanization of the Tecolote Creek, Goleta Slough, Mission Creek, Montecito Creek, and Carpinteria Creek watersheds creates a number of threat sources ranging from increased road density to floodplain encroachment and increased need for flood control structures, such as levees and channelization, and channel maintenance.

Five other threat sources are specific to one or two watersheds and have seriously degraded habitat conditions for steelhead there. For example, past quarrying activities in Rincon Creek have created a rock barrier the completely blocks upstream migration of steelhead and severely impedes downstream migration of resident rainbow trout above this barrier. Fire has recently burned much of the Gaviota Creek watershed and erosion of burned slopes in the watershed is a significant, though diminishing source of sediment input. Gaviota State Beach campground was developed along the shores of the estuary at the mouth of the Gaviota Creek watershed and has affected the size of the estuary, degraded water quality in the estuary, and created a severe passage impediment at a road crossing that provides access to Gaviota State Beach campground and the Hollister Ranch. Jalama Creek and Canada de Santa Anita have dams or other severe passage impediments on their main stems and tributaries.

Table 8. The top sources of threats, ranked in order of frequency of occurrence and severity, in component watersheds in the Conception Coast BPG (see CAP Workbooks for individual watersheds for details).

Threat Sources	Component Watersheds (west to east)									
	Jalama Creek	Canada de Santa Anita	Gaviota Creek	Arroyo Hondo	Tecolote Creek	Goleta Slough*	Mission Creek	Montecito Creek	Carpinteria Creek	Rincon Creek
Roads										
Culverts & Crossings (passage barrier)										
Groundwater Extraction										
Levees and Channelization										
Urban Development										
Wildfires										
Recreational Facilities										
Non-Point Pollution										
Flood Control										
Mining and Quarrying										
Agricultural Development										

Dams and Surface Water Diversions										
Livestock Ranching										

Key: Threat cell colors represent threat rating from CAP Workbook:
Red = Very High threat
Yellow = High threat
Light green = Medium threat
Dark green = Low threat
* includes San Jose, Maria Ygnacio, and Atascadero creeks only.

Estuarine habitats at the mouths of these watersheds in this BPG have been reduced in size by 70% to 95% of their natural size by the development of transportation corridor (roads and railroad), urbanization, and development of recreational facilities (see Table 3 in ESU summary). In many cases, these estuaries were not large to begin with. The Goleta Slough, formed by the confluence of several watersheds and the estuary associated with Mission Creek and lands immediately to the east, were the largest estuarine habitats in this BPG. They have been reduced by 70% to 90% of their former size, respectively. The remaining estuarine habitats are subject to constriction and isolation from urban, agricultural, and/or recreational development, as well as degradation of the amount and quality of surface flows as a result of surface runoff inputs from roads and groundwater extraction.

Despite widespread and varied impacts to the coastal and middle portions, steelhead continue to spawn in each of the component watersheds in this BPG and native rainbow trout populations still inhabit the high-quality habitat found in the upper watersheds. Improving conditions for steelhead passage, spawning, and/or rearing in these watersheds will require multiple, long-term, measures in the urbanized watersheds, such as Goleta Slough and Mission Creek, while conditions in others (e.g., Maria Ygnacio and Rincon creeks) can be substantially improved with focused restoration projects that target fish passage beneath Highway 101 and other road crossings and the Union Pacific Railroad right-of-way, controlling sediment inputs from unpaved rural roads, and water management.

The threat sources discussed in this section should be the focus of a variety of recovery actions to address specific stresses on steelhead viability associated with these threats. Spatial and temporal data acquired on specific indicators associated with sources of threats or stresses, such as water temperature, pH, nutrients, etc., are generally inadequate to be the target of specific recovery actions. This type of data acquisition should be the subject of site-specific investigations in order to refine the primary recovery actions or to target additional recovery actions. Impediments to fish passage stemming from the construction and maintenance of roads and other transportation corridors, privately-owned dams and other passage barriers on some drainages, groundwater extraction, modification of channel morphology and adjacent riparian habitats through flood control, instream activities such as sand and gravel mining, and loss of estuarine functions caused by filling and point and non-point waste discharges from agricultural and other anthropogenic activities should be further evaluated and addressed as part of any recovery strategy for the Conception Coast BPG (see recovery action matrices for more specific recovery actions).

ATTACHMENT. SUMMARY TABLES FOR STRESSES AND THREATS, STRESS MATRIX, AND OVERALL VIABILITY SUMMARY FOR THE CONCEPTION COAST BPG

Threats Assessment for the Santa Monica Mountains Biogeographic Population Group

Location and Physical Characteristics. The Santa Monica Mountains Biogeographic Population Group (BPG) consists of five coastal watersheds located in southern Ventura and western Los Angeles counties. These watersheds are formed by the east-west coastal Santa Monica Mountains. These mountains are composed of recently uplifted marine and volcanic formations that extend approximately 32 miles between the Oxnard Plain on the west and the Los Angeles Basin on the east. With the exception of Malibu Creek, these watersheds are relatively small and do not extend inland beyond the Santa Monica Mountains. The watersheds, from west to east, are: Big Sycamore Canyon Creek, Arroyo Sequit, Malibu Creek, Las Flores Canyon Creek, and Topanga Canyon Creek (Fig. 8).

The Santa Monica Mountains BPG is similar to the Conception Coast BPG in comprising a series of short, nearly parallel streams that drain steep south-facing slopes, with an average elevation of less than 2,500 feet. The annual seasonal rainfall in the watershed basins of this BPG is approximately 18 inches, although rainfall is lower along the coast and increases with increasing elevation in the upper reaches of the watersheds. Malibu Creek is the largest watershed of the five basins presented here, encompassing approximately 110 square miles and, unlike coastal streams in the Big Sur Coast and Conception Coast BPGs, penetrates through a break in the Santa Monica Mountains to drain a portion of its north-facing slopes and the south-facing slopes of the Simi Hills. Calleguas Creek and the Los Angeles River drain the remainder of the northern slopes of the Santa Monica Mountains.

Land Use. A significant portion of the Santa Monica Mountains is undeveloped, and portions are publicly held as part of the Santa Monica Mountains National Recreation Area, seven state parks and beaches (Point Mugu State Park, Malibu Creek State Park, Leo Carrillo State Beach, Topanga State Park, R.H. Meyer Memorial State Beach, Dan Blocker State Beach, and Will Rogers State Park), and several local parks and beaches, including Zuma County Beach and Solstice Canyon Park. The large amount of public land and recreational facilities, coupled with the proximity of the BPG to a large urban area (the Los Angeles Basin) results in the watersheds here receiving very high recreational use.

Table 9 lists physical and land use characteristics of the component watersheds in the Santa Monica Mountains BPG. Development within the Santa Monica Mountain watersheds is principally residential, with some commercial and recreational development concentrated near the mouths of several of the streams. The Malibu Creek and Topanga Canyon Creek watersheds support the highest human population densities. Watersheds in the western portion of the Santa Monica Mountains generally have less development and significantly more area in public ownership than watersheds in the eastern half of the range. Human population density and private land ownership increases in the Santa Monica Mountains from west to east with increasing proximity to the Los Angeles Basin. Agricultural conversion of watershed lands is generally light throughout this BPG.

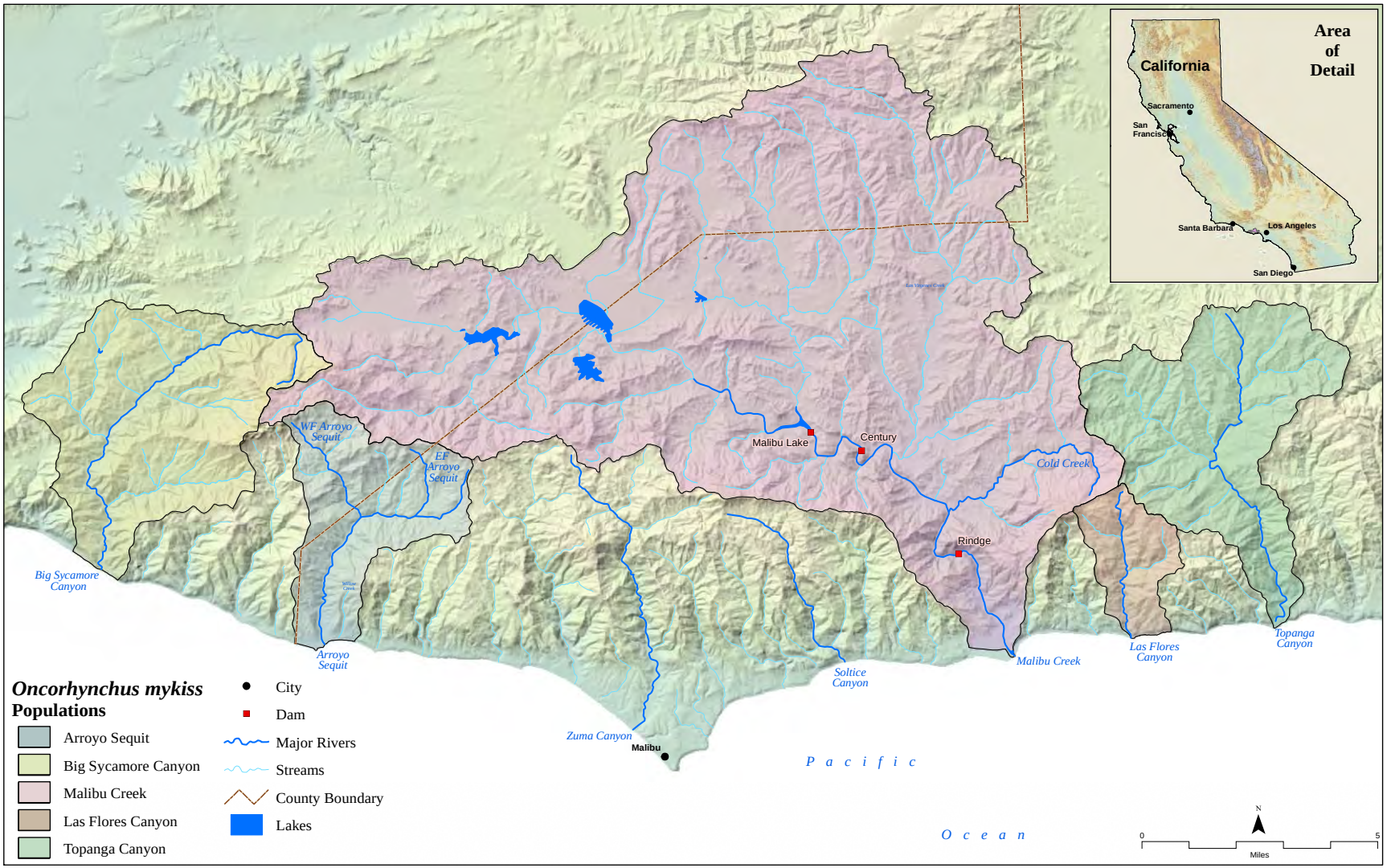


Figure 8. The Santa Monica Mountains Biogeographic Population Group region. Five steelhead populations/watersheds were analyzed in this region.

Table 9. Physical and Land Use Characteristics of Watersheds in the Santa Monica Mountains BPG.

Physical Characteristics				Land Use				
Watershed (north to south)	**Area (acres/miles^2)[1]**	**Stream Length[2] (miles)**	**Average Annual Rainfall[3] (in.)**	**Total Human Population[4]**	**Public Ownership***	**Urban Area[5]**	**Agriculture/ Barren[5]**	**Open Space[5]**
Big Sycamore Canyon Creek	13,649/21	32	17.9	27	76%	< 1%	< 1%	99%
Arroyo Sequit	7,572/12	17	17.9	370	38%	3%	1%	96%
Malibu Creek	70,726/110	161	18.0	74,585	7%	23%	2%	75%
Las Flores Canyon Creek	2,908/5	6	18.5	1,144	5%	15%	< 1%	85%
Topanga Canyon Creek	12,616/20	30	17.9	5,561	2%	15%	< 1%	85%
Total/Average	**107,471/168**	**246**	**18.0**	**81,687**	**---**	**18%**	**1%**	**81%**

Sources: 1. CDFFP CalWater 2.2 Watershed delineation, 1999
6. CDFG 1:1,000,000 Routed stream network, 2003
7. USGS Hydrologic landscape regions of the U.S., 2003 (1 km grid cells)
8. CDFFP Census 2000 block data (migrated), 2003
9. CDFFP Multi-source land cover data (v02_2), 2002 (100 m grid cells)

* National Recreation Areas, State Parks, and County Parks.

Current Watershed Conditions. Indicator ratings for the five watersheds in the Santa Monica Mountains BPG are presented in Figure 9.

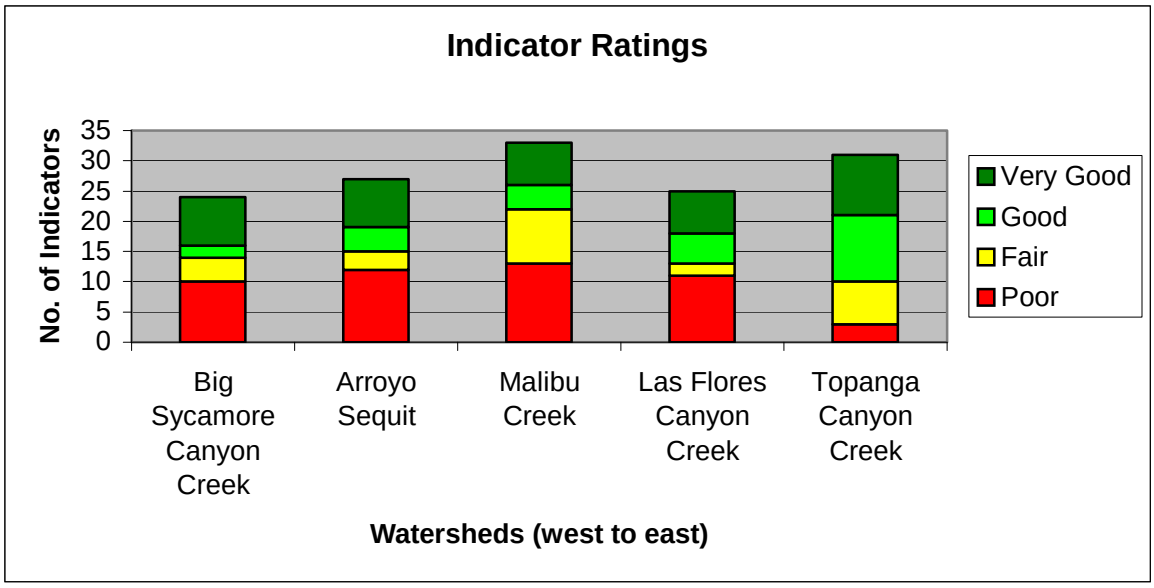


Fig. 9. Relative frequency of current indicator ratings for watersheds in the Santa Monica Mountains BPG. Indicators are the current condition of landscape, habitat, or population variables within a watershed. Although the amount of information available for particular watersheds varies, the relative ranking of indicators as "Very Good", "Good", etc., provides a general picture of watershed conditions across the BPG (see CAP Workbooks for each watershed for details).

The number of indicators used to assess existing conditions for steelhead in these watersheds varied from 24 indicators in the Big Sycamore Canyon watershed to 33 indicators in the Malibu Creek watershed. Information on existing conditions is found in the CAP Workbooks for each watershed.

Existing steelhead habitat quality was rated as "Fair" in the Big Sycamore Canyon, Arroyo Sequit, Malibu Creek, and Las Flores Canyon watersheds, and "Good" in the Topanga Canyon Creek watershed (see attached "Overall Viability Summary" for each watershed). Existing conditions within the Topanga Canyon Creek watershed, despite having the second highest human population density in this BPG (Table 9), are relatively good for steelhead: perennial flows, high-quality instream and riparian conditions, barriers to upstream and downstream movement, if present, are seasonally passable, and non-native predators, which infest other watersheds in this BPG, are absent.

Threats and Sources of Threats. The relatively high population and development pressures along the coastal portions of the Santa Monica Mountains, coupled with the proximity of this BPG to the densely populated Los Angeles Basin, creates a series of recurring, severe to very severe threats to steelhead persistence in each of the component watersheds. The number of threat sources used by the CAP Workbooks in determining threat status for the Santa Monica Mountains BPG watersheds varied from 8 in the Big Sycamore Canyon Creek watershed to 16 in the Malibu Creek watershed (Fig. 10).

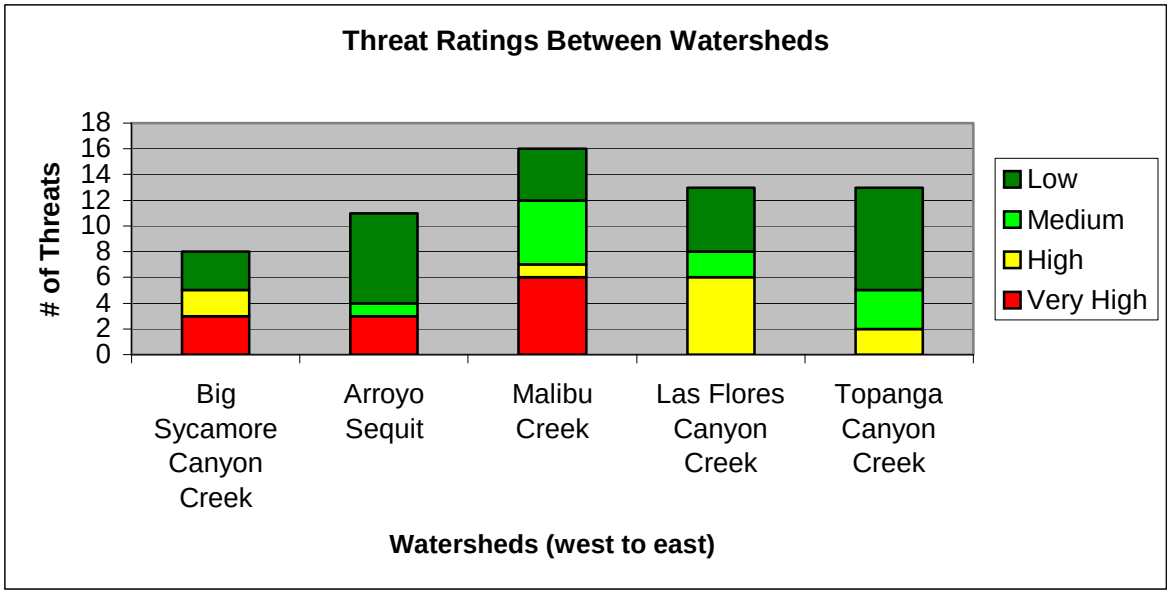


Fig. 10. Relative frequency of threat ratings between watersheds in the Santa Monica Mountains BPG. The sources, number, and severity of threats varies between watersheds, but watersheds in the western and middle portion of the BPG are subject to more severe threats than those in the east.

The relative number of severe threats is generally less in the Las Flores and Topanga Canyon Creek watersheds relative to the Big Sycamore Canyon Creek, Arroyo Sequit, and Malibu Creek watersheds, which are subject to a number of threats related to

impediments to movement, disturbance of instream habitats, and the introduction of non-native wildlife that either prey on steelhead life history stages or compete with them for food and space (Fig. 10).

Ten anthropogenic activities ranked as the top five sources of stress to steelhead in the Santa Monica Mountains BPG (Table 10). Each watershed has a unique combination of threats, however, recurring threats among most or all of the watersheds include: high road density, including roads in close proximity to riparian corridors, impacts from recreational facilities, barriers to movement caused by culverts and roadway stream crossings. Other threats are unique to particular watersheds, such as the Rindge and Malibou Lake dams on Malibu Creek.

Table 10. The top five sources of threats, ranked in order of frequency of occurrence and severity, in the component watersheds of the Santa Monica Mountains BPG (see CAP Workbook for details).

Threat Sources	Watershed (west to east)				
	Big Sycamore Canyon Creek	Arroyo Sequit	Malibu Creek	Las Flores Canyon Creek	Topanga Canyon Creek
Roads					
Recreational Facilities					
Other Passage Barriers					
Wildfires					
Urban Development					
Levees and Channelization					
Dams and Surface Water Diversions					
Non-Native Species					
Pipeline Crossing*					
Non-Point Pollution					

Key: Threat cell colors represent threat rating from CAP Workbook:
Red = Very High threat
Yellow = High threat
Light green = Medium threat
Dark green = Low threat

* The impediment to steelhead movement caused by the pipeline crossing on Big Sycamore Canyon Creek is currently the focus of restoration efforts and is also discussed in the recovery actions matrix under “Other Recovery Actions”.

Each of these threat sources generates multiple stresses on steelhead habitat and viability. Road density is high throughout the Santa Monica Mountains BPG, both on private and public lands. Road density, particularly roads that are within 300 feet of riparian corridors are affecting each of these watersheds by: altering surface runoff patterns and the stream hydrograph, encroaching on floodplains and decreasing floodplain

connectivity, creating the need for bank stabilization and levee construction to protect development, and providing a conduit for sediment, pollutant, and bacterial input to the watercourse. In other cases, roads create barriers to upstream and downstream movement of steelhead.

Because of the proximity of the Santa Monica Mountains to large urban areas, there is significant pressure to develop and maintain recreational facilities. Each of the watersheds in the Santa Monica Mountains BPG support one or more coastal and inland campgrounds and other high-use recreational facilities. This is particularly the case in the Big Sycamore, Arroyo Sequit, and Malibu watersheds, where large portions of the watersheds are publicly-owned. Recreational activities were recurring sources of direct and indirect threats to steelhead, including roadway stream crossings in and around campgrounds that pose physical barriers to upstream and/or downstream movement of steelhead, introduction of non-native plants and animals, disturbance to stream banks, instream habitats, and even redds by foot traffic and off-road vehicles, loss of or disturbance to riparian corridors around campgrounds, and constriction of the floodplain. The type of threat posed by recreational facilities varies significantly between watersheds, from one location, such a single road crossing on Arroyo Sequit, to multiple sites, such as the location of campgrounds in floodplains or multiple stream crossings in the Malibu Creek watershed.

Increased residential development, including high road densities, has significantly altered natural fire regimes in the Santa Monica Mountains BPG because it has allowed human access to almost all portions of the component watersheds. Fires have consumed 71% to 100% of the Big Sycamore Canyon Creek, Arroyo Sequit, Malibu Creek, and Las Flores Canyon Creek watersheds within the past 25 years, including recent fires in 2007. Approximately 32% of the Topanga Canyon Creek watershed has burned in the last 25 years (see CAP Workbooks for specifics). Increased fire frequency can increase slope erosion and sediment input to streams, resulting in long-term changes to substrate texture and embeddedness, water quality (e.g., turbidity), and water temperature (loss of riparian canopy cover). Steelhead in each of the watersheds in the Santa Monica Mountains BPG have been subjected to these secondary effects of fire.

The terrain of the Santa Monica Mountains results in development on steep slopes, often accompanied by road cuts to provide access, thus affecting watershed processes such as erosion and sedimentation. Development has also occurred along narrow riparian corridors, which physically constrains the ability of streams to meander, decreases floodplain connectivity, removes fringing riparian vegetation, encourages bank stabilization, levee construction, and other flood control activities, may constrict the floodplain, removes fringing riparian vegetation, which can result in increased human activity within stream channels.

The Malibu Creek watershed is highly constrained by two major dams: the Rindge Dam and the Malibou Lake Dam. The former structure is located approximately two stream miles upstream of the lagoon and blocks access to over 90% of the steelhead spawning and rearing habitat within Malibu Creek. It also has isolated native rainbow trout that

otherwise would be anadromous and prevents the periodic re-colonization of upstream habitats that may experience periodic temporary extirpations as a result of natural stochastic processes, such as wildfires, droughts, and landslides. Dams have manifold effects on physical, hydrological, and habitat characteristics of the middle and lower reaches of the main stem and create and maintain suitable habitat conditions for several species of non-native fishes and bullfrogs, that may affect one or more life history stages of steelhead directly (predation) or indirectly (competition for food). Non-native crayfish, snails, fishes, and bullfrogs are particular problems in the Malibu and Las Flores Canyon watersheds.

Estuarine habitat loss in the component watersheds of the Santa Monica Mountains BPG ranges from 66% to 97%. Malibu Creek formerly had the largest estuary of any of these watersheds in the BPG and still has the highest amount of remaining estuarine habitat (34%) (see Table 3 in ESU Summary). Topanga Canyon Creek has the second highest amount of remaining estuarine habitat (30%), but the estuary is highly impacted by Highway 1, commercial development, and recreational activities. Road construction, bridges, levees, floodplain encroachment by residential and commercial development (e.g., City of Malibu and Malibu Colony in Malibu Creek) have significantly reduced estuarine habitat in almost all cases in this BPG.

Some of the watersheds in the Santa Monica Mountains BPG, particularly those in the western portion of the range where population impacts are reduced and the watersheds are mostly publicly-owned, could significantly improve steelhead viability by correcting one or more specific threats (e.g., pipeline crossing in Big Sycamore Canyon Creek and roadway culvert/crossing in Arroyo Sequit are impediments to steelhead movement). Improving habitat conditions in other watersheds, such as Malibu Creek, will require multiple, long-term measures (e.g., dam removal, non-native wildlife control).

The ten threat sources listed in Table 10 are not mutually exclusive and can be grouped into the following general threat categories:

- barriers to upstream and downstream movement (roads, dams, etc.);
- water quality impacts caused by roads as conduits for sediment and pollutants;
- recreational facilities;
- fire frequency, and;
- non-native predators and/or competitors.

These threat sources should be the focus of a variety of recovery actions to address specific stresses on steelhead viability associated with these threats. Spatial and temporal data acquired on specific indicators associated with sources of threats or stresses, such as water temperature, pH, nutrients, etc., are generally inadequate to be the target of specific recovery actions. This type of data acquisition should be the subject of site-specific investigations in order to refine the primary recovery actions or to target additional recovery actions. Impediments to fish passage stemming from the construction and maintenance of roads and other transportation corridors, dams and other passage barriers

on some drainages, groundwater extraction, modification of channel morphology and adjacent riparian habitats through flood control, instream activities such as sand and gravel mining, and loss of estuarine functions caused by filling and point and non-point waste discharges from agricultural and other anthropogenic activities should be further evaluated and addressed as part of any recovery strategy for the Santa Monica Mountains BPG (see recovery action matrices for more specific recovery actions).

ATTACHMENT. SUMMARY TABLES FOR STRESSES AND THREATS, STRESS MATRIX, AND OVERALL VIABILITY SUMMARY FOR THE SANTA MONICA MOUNTAINS BPG

Threats Summary for the Mojave Rim Biogeographic Population Group

Location and Physical Characteristics. The Mojave Rim BPG region encompasses three large coastal watersheds that drain the northern slopes of the Santa Monica Mountains and the coastal slopes of the San Gabriel and San Bernardino mountains in southern Los Angeles County, southwestern San Bernardino, and western Riverside and Orange counties: Los Angeles River, San Gabriel River, and the Santa Ana River (Fig. 11). Habitat conditions also were evaluated for five major tributaries of these drainages: Arroyo Seco in the Los Angeles River watershed; East and West forks of the San Gabriel River, and Mill and Lytle creeks in the upper Santa Ana River watershed. The upper portion of each of these watersheds includes steep, montane regions; the lower watersheds cut across the Los Angeles Basin—an extensive coastal plain. The Los Angeles, San Gabriel, and Santa Ana rivers have not always discharged to the Pacific Ocean at their current locations, but sometimes migrated across the Los Angeles Basin and discharged as far west as Ballona Creek and as far east as present-day Huntington Beach. The Los Angeles, San Gabriel, and Santa Ana rivers currently discharge to the Pacific Ocean within 20 miles of each other in southern Los Angeles and northern Orange counties. The component watersheds are large, extending up to 83 miles inland in the case of the Santa Ana River watershed (Fig. 11).

Average annual precipitation in these three watersheds is higher than that of the two adjacent BPGs (Santa Monica Mountains and Santa Catalina Gulf Coast) because the upper watersheds include the San Gabriel and San Bernardino mountain ranges, whose upper elevations receive high annual rainfall and snowfall (Table 11). Rainfall along the coastal terrace portion of each of these watersheds is significantly lower than in the mountainous portions. For example, the average annual total precipitation for the City of Los Angeles is about 14.4 inches; much lower than the average for the Los Angeles River watershed. Much of the main stem and tributaries of the Mojave Rim BPG drainages flow across the relatively level Los Angeles Basin, with relatively few tributaries for their overall watershed size; as a result, the overall stream length is less than that of other BPG watersheds of comparable area.

Table 11. Physical and Land Use Characteristics of Watersheds in the Mojave Rim BPG region.

Physical Characteristics				Land Use				
Watershed (north to south)	**Area (acres/miles^2)[1]**	**Stream Length[2] (miles)**	**Average Annual Rainfall[3] (in.)**	**Total Human Population[4]**	**Public Ownership***	**Urban Area[5]**	**Agriculture/ Barren[5]**	**Open Space[5]**
Los Angeles River	535,923/837	766	19.1	4,383,260	25%	61%	1%	38%
San Gabriel River	463,167/723	784	19.8	2,417,034	35%	53%	2%	46%
Santa Ana River	1,141,195/1,783	2,074	17.3	3,109937	29%	37%	8%	55%
Total/Average	**2,140,285/3,343**	**3,624**	**18.7**	**9,910,231**	**30%**	**50%**	**4%**	**46%**

Sources: 1. CDFFP CalWater 2.2 Watershed delineation, 1999
10. CDFG 1:1,000,000 Routed stream network, 2003

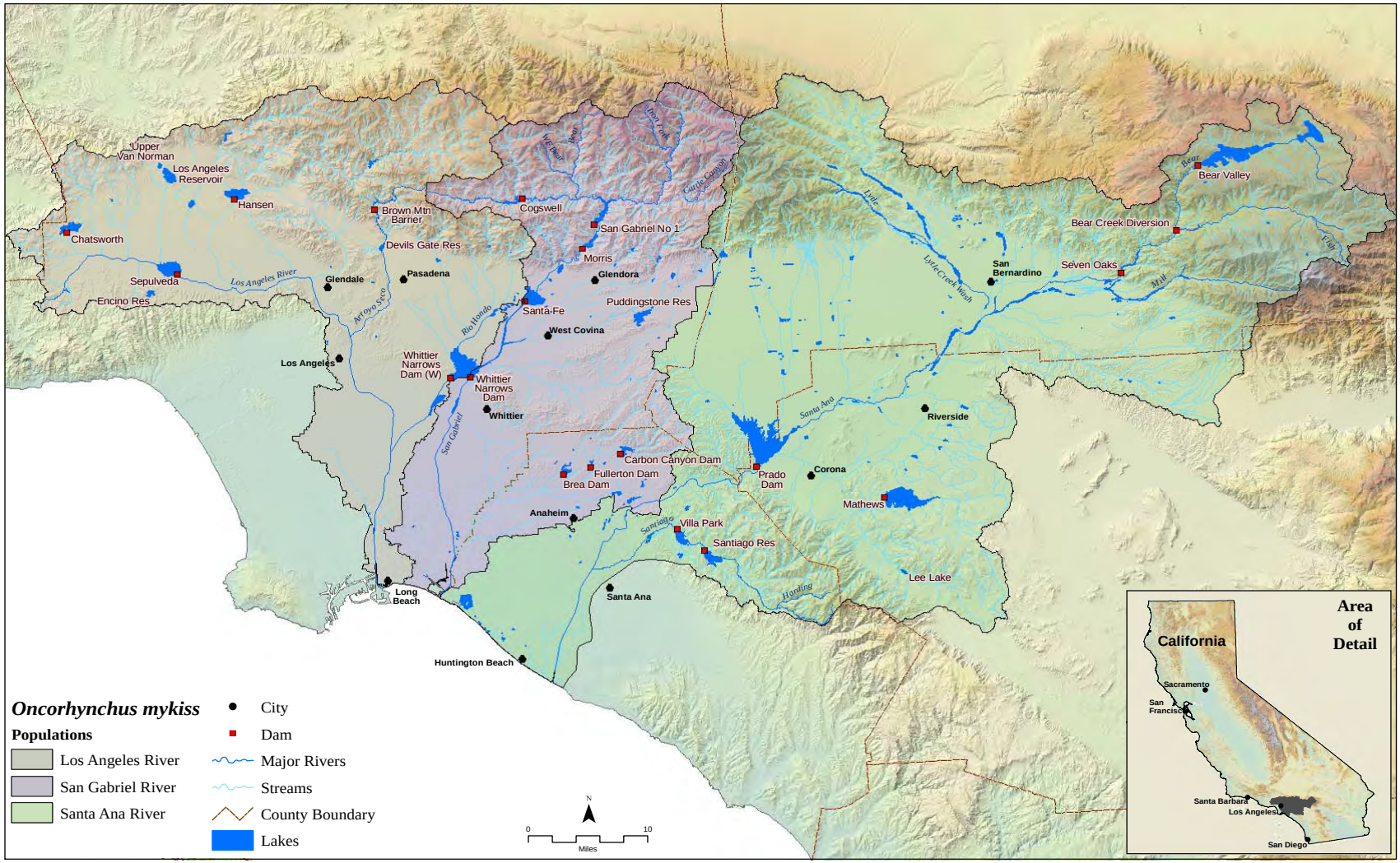
11. USGS Hydrologic landscape regions of the U.S., 2003 (1 km grid cells)
12. CDFFP Census 2000 block data (migrated), 2003
13. CDFFP Multi-source land cover data (v02_2), 2002 (100 m grid cells)

* National Forest Lands only; Military Reservations or State and County Parks not included.

Land Use. Table 11 summarizes land use and population density in this region. This BPG region encompasses the second-largest metropolitan area in the United States. Human population density here is the highest of any of the five BPG regions, averaging 2,964 persons per square mile, over six times greater than the next most densely populated BPG, the Santa Catalina Gulf Coast. Population density is much greater in some of the component watersheds: the Los Angeles River watershed supports 5,237 persons/square mile. Population centers are mostly concentrated in the Los Angeles Basin portion of these watersheds, but the interior portions of the Santa Ana River watershed also have extensive metropolitan areas (see Table 2 and Figure 1 in ESU Summary).

There are at least 20 dams on the main stem and/or major tributaries of each of the three drainages in this BPG that are large enough to be regulated by the California Department of Water Resources and/or Department of Defense (also see Fig. 11 for distribution and size of reservoirs). These dams are owned and operated by federal, state, public utility, local government, or private interests for irrigation, flood control and storm water management, recreation, municipal water supply, fire protection, farm ponds, or some combination of these purposes. Most of the reservoirs and lakes in this region receive high recreational use and many are sources of non-native crayfish, fishes, and bullfrogs, and other non-native species that prey on steelhead or compete with steelhead for food and habitat space.

Public land ownership is concentrated in the montane regions of these watersheds, mostly within the Angeles National Forest, San Bernardino National Forest, and the northern portion of Cleveland National Forest. These three National Forests encompass several federally-designated wilderness areas: San Gabriel and Sheep Mountain Wilderness Areas (Angeles National Forest); San Gorgonio, Cucamonga, San Jacinto, Santa Rosa, and Big Horn Mountain Wilderness Areas (San Bernardino National Forest), and Aqua Tibia Wilderness Area (Cleveland National Forest). Additionally, several rivers have been evaluated for inclusion in the federally-designated Wild and Scenic River system: Little Rock Creek, North and South forks of the San Gabriel River (tributaries to the San Gabriel River), Middle Fork Lytle Creek, Bear Creek, and Siberia Creek (tributaries to the Santa Ana River). Agriculture (row crop, orchard cultivation, and livestock ranching), used to be important land uses throughout the flatter portions of these watersheds, but have largely been displaced by urban development.


Upper Van Norman
Los Angeles Reservoir
Hansen
Chatsworth
Sepulveda
Encino Res
Los Angeles River
Glendale
Pasadena
Brown Mtn Barrier
Devils Gate Res
Cogswell
San Gabriel No 1
Morris
Glendora
Puddingstone Res
Santa Fe
West Covina
Arroyo Seco
Rio Hondo
Whittier Narrows Dam (W)
Whittier Narrows Dam
Whittier
Los Angeles
San Gabriel
Carbon Canyon Dam
Fullerton Dam
Brea Dam
Anaheim
Villa Park
Santiago Res
Santiago
Long Beach
Santa Ana
Huntington Beach
Harding
Lee Lake
Mathews
Corona
Prado Dam
Santa Ana
Riverside
Lytle Creek Wash
Lytle
San Bernardino
Seven Oaks
Bear Creek Diversion
Bear Valley
Mill
Bear
Lytle
Cattle Canyon
Deer
Middle Fork
Oro Grande
Oro Grande
Oro Grande

Current Watershed Conditions. The relative ratings of current habitat and land use conditions (indicators) used to assess the viability of watersheds to support steelhead in the Mojave Rim BPG are presented in Figure 12. The number of indicators varied widely between watersheds, from 12 for the Arroyo Seco and Mill Creek sub-watersheds to 28 indicators for the main stem of the Santa Ana River.

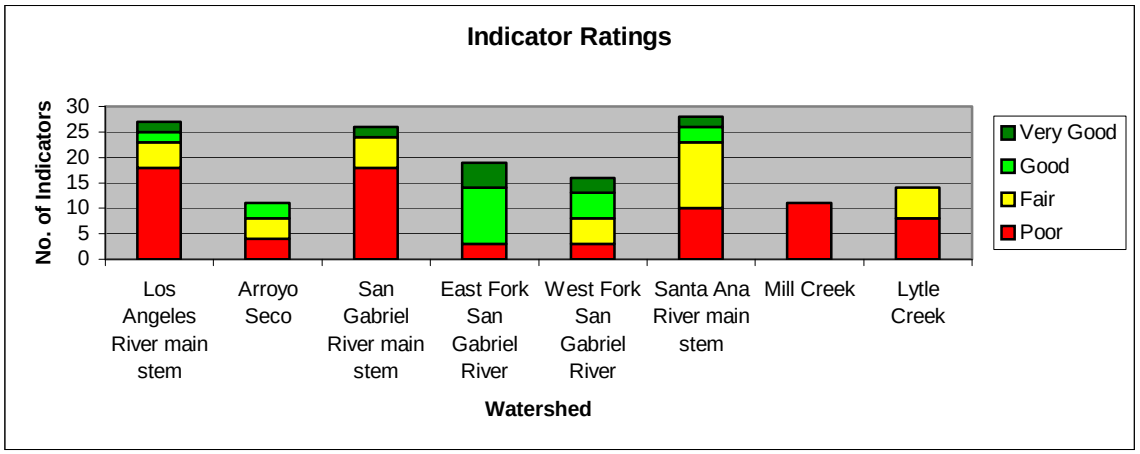


Figure 12. Relative frequency of indicator ratings for watersheds in the Mojave Rim BPG. Indicators are rated as "Very Good", "Good", etc., based on the habitat conditions for steelhead. The relative ranking of indicators provides a general picture of existing habitat and land use conditions across the BPG (see individual CAP workbooks for details).

In general, instream, riparian, and floodplain conditions for steelhead in watersheds in this BPG are in poor shape, reflecting pervasive urban conversion of watershed lands, particularly along the main stem of these drainages, but even in the upper sub-watersheds in the Santa Ana River watershed. The upper watersheds of the San Gabriel River watershed (East and West forks) still provide good to very good habitat conditions for resident rainbow trout, but these reaches are isolated from the anadromous population component found in the main stem.

Threats and Sources of Threats. Habitat impairments were rated as severe to very severe in five of the eight watersheds and sub-watersheds in this region because of the very high population density throughout this BPG (Fig. 13).

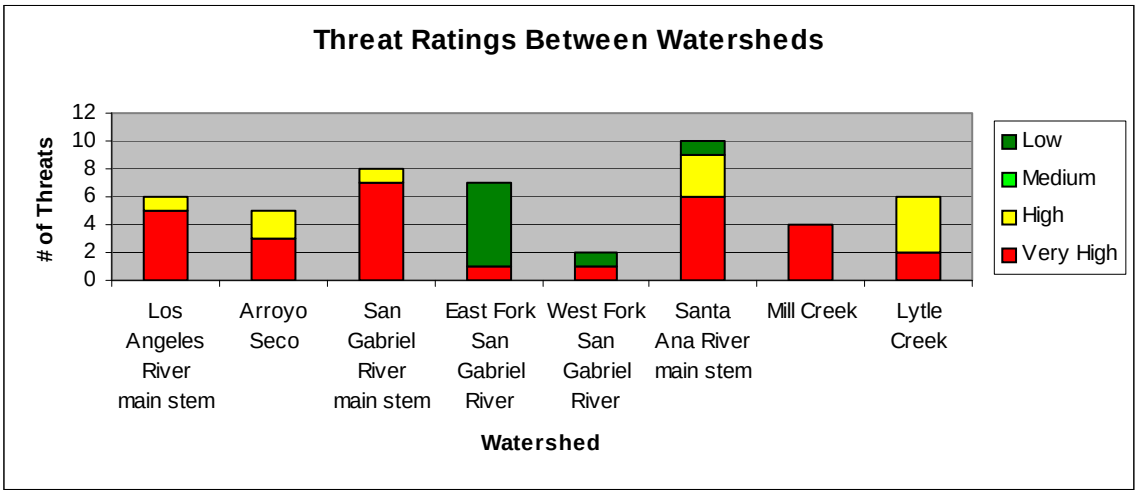


Figure 13. Relative frequency of ratings of the sources of threats to steelhead habitat in watersheds in the Mojave Rim BPG. The sources, number, and severity of threats varies between watersheds.

Ten anthropogenic activities ranked as the top five sources of stresses to steelhead and their habitat in the Mojave Rim BPG (Table 12). These sources of threats focus on water management activities to serve municipal uses (dams, surface water diversions, and groundwater extraction). The main stems of the Los Angeles, San Gabriel, and Santa Ana rivers, including the main tributaries of the latter, provide little suitable spawning or rearing habitat for steelhead because of loss of passage barriers, channelization and flood control activities, loss of surface flows, and impaired water quality. The East and West forks of the San Gabriel River watershed, above Morris and Cogswell dams and their reservoirs, are mostly are in public ownership (Angeles National Forest and Cleveland National Forest) and these reaches provide relatively good habitat conditions for steelhead. Both of these sub-watersheds support reproducing populations of resident rainbow trout that are isolated from their anadromous counterparts downstream of the dams.

Table 12. The top five sources of threats, ranked in order of frequency of occurrence and severity, in the Mojave Rim BPG (see CAP Workbooks for individual watersheds for details).

Threat Sources	Compenent Watersheds							
	Los Angeles River main stem	Arroyo Seco	San Gabriel River main stem	East Fork San Gabriel River	West Fork San Gabriel River	Santa Ana River main stem	Lytle Creek	Mill Creek
Dams and Surface Water Diversions								
Flood Control								
Groundwater Extraction								

Levees and Channelization								
Urban Development								
Recreational Facilities								
Other Passage Barriers								
Agricultural Development								
Non-Point Pollution								
Wildfires*								

Key: Threat cell colors represent threat rating from CAP Workbook:

Red = Very High threat
Yellow = High threat
Light green = Medium threat
Dark green = Low threat

* Wildfires as a source of threats to steelhead habitat is not reflected in the top five threat sources in the CAP summary for these watersheds (see CAP workbooks), but is included here because of the extent and severity of recent (2005-2007) wildfires in this region.

At least 18 major dams and surface water diversions have been constructed in the watersheds of this region to serve mostly urban purposes. These structures and water management practices have significantly altered natural sediment and hydrological processes in these watersheds. The reservoirs behind these dams create suitable habitat conditions for several species of non-native snails, fishes, bullfrogs, and other introduced species that may affect one or more life history stages of steelhead directly (predation) or indirectly (competition for food). Non-native crayfish, fishes, and/or amphibians occur in the main stems of the Los Angeles, San Gabriel, and Santa Ana rivers, as well as in most or all of the major tributaries. A major indirect impact to the main stem of the San Gabriel River as a result of dam construction and operation is periodic sluicing of sediments accumulated behind the dams, which severely degrade instream and riparian habitat quality for salmonids downstream of these structures.

Widespread pumping of groundwater in aquifers throughout the watershed basins routinely eliminate surface flows in portions of most of these drainages and the magnitude of loss of surface flows and passage barriers is exacerbated during years of below-average precipitation. Very high road density in the urbanized portions of these watersheds also is a common source of passage barriers for steelhead that constricts the main stems of the three watersheds to a narrow channel.

Urban and agricultural conversion of coastal and middle reaches of these watersheds has created a number of severe stressors on steelhead. High road density throughout the floodplains of the main stems has increased sediment and non-point pollutant inputs to these drainages and their estuaries and degraded rearing and spawning habitat. Nutrient and coliform bacteria loading from agricultural and wastewater treatment effluents are

important sources of degraded water quality in most of these drainages. Channelization, levee construction, and other flood control activities have completely removed instream and riparian habitat from extensive reaches of the main stems of these drainages as they pass through urban areas.

The formerly extensive estuaries that formed at the mouths of the Los Angeles, San Gabriel, and Santa Ana rivers have been all but eliminated by urban and commercial development (see Table 3 in the ESU Summary).

All three watersheds receive very high recreational activity because of their proximity to large urban areas. Trash, foot traffic, and ORV traffic have significantly affected instream and riparian habitats along extensive reaches of the upper watersheds.

Fires have burned 21% and 26% of the San Gabriel River and Santa Ana River watersheds, respectively, in the past 25 years and may be significant, widespread, and long-term sources of sedimentation, turbidity, substrate embeddedness, and loss of riparian canopy cover.

Despite widespread and varied habitat degradation to the coastal and middle main stems of all three watersheds, including the main tributaries of the latter, steelhead continue to spawn in each of the watersheds in this BPG and resident rainbow trout populations still inhabit the relatively high-quality habitat that survive upstream of the dams in this region. Improving conditions for steelhead passage, spawning, and/or rearing in these watersheds will require multiple, long-term, measures related to water management, recreation, and fish passage past large dams.

The threat sources discussed in this section should be the focus of a variety of recovery actions to address specific stresses on steelhead viability associated with these threats. Spatial and temporal data acquired on specific indicators associated with sources of threats or stresses, such as water temperature, pH, nutrients, etc., are generally inadequate to be the target of specific recovery actions. This type of data acquisition should be the subject of site-specific investigations in order to refine the primary recovery actions or to target additional recovery actions. A fish passage impediment inventory and assessment should be conducted for each of the major watershed in the Mojave Rim BPG. Impediments to fish passage stemming from the construction and operation of dams and groundwater extraction, modification of channel morphology and loss of adjacent riparian habitats through flood control, instream activities such as sand and gravel mining, and loss of estuarine functions due to filling and point and non-point waste discharges should be further evaluated and addressed as part of any recovery strategy for the Mojave Rim BPG (see recovery action matrices for more specific recovery actions).

ATTACHMENT. SUMMARY TABLES FOR STRESSES AND THREATS, STRESS MATRIX, AND OVERALL VIABILITY SUMMARY FOR THE MOJAVE RIM BPG

Threats Assessment for the Santa Catalina Gulf Coast Biogeographic Population Group

Location and Physical Characteristics. The Santa Catalina Gulf Coast Biogeographical Population Group (BPG) region encompasses ten coastal watersheds of moderate size that drain the western slopes of the Santa Ana Mountains and Peninsular Range in southwestern Orange and Riverside counties southward through San Diego County to the United States-Mexico border (Figure 14). The upper portion of almost all of these watersheds includes steep, montane regions; the lower watersheds cut across coastal terraces. Two watersheds, Sweetwater River and Otay River, drain into San Diego Bay; the other eight watersheds drain directly into the Pacific Ocean. The component watersheds vary greatly in size—the San Luis Rey River watershed is twelve times the size of the San Onofre Creek watershed.

Average annual precipitation in this region is relatively low and is spatially variable (Table 13). The coastal terrace portion of each of these watersheds receives significantly less rainfall that the interior montane portions. For example, the average annual total precipitation for the City of San Diego is about 9.9 inches; much lower than the average for the San Diego River watershed as a whole (i.e., 18 inches). Because of low rainfall, many of the drainages in this BPG are naturally seasonal or have extensive seasonal reaches during years of below-average precipitation. Stream length increases substantially in the interior portions of these watersheds because of the highly dissected terrain and associated tributaries and contributes to the large total stream length found in this region (4,235 miles). Because of low rainfall, many of the drainages are naturally seasonal or have extensive seasonal reaches during years of below-average precipitation.

Table 13. Physical and Land Use Characteristics of Watersheds in the Santa Catalina Gulf Coast BPG region.

Physical Characteristics				Land Use				
Watershed (North to South)	Area (acres/miles^2)[1]	Stream Length[2] (miles)	Average Annual Rainfall[3] (in.)	Total Human Population[4]	Public Ownership*	Urban Area[5]	Agriculture/ Barren[5]	Open Space[5]
San Juan River	113,977/178	280	12.5	191,997	37%	23%	7%	70%
San Mateo Creek	85,964/134	200	13.3	4,011	48%	3%	2%	95%
San Onofre Creek	37,617/59	86	14.0	4,981	---	6%	< 1%	94%
Santa Margarita River	472,633/738	949	15.6	181,376	10%	10%	13%	77%
San Luis Rey River	367,329/574	749	17.8	147,782	11%	8%	19%	73%
San Dieguito River	223,155/349	432	18.3	129,475	11%	18%	10%	72%
San Diego River	281,059/439	537	18.0	500,469	17%	26%	2%	72%
Sweetwater River	142,511/223	271	17.7	249,589	15%	27%	1%	72%
Otay River	93,504/146	256	16.7	122,342	---	16%	9%	75%

Tijuana River	301,649/471	475	17.3	75,117	38%	5%	2%	93%
Total/Average	**2,119,398/3,311**	**4,235**	**16.1**	**1,607,140**	**---**	**14%**	**7%**	**79%**

Sources: CDFFP CalWater 2.2 Watershed delineation, 1999
CDFG 1:1,000,000 Routed stream network, 2003
USGS Hydrologic landscape regions of the U.S., 2003 (1 km grid cells)
CDFFP Census 2000 block data (migrated), 2003
CDFFP Multi-source land cover data (v02_2), 2002 (100 m grid cells)

* National Forest Lands only; does not include Military Reservations or State and County Parks

Land Use. Table 13 summarizes land use and population density in this region. Human population density varies widely between the component watersheds, but collectively, population density here is the second highest among the nine BPGs, averaging 485 persons per square mile. Population centers are concentrated on the coastal terrace portion of these watersheds, especially around San Diego Bay, which comprises one of the largest urban areas in the United States. The San Mateo Creek and portions of the Santa Margarita River and San Onofre Creek watersheds have very low population densities compared to the other watersheds, averaging less than 30 and 84 persons/square mile, respectively. Average population densities in the San Diego River and Sweetwater River watersheds, which contains the very large urban center of greater San Diego, average over 1,100 persons/square mile (see Table 2 and Figure 1 in ESU Summary).

In most of these watersheds, the first land use change was row crop agriculture, primarily orchard crops, followed by increasing urbanization, especially on the coastal terraces. Specialty agriculture to supply nurseries still remains and in some areas has expanded. More recently, the upper watersheds of the Santa Margarita River and the San Luis Rey River have experienced rapid urban growth. Semi-developed rural land and orchards cover extensive portions of the coastal and middle portions of these watersheds. Public ownership of land (mostly in Cleveland National Forest lands) is largely concentrated in the interior, montane watersheds and includes several federally-designated Wilderness Areas: Agua Tibia, San Mateo, Pine Creek, and Hauser Wilderness Areas. Portions of several watersheds have also been evaluated for inclusion in the Federal system of Wild and Scenic Rivers: upper San Luis Rey River; Cottonwood Creek (tributary to the Tijuana River), upper San Mateo Creek, and Devil's Canyon (tributary to San Mateo Creek). The San Juan River/Trabuco Creek watershed contains large county parks (e.g., Caspers Regional Park) that cover much of the upper watersheds of these drainages. Marine Corps Base Camp Pendleton covers the coastal and middle portions of the San Mateo Creek, San Onofre Creek, and Santa Margarita River watersheds. Overall though, public ownership constitutes a minority of land ownership in the watersheds in this BPG, especially the coastal and middle portions.

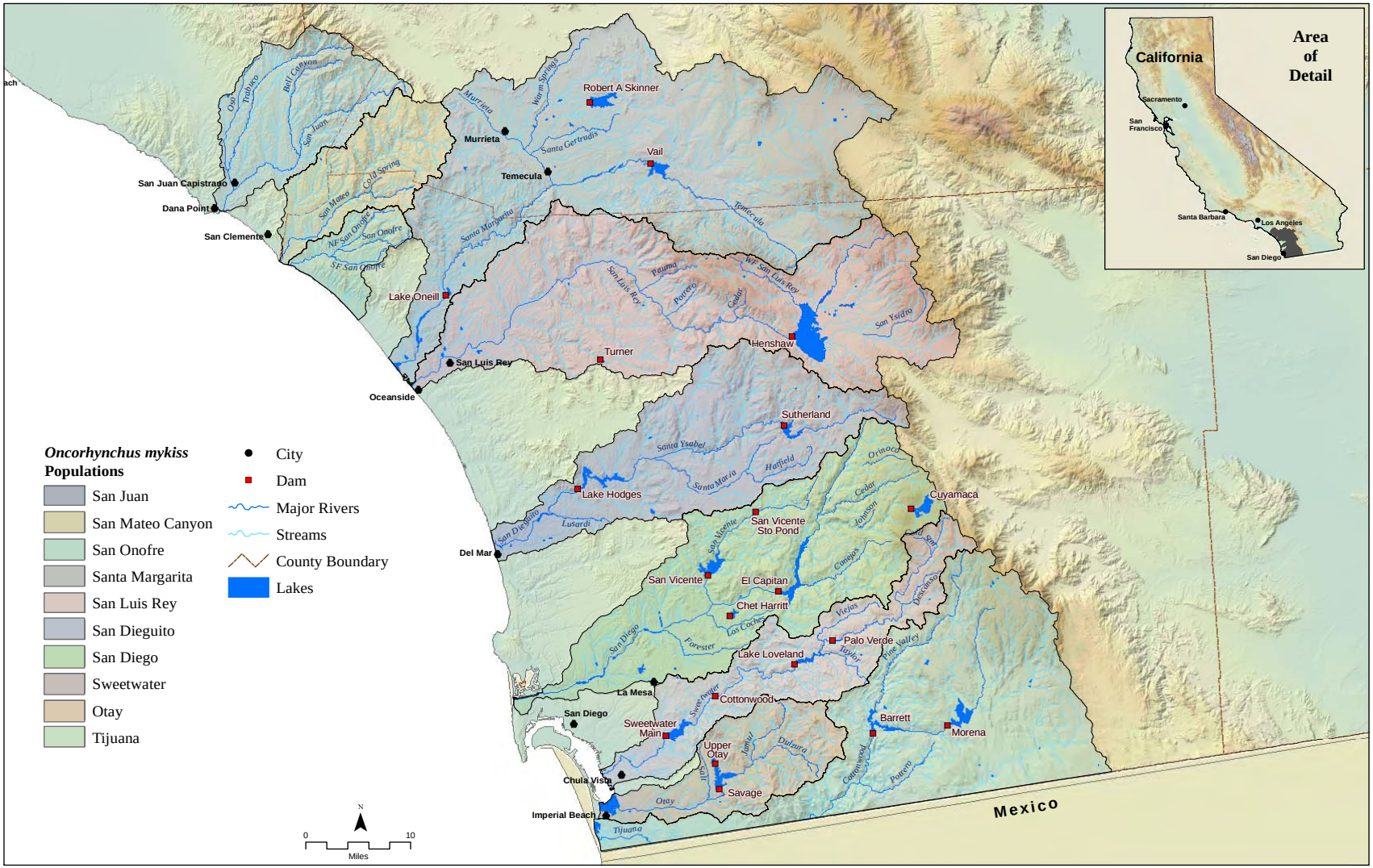


Figure 14. The Santa Catalina Gulf Coast Biogeographic Population Group region. Ten steelhead populations/watersheds were analyzed in this region.

Agriculture (row crop and orchard cultivation and livestock ranching), are important land uses that directly or indirectly impact watershed processes throughout these watersheds. A major consequence of agricultural and urban growth in this region is reservoir development. There are at least 20 major dams on watersheds in this region that are large enough to be regulated by the California Department of Water Resources and/or Department of Defense (Fig. 14 shows 18 of the largest dams). These dams are owned and operated by federal, state, public utility, local government, or private interests for irrigation, flood control and storm water management, recreation, municipal water supply, fire protection, farm ponds, or a combination of these purposes. Two of these dams have enlarged natural lakes: Lake Henshaw in the San Luis Rey River watershed and Vail Lake in the Santa Margarita River watershed. None of these facilities have incorporated fish passage provisions, including downstream flow provisions, into their operation. Most of the reservoirs and lakes in this region receive high recreational use and many are sources of non-native crayfish, fishes, and bullfrogs, and other non-native species that prey on steelhead or compete with steelhead for food and habitat space.

Current Watershed Conditions. The relative ratings of current habitat and land use conditions (indicators) used to assess the viability of watersheds to support steelhead in the Santa Catalina Gulf Coast BPG are presented in Figure 15. The number of indicators varied widely between watersheds, from 20 for the San Diego River, Sweetwater River, and Otay River watersheds to 40 indicators for the San Mateo Creek watershed.

In general, instream, riparian, and floodplain conditions for steelhead in watersheds in this BPG are rated as “Poor” to “Very Poor”, reflecting pervasive agricultural and urban conversion of watershed lands, particularly along the middle and coastal reaches. In contrast, the upper watersheds of many of these drainages are in relatively good condition (exceptions are the upper watersheds of the Santa Margarita River and San Luis Rey River). Relatively few indicators were rated as “Good” or “Very Good”.

Threats and Sources of Threats. Varying numbers and intensity of habitat impairment (threats) were identified in the CAP Workbooks analyses, ranging from 11 in the San Onofre Creek watershed to 17 in the Santa Margarita River and San Luis Rey River watersheds (Figure 16). Most of the habitat impairments were rated as severe to very severe in all but the San Mateo Creek and San Onofre Creek watersheds, and are related to high population density and urban and agricultural conversion of watershed lands. The relatively good steelhead habitat quality in San Mateo and San Onofre creeks, and, to a lesser degree in the Santa Margarita River, is due to the fact that Camp Pendleton Marine Corps Base, which covers substantial portions of the coastal and middle reaches of these watersheds. The upper watersheds, above dams and reservoirs, mostly are in public ownership (Cleveland National Forest). These reaches provide relatively good habitat conditions for steelhead and support reproducing populations of resident rainbow trout.

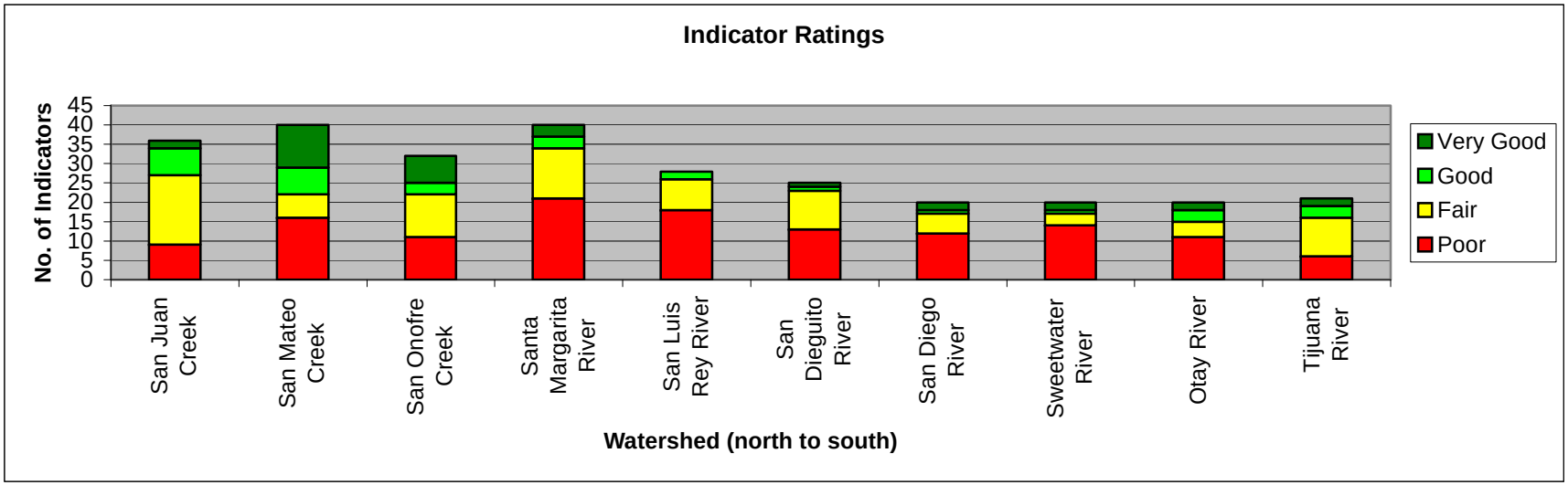


Fig. 15. Indicator ratings for watersheds in the Santa Catalina Gulf Coast Range BPG. Indicators are rated as "Very Good", "Good", etc., based on the current condition of landscape, habitat, or population variables. Although the amount of available information (the number of indicators) varies between watersheds, the relative ranking of indicators provides a general picture of existing habitat and land use conditions across the BPG (see individual CAP Workbooks for details).

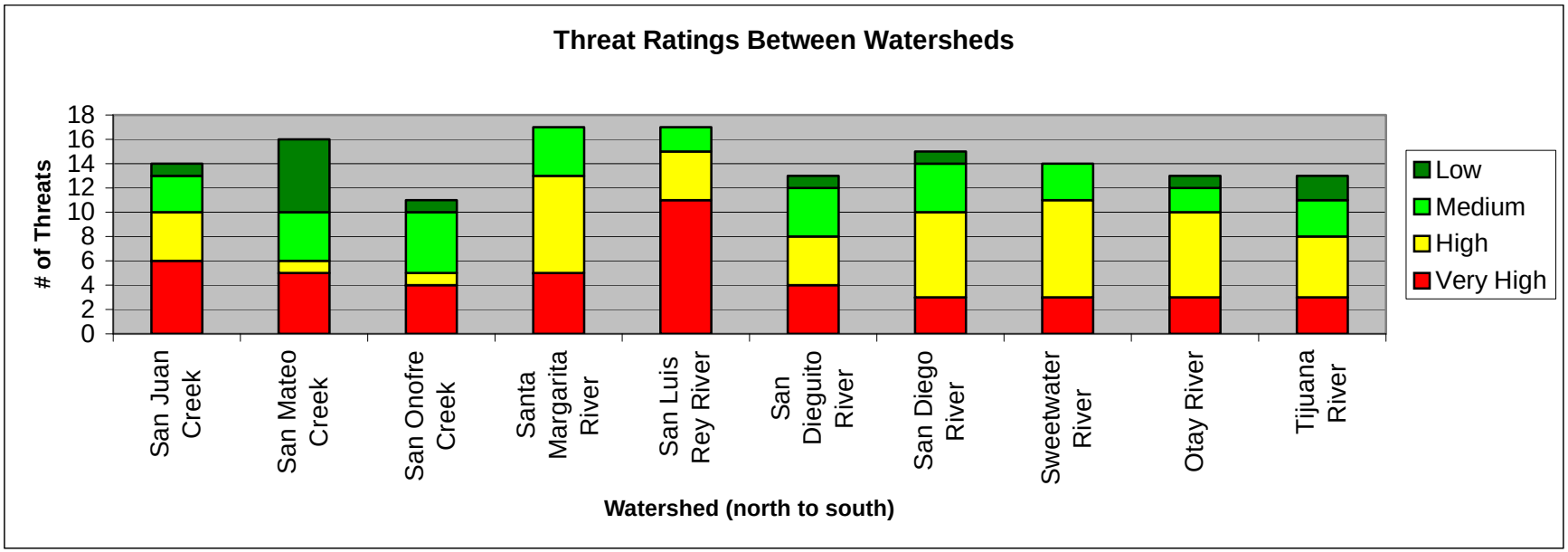


Fig. 16. Relative frequency of threat ratings to steelhead and their habitats in watersheds in the Santa Catalina Gulf Coast BPG. The sources, number, and severity of threats varies between watersheds.

Twelve anthropogenic activities ranked as the top five sources of stress to steelhead in the Santa Catalina Gulf Coast BPG (Table 14). The most significant feature of this ranking is that each of the top five threats are rated as "Severe" or "Very Severe" and that groundwater extraction and/or dams or surface water diversions are pervasive sources of threats to steelhead in each of the watersheds. Although open space is the dominant land use in this BPG region, urban and agricultural conversion of the coastal and middle portions of these watersheds, especially within the floodplains of these drainages, has disproportionately degraded habitat conditions for steelhead here.

Water management activities associated with urban and agricultural conversion of watershed lands are the most pervasive source of threats to steelhead in this region. Climatically, the Santa Catalina Gulf Coast BPG region is classified as semi-arid. Steelhead compete for water with urban and agricultural interests throughout the watersheds in this region. At least 20 major dams and surface water diversions without provisions for fish passage have been constructed on the BPG watersheds south of the San Juan Creek watershed to serve agricultural, urban, and recreational purposes. These structures and water management practices have significantly altered natural sediment and hydrological processes in these watersheds. Dams also have isolated rainbow trout in the upper watersheds of these drainages that otherwise would be anadromous. The reservoirs behind these dams create suitable habitat conditions for several species of non-native snails, fishes, bullfrogs, and other introduced species that may affect one or more life history stages of steelhead directly (predation) or indirectly (competition for food). Non-native crayfish, fishes, and bullfrogs occur in all of the drainages in this BPG, but are particularly abundant in the San Mateo Creek, San Onofre Creek, and Santa Margarita River watersheds.

Widespread pumping of groundwater in aquifers below these dams routinely eliminate surface flows in portions of most of these drainages and the magnitude of loss of surface flows and passage barriers is exacerbated during years of below-average precipitation. High road density and frequency of stream crossings (culverts, bridges, etc.) in most of the urbanized portions of these watersheds also is a common source of passage impediments for steelhead. As a result of widespread construction of dams in the lower and middle reaches of these watersheds, resident rainbow trout populations are isolated in high-quality instream and riparian habitat in the upper watersheds above these reservoirs.

Urban and agricultural conversion of coastal and middle reaches of these watersheds has created a number of severe stressors on steelhead. High road density increases sediment and pollutant inputs to these drainages and their estuaries, degrading rearing and spawning habitat and increasing mortality of one or more life stages. Channelization and levee construction have, in some cases, completely removed instream and riparian habitat from extensive reaches of these drainages as they pass through urban and agricultural areas or has, at best, severely reduced instream refugia and structural complexity. Flood control structures are widespread along the lower portions of drainages that pass through large urban areas, such as San Juan Creek, San Luis Rey River, San Dieguito River, San Diego River, Sweetwater River, and the Otay River.

Table 14. The top five sources of threats to steelhead and their habitats in each watershed of the Santa Catalina Gulf Coast BPG (see CAP Workbooks for details).

Threat Sources	Watershed (north to south)									
	San Juan Creek	San Mateo Creek	San Onofre Creek	Santa Margarita River	San Luis Rey River	San Dieguito River	San Diego River	Sweetwater River	Otay River	Tijuana River
Groundwater Extraction										
Dams and Surface Water Diversions										
Urban Development										
Agricultural Development										
Levees and Channelization										
Other Passage Barriers										
Recreational Facilities										
Non-Native Species										
Roads										
Flood Control										
Non-Point Pollution										
Agricultural Effluents										
Wildfires*										

Key: Threat cell colors represent threat rating from CAP Workbook:

Red = Very High threat Light green = Medium threat
Yellow = High threat Dark green = Low threat

* Wildfires were not recognized during the CAP Workbook analyses as one of the top five threats in these watersheds, but recent fires in coastal watersheds of southern Orange and northern and central San Diego counties in Fall, 2007 could result in significant, long-term impacts to steelhead habitat.

Agricultural use of floodplains, increased density of roads throughout the watershed, and the placement of roads in or near the riparian corridor, increases sedimentation and substrate embeddedness, and creates non-point source pollution. Nutrient and coliform bacteria loading from agricultural and wastewater treatment effluents are important sources of threats to steelhead in most of these drainages.

Severe loss of estuary habitat has occurred throughout these BPG watersheds. Only the San Mateo Creek estuary was rated as "Good" (based on remaining acreage), with 76% of the historic estuary intact. At least 48% to 95% of the estuaries in the other watersheds have been lost. The remaining estuarine habitats are subject to constriction and isolation from urban, agricultural, and/or recreational development, as well as degradation of water quality and inflows as a result of surface runoff from roads, wastewater treatment effluent, and loss of upstream surface flows (see Table 3 in ESU Summary).

Development of recreational facilities within the floodplain and/or mouths of the San Mateo Creek, San Onofre Creek, Santa Margarita River, and Tijuana River watersheds are sources of estuarine, riparian, and instream habitat degradation and loss. Loss of estuarine habitat as a result of recreational development is most pronounced around the mouths of the San Juan, San Dieguito, San Diego, Sweetwater, and Otay Rivers, though significant portions of the Santa Margarita estuarine complex has been isolated from regular freshwater inflow as a result of the construction of the Interstate 5 highway. ORV activity is common in the middle and upper portions of several of these watersheds (e.g., upper Santa Margarita and San Luis Rey watersheds).

Fires have burned from 22% (San Mateo Creek) to 74% (San Diego River) of the component watersheds in this BPG region in the past 25 years, including significant coastal portions of watersheds in southern Orange and northern and central San Diego counties in 2007), and may be significant, widespread, and long-term sources of sedimentation, turbidity, substrate embeddedness, loss of riparian canopy cover, and other threats.

Despite widespread and varied habitat degradation to the coastal and middle portions, steelhead attempt to enter and spawn in each of the watersheds of the Santa Catalina Gulf Coast BPG and native rainbow trout populations still inhabit the relatively high-quality habitat that remains upstream of most of the dams in this region. Improving conditions for steelhead passage, spawning, and/or rearing in these watersheds will require multiple, long-term, measures related to water management, recreation, and fish passage past large dams.

The threat sources discussed in this section should be the focus of a variety of recovery actions to address specific stresses on steelhead viability associated with these threats. Spatial and temporal data acquired on specific indicators associated with sources of threats or stresses, such as water temperature, pH, nutrients, etc., are generally inadequate to be the target of specific recovery actions. This type of data acquisition should be the subject of site-specific investigations in order to refine the primary recovery actions or to target additional recovery actions. A fish passage impediment inventory and assessment

should be conducted for each of the major watersheds in the Santa Catalina Gulf Coast BPG. Impediments to fish passage stemming from the construction and operation of dams and groundwater extraction, modification of channel morphology and adjacent riparian habitat due to flood control, instream activities such as sand and gravel mining, and loss of estuarine functions from filling and point and non-point waste discharges should be further evaluated and addressed as part of any recovery strategy for the Santa Catalina Gulf Coast BPG (see recovery action matrices for more specific recovery actions).

ATTACHMENT. SUMMARY TABLES FOR STRESSES AND THREATS, STRESS MATRIX, AND OVERALL VIABILITY SUMMARY FOR THE SANTA CATALINA GULF COAST BPG

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Matilija Dam Ecosystem Restoration Project
Giant Reed Removal Element

Post-Treatment Vegetation Monitoring Program



Prepared for:

Ventura County Public Works Agency
Watershed Protection District
800 South Victoria Avenue
Ventura, CA 93009

Contact: Pam Lindsey
(805) 654-2036

Prepared by:

Hunt & Associates Biological Consulting Services
5290 Overpass Road, Ste 108
Santa Barbara, CA 93111

Contact: Lawrence E. Hunt
(805) 967-8512

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MATILIJA DAM ECOSYSTEM RESTORATION PROJECT
GIANT REED REMOVAL ELEMENT
POST-TREATMENT VEGETATION MONITORING PROGRAM

1.0 Executive Summary. This report establishes a monitoring protocol and describes baseline conditions for monitoring the response of native and non-native vegetation following implementation of the Matilija Giant Reed Removal Element (hereafter called the "Project") along Matilija Creek and portions of the upper main stem of the Ventura River from September 2007 to October 2009.

This study established the following conclusions:

- Treatment of exotic vegetation (primarily composed of giant reed), was highly successful in reducing infestation and percent cover in the project area.
- Native species are recolonizing treated substrates at a 2:1 ratio compared to non-native species.
- Native cover is significantly higher than non-native cover in the treatment areas.
- Re-sprouting of giant reed continues to be a problem despite five re-treatment cycles to date. Percent cover of live giant reed in treatment plots ranged from 0% to 25%, averaging less than 5%.
- Future monitoring of all or a subset of the releve plots established in this study should be conducted to track natural restoration of the project area.

2.0 Introduction. Five invasive plant species were targeted for chemical and mechanical control: giant reed (*Arundo donax*), Scotch broom (*Genista monspessulanus*), castor bean (*Ricinus communis*), pepper tree (*Schinus molle*), and salt cedar (*Tamarix ramossisima*). Giant reed was by far the most common and ecologically-damaging invasive, comprising at least 140 acres (68%) of the 207 acres of non-native vegetation identified for treatment and control in the project area.

This project was the first phase of a watershed-wide effort to control invasive non-native vegetation in the Ventura River and its tributaries. Controlling non-native vegetation is one component of the multi-phase Matilija Dam Ecosystem Restoration Project that includes removing the dam and the sediment it has accumulated in order to improve wildlife habitat quality in the watershed.

The Phase 1 project area was divided into five stream reaches (Reach 9-Reach 5) that extended downstream from a series of waterfalls in the upper watershed of the main stem of Matilija Creek to the Highway 150 Bridge over the main stem of the Ventura River, a distance of approximately 16 stream miles and encompassing approximately 1,272 acres of floodplain habitats (Figure 1).

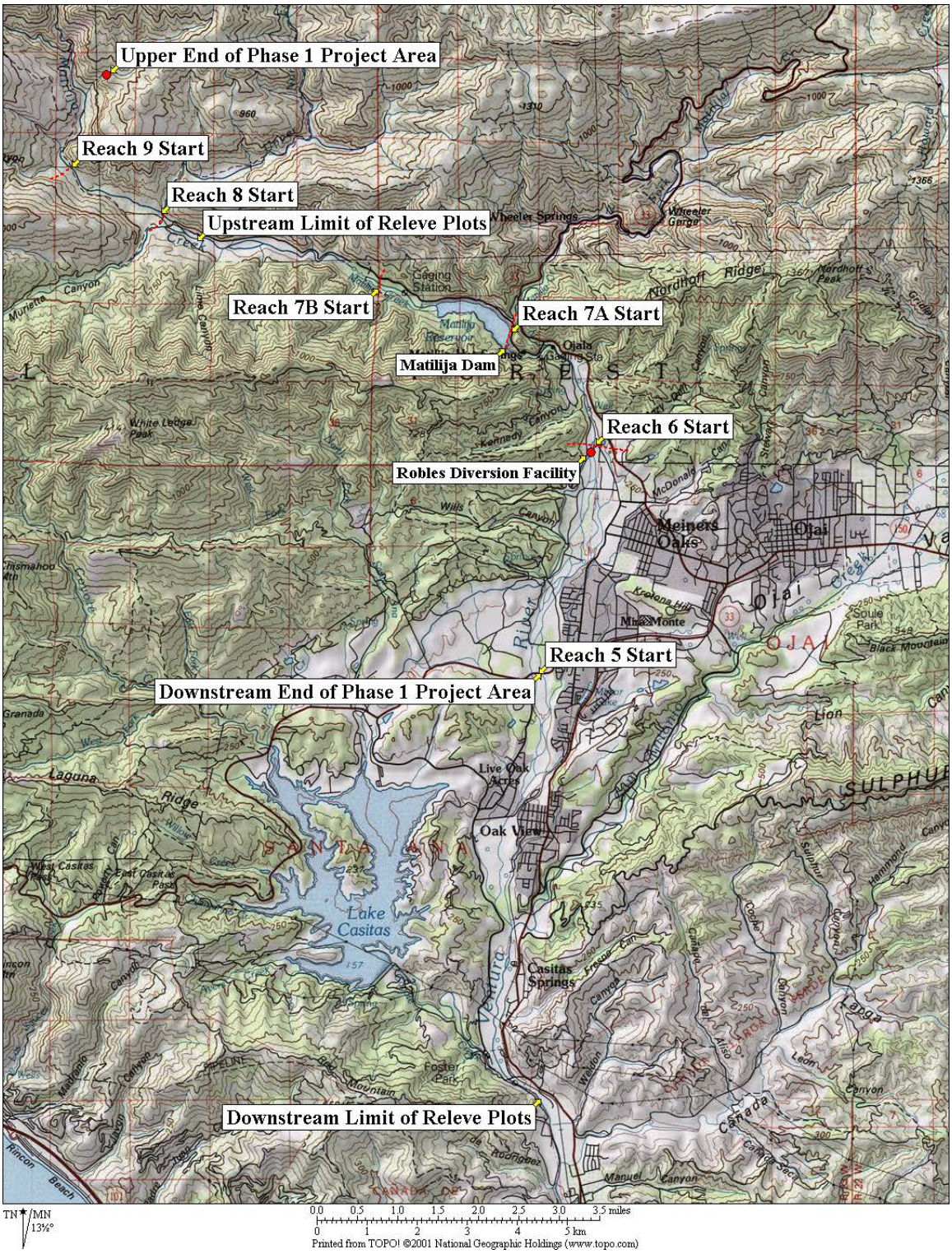


Figure 1. Project and study area limits.

Pre-Treatment Condition of the Project Area. Exotic vegetation targeted for control occurred throughout the project area prior to initiating treatment, but the magnitude of infestation differed widely between species and areas. Prior to implementation of the

project, five categories of infestation (percent cover) were identified and mapped throughout the project area (Ecosystems Restoration Associates, 2007; County of Ventura, 2007). Figure 2 summarizes the results of those calculations. The intensity of infestation was spatially variable within and between reaches. Infestation was lowest in Reaches 8 and 9 in the upper and middle portions of the Matilija Creek watershed, but increased rapidly downstream in the vicinity of Matilija Reservoir. Infestation was highest on floodplain substrates formerly inundated by the reservoir that were exposed when the dam was notched repeatedly beginning in the 1960s for safety reasons in order to reduce the amount of water it impounded. These exposed substrates were rapidly colonized by giant reed that, in time, formed extensive, nearly monotypic stands covering dozens of acres. Exotic species infestation also was relatively high in Reach 6 between the dam and the Robles Diversion facility, then declined in the downstream reach of the project area (Figure 2).

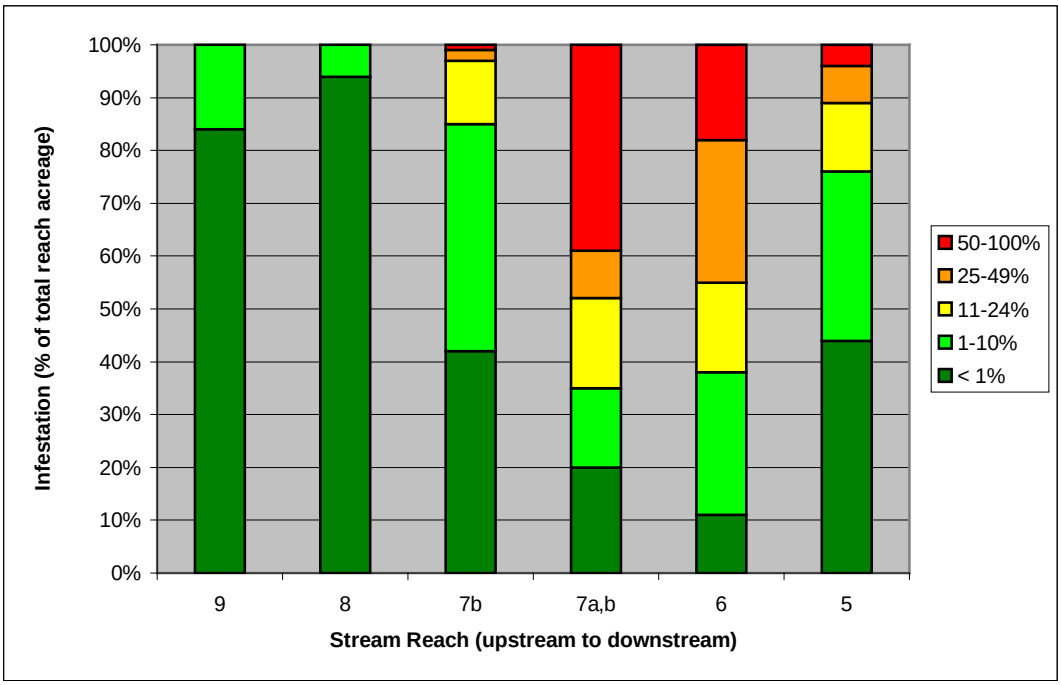


Figure 2. Intensity of infestation of target exotics in the 1,272-acre project area. Stream reaches are shown on Figure 1.

Infestation of giant reed, the dominant non-native species throughout the project area, was spatially variable, ranging from extensive, nearly monotypic stands dispersed individual plants. Where infestation was high, floodplain woodland and scrub habitats were all but completely covered by impenetrable thickets up to 25 feet high (Figures 3a,b). The other four target invasive species usually occurred as sparsely-distributed individual plants throughout the project area.



Figure 3a. Heavy infestation of woodland by giant reed in Reach 7a. Remnant native riparian trees visible here include *Salix lasiolepis, Platanus racemosa,* and *Populus fremontii* (photo taken 4 September 2007).



Figure 3b. Heavy infestation of floodplain scrub by giant reed in Reach 7a,b (photo taken 4 September 2007).

Initial Treatment of Non-Native Vegetation. Initial treatment of target invasives in the project area began on 10 September 2007 and was completed on 12 June 2008 in Reaches 5a,b, and Reaches 6 through 9. Reach 5c (downstream end of Phase 1 project area – Figure 1), received initial treatment in October 2009. A glyphosate-based systemic herbicide was sprayed on target foliage, allowed to translocate to all portions of the plant for a minimum of 30 days, then followed by mechanical shredding and/or cut-daub methods, depending on the intensity of infestation (Figures 4a-f).



Figure 4a. Foliar application of herbicide in monotypic stands of giant reed (photo taken 10 September 2007).



Figure 4b. Worker cutting giant reed with blade trimmer; cut stems were then daubed with herbicide (photo taken 27 September 2007).



Figure 4c. Hauling giant reed cut by hand to central location for shredding. Note amount of ground litter (photo taken 27 September 2007).



Figure 4d. Post-treatment aspect of floodplain woodland in area where giant reed was sprayed and left in place (photo taken 11 April 2008).



Figure 4e. *In situ* shredding of giant reed in woodland (photo taken 12 December 2007).



Figure 4f. Woodland substrate following shredding of giant reed with shredder shown in Figure 5e (photo taken 12 December 2007).

Shredding was conducted over approximately 103 acres of Reaches 7a and 7b where giant reed infestation was greatest. Cut-daub methods were applied elsewhere. Target vegetation was sprayed and the standing biomass was left intact in some areas with sparse to medium infestations of giant reed (Figure 4d). The other four target species were typically sprayed and left in place. Initial treatment of the target vegetation throughout the project area took approximately 180 work-days to complete (Figure 5).

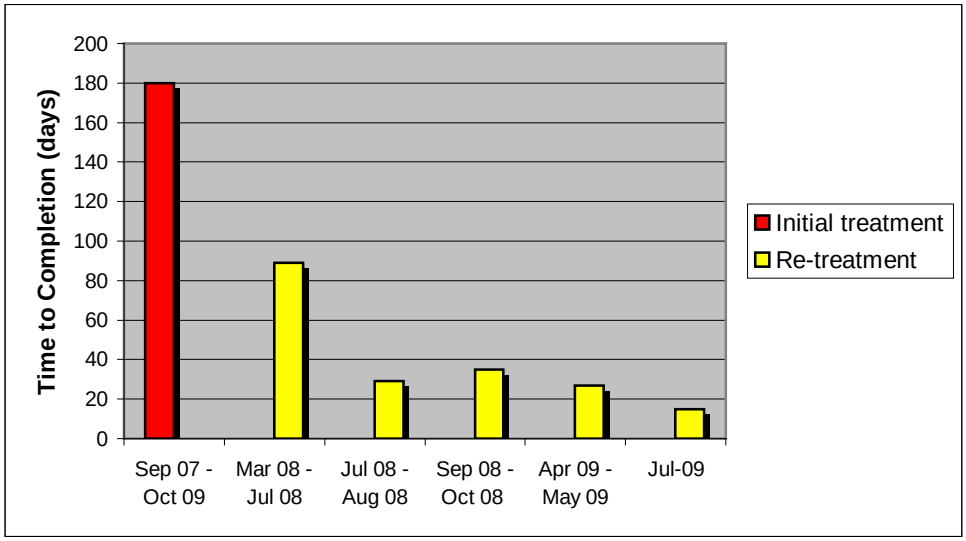


Figure 5. Timing and effort of initial and re-treatment phases of project.

Re-Treatment of Non-Native Vegetation. Re-treatment employed hand methods only (foliar spraying using backpack sprayers and cut-daub technique), to control re-sprouting vegetation or to treat plants that were either missed or survived the initial treatment. To date, target vegetation in the project area has been re-treated five times since initial treatment was completed (15 March 2008 to 31 July 2009) and the level of effort required to re-treat re-sprouting vegetation typically declined with each re-treatment cycle (Figure 5). The first re-treatment cycle began in March 2008 and moved from reach to reach as initial treatment and/or the 30-day herbicide translocation period was completed. Four subsequent treatment cycles began in Reach 5b and moved systemically upstream in a coordinated sweep, to Reach 9. Initial treatment of Reach 5c, the downstream portion of the Phase 1 project area (Figure 1), occurred in October 2009. This reach has not been re-treated to date.

3.0 Methods. The study reported herein seeks to answer the central question: *What is the structure and composition of vegetation colonizing areas that were formerly infested with invasive, non-native species?* A proper sampling design would set up a series of experimental treatments and controls to reject one or more *a priori* null hypotheses (H_0), such as: *H_0: spatial variation in native species richness or percent cover is unrelated to infestation* or *H_0: the recovery of treatment areas is independent of infestation.*

The study reported herein analyzes a *natural experiment.* Non-native vegetation was treated over a relatively large portion of the watershed with no supplemental habitat restoration effort. Consequently, this study is more observational than experimental. It establishes one or more *a posteriori* null hypotheses to answer an alternative question: *How can I optimally describe variation in native species richness and percent cover in this data set?* This study compares native species richness and percent cover in different infestation and treatment categories to control plots established in two types of floodplain environments that were not subjected to treatment: a) infested areas and, b) areas devoid of target non-native species.

Proper experimental field and laboratory designs employ random sampling methods to collect data. Diamond (1986) described the trade-off between control of independent variables and correct experimental design versus the large spatio-temporal scales and realism afforded by natural experiments. He advocates conducting small-scale, statistically correct experimental studies as an adjunct to natural experiments. Leps and Smilauer (2007) concluded that random sampling is not logistically feasible in many studies of vegetation patterns, but rather than not applying statistical analyses to natural experiments, they recommend collecting the data that can be collected even if it does not conform to strict statistical requirements, then keeping these limitations in mind when interpreting the results. Truly random samples in vegetation studies are difficult to collect because plant communities themselves defy operational definition and the boundaries are typically broadly distributed across environmental gradients.

In this study, random vegetation sampling methods, such as transect-based point-quarter or wandering point-quarter methods (Cottam and Curtis, 1956; Catana, 1963), were not used in favor of a non-random, plot-based approach. The most appropriate vegetation sampling technique for this kind of natural experiment is the releve. The releve is a plot-based method that was developed by vegetation scientists in the 1930s as means of rapidly (and largely subjectively), characterizing vegettion patterns in a defined area (Braun-Blanquet, 1932). The releve or plot is considered to be a "semi-quantitative" method because it relies on visual estimates of plant cover rather than counts of the "hits" of a particular species along a transect line or on precise measurements of cover/biomass by planimetric techniques used in quadrat-based studies.

Releves or plots measure vegetation patterns in a *stand* of vegetation. A stand is the basic physical unit of vegetation in a landscape and may vary in size from less than one acre to thousands of acres, depending on the type of vegetation. Stands must be *homogeneous,* i.e., they must possess two unifying characteristics:

- *Compositional* integrity: Throughout a stand, the combination of species is similar. The stand is differentiated from other stands by a discernable boundary that may be abrupt or indistinct. This study identified two types of stands: woodland and scrub.

- *Structural* integrity: A stand has a similar history or environmental setting that affords relatively similar horizontal and vertical spacing of plant

species. For example, woodland on upper slopes with shallow soils and sparse canopy cover would be considered a different stand from woodland on lower slopes with deep soils and dense canopy cover. In this study, woodland and scrub stands identified for analysis were restricted to the floodplain of the drainages and on stream terraces of similar heights above the low-flow channel.

It is difficult and time-consuming to efficiently summarize species composition, cover, and structure of an entire stand because of the size of most stands of vegetation. Consequently, smaller, representative portions of stands are sampled. The releve method of sampling vegetation is stand-based and in many cases is preferable to stand-blind sampling methods, such as line or belt transects, especially where the goal is to characterize vegetation patterns, rather than define vegetation boundaries (i.e., map community types) (CNPS, 2009).

Exploratory analyses might lack statistical rigor, but they are still a mainstay of vegetation research. The purpose of exploratory analysis is to find pattern in nature, which is an inherently subjective enterprise. While it is possible to perform exploratory analyses on sample plots located according to a rigorous, objective sampling design, such careful placement is not necessary. Indeed, an exploratory analysis can be aided if the investigator subjectively places study plots in locations he or she considers to be important or interesting. Vegetation scientists have found that orienting plots within vegetation that appears homogeneous is highly subjective, but very useful in evaluating differences between plots (CNPS/CDFG, 2009).

Sampling Design. Existing maps of treatment areas (County of Ventura, 2007) were used to select infestation categories for sampling. Samples were stratified by:

- Stand (woodland or scrub);
- Pre-Treatment Infestation (51-100% (uniform); 1-50% (dispersed), or no infestation);
- Treatment Type (shred, cut-daub, or no treatment).

Treatment plots were collected across the various Infestation and Treatment categories. Treatment plots were subjectively located within a particular infestation polygon within the project area. Two types of control plots were established: infested areas outside the project area that were not treated, and areas within and outside of the project area that were devoid of invasive vegetation (Table 1).

Table 1. Sampling design.

Stratum 1	Stratum 2	Stratum 3	Plot Number
Stand	**Pre-Treatment Infestation**	**Treatment Type***	
Riparian Woodland	51-100%	Spray-Shred	1, 4, 5, 9, 10, 11, 12, 13, 20, 21
Riparian Woodland	51-100%	None (Control)	32, 35, 36, 43, 44
Floodplain Alluvial Scrub	51-100%	Spray-Shred	2, 3, 6, 7, 8, 14
Floodplain Alluvial Scrub	51-100%	None (Control)	45
Riparian Woodland	1-50%	Spray Cut-Daub	19, 25, 37, 39, 40, 41
Riparian Woodland	1-50%	None (Control)	49
Floodplain Alluvial Scrub	1-50%	Spray Cut-Daub	15, 23, 26, 27, 28, 29
Floodplain Alluvial Scrub	1-50%	None (Control)	33, 34, 46, 47, 50
Riparian Woodland	0%	No Infestation (Control)	30, 31, 38, 48, 42
Floodplain Alluvial Scrub	0%	No Infestation (Control)	16; 17; 18, 22, 24

* Treatment and Infestation are largely coincident because shredding was largely restricted to uniform stands of giant reed and cut-daub methods were used where giant reed was dispersed. In some areas, non-native vegetation was sprayed and left standing. This was considered equivalent to the cut-daub technique.

Plot Size and Site Selection. This study used square releves or plots, measuring 20 meters on a side (400 m^2 total size). Plot size was determined by recommendations from the Sawyer and Keeler-Wolf (1995) and California Native Plant Society/California Department of Fish and Game (2009) releve protocols.

Plot locations were not randomly selected. Mapped infestation polygons frequently contained stands of both floodplain alluvial scrub and riparian woodland habitat. Once the infestation polygon had been identified, one or both stands within the polygon were reconnoitered on foot. Sites that appeared to be representative of each stand with regards to species composition, substrate, and vegetation structure and pre-treatment infestation were selected for measurement. Multiple plots were sometimes collected in large stands.

Plots were established by positioning a pin-flag at the southwestern corner of the plot, then aligning the western edge of the plot with north using a compass. The UTM coordinates and the elevation of the southwestern corner of the plot were recorded using a Garmin GPSmap 60CSx hand-held unit. Most coordinate locations had an accuracy of 3-3 meters. The remaining three orthogonal corners of the plot were established with an open-reel 50-meter tape measure and a compass and marked with colored plastic flagging tape. Photographs were taken in a north and northwestern direction from the southwestern corner of each plot (see CD attached to this report). Information on exposure, steepness, macro- and micro-topography, geology, soil texture, % surface

cover of substrate types, site history, vegetative structure, canopy cover, species composition and % cover of each species were recorded on standardized releve data forms provided on the California Native Plant Society/California Department of Fish and Game website (www.cnps.org). A densitometer was used to determine percent canopy cover at five points in each woodland plot: plot center and each corner, and the values were averaged. Percent cover of each living perennial plant species or dead annual species in the plot was estimated visually initially using standard Braun-Blanquet percent cover intervals: < 1%; 1-5%; >5-15%; >15-25%; >25-50%; >50-75%; >75%, then refined to get an estimate of % cover for each species. Plant species that could not be identified in the field were collected and identified using Hickman (1993) and Smith (1998) or, in some cases, were brought to local botanists and the Santa Barbara Botanic Garden for identification. Pre-treatment cover of target exotics in each plot (usually giant reed) was estimated from the percent cover of cut stumps and/or dead standing vegetation of these species. Living non-native target vegetation that re-sprouted after initial treatment was counted as post-treatment infestation and was not included in pre-treatment infestation cover estimates. Data were collected on the variables listed in Table 2.

Table 2. Data collected for this study.

Variable (Variable Name)*	Description
Plot Number (PLOT)	Field number of releve
Date (DATE)	Date releve was recorded
UTME (UTME)	Universal Transverse Mercator coordinate - Easting (meters)
UTMN (UTMN)	Universal Transverse Mercator coordinate - Northing (meters)
Elevation (ELEVATION)	Elevation above mean sea level (feet)
Stand (STAND$)	Two plant communities were identified (CNDDB, 2002): • Riparian Woodland (Southern Cottonwood-Willow Riparian Forest, White Alder Riparian Forest, Southern Sycamore-Alder Riparian Woodland) • Riparian Scrub (Scalebroom Scrub)
Infestation (INFESTATION$)	Pre-treatment (pre-September 2007) percent cover of target non-native vegetation (primarily giant reed and Scotch broom) in stand, as determined from Ecosystems Restoration Associates mapped polygons (VCWPD, 2007), or current condition where releve plot is outside project area limits. Three infestation categories were identified: • 0% • 1-50% (clumped distribution) • 51-100% (uniform distribution)
Treatment (TREATMENT$)	Method of initial treatment of giant reed. Three treatment categories were identified: • None (no treatment - 6 sub-categories) • Shred (2 sub-categories) • Cut-daub or spray only (2 sub-categories)
Soil Texture (SOILTEXT$)	Dominant surface soil texture in releve, using CNPS/CDFG Simplified Key to Soil Texture (2009)
Canopy Cover (CANOPYCOV)	Percent of plot covered by overstory and low-medium trees
% Surface Cover Fines (FINECOVER)	Percent of exposed, fine-textured soils in releve
% Surface Cover Litter (LITTERCOVER)	Total percent cover of woody, stick, and/or leaf litter in releve
Total % Vascular Vegetative Cover (TOTVEGCOVR)	Total percentage of releve covered by living vascular vegetation (all vegetative strata combined)
% Non-Native Vegetative Cover (RELNNATCOVR)	% of releve covered by non-native vegetation (all vegetative strata combined)

% Native Vegetative Cover (RELNATCOVR)	% of releve covered by native vegetation (all vegetative strata combined)
% Live Giant Reed (LIVEARUNDO)	Percent of releve covered by live giant reed and/or other target species (e.g., Scotch broom and/or castor bean)
Pre-Treatment Infestation (PRETRINFEST)	Percent of releve covered by giant reed or other target species prior to treatment
Total Species Richness (SPRICHNESS)	Total number of vascular plant species in releve
Non-Native Species Richness (RELNNATSPRICH)	% number of non-native vascular plant species in releve
Native Species Richness (RELNATSPRICH)	% number of native vascular plant species in releve

*** "$" after name denotes categorical variable**

Fifty 400 m^2 plots were recorded between 4 November 2009 and 27 December 2009: 27 plots were located in woodland stands; 23 were located in scrub stands. Twenty-eight treatment plots and 22 control plots (12 no treatment plots; 10 no infestation plots) were collected (Table 1). Treatment plots were collected within project reaches 5, 6, and 7 within the project area. Control plots were collected within these reaches as well as downstream of the project area ("no treatment" and some "no infestation" plots). The location of each of the 50 plots is tabulated and mapped in Appendix 1. The field data sheets for the releves are found in Appendix 4.

Raw data taken from the field data sheets is tabulated in Appendix 2. Six variables were extracted from these data for analysis in this report: species list, pre-treatment infestation; post-treatment infestation, total species richness, native species richness, and native species cover. Exploratory univariate and multivariate statistical analyses were conducted using SYSTAT, version 7 statistical software.

4.0 Results. Exploratory data analysis (analysis of variance (ANOVA), comparisons of group means and variances, etc.) revealed that the most important variables of interest (native plant cover, native species richness, and pre-treatment infestation) in the treatment plots did not differ significantly between Treatment (shred, cut-daub), Infestation (uniform, dispersed), or Stand (woodland, scrub) categories (single factor ANOVA, $p > 0.05$), so the data set was collapsed into comparisons between the 28 treatment plots and 22 control plots in subsequent analyses.

Species Richness. A total of 152 plant species were recorded in the 50 releve plots. Non-native taxa comprised about 30% of total species richness (Figure 6; Appendix 3).

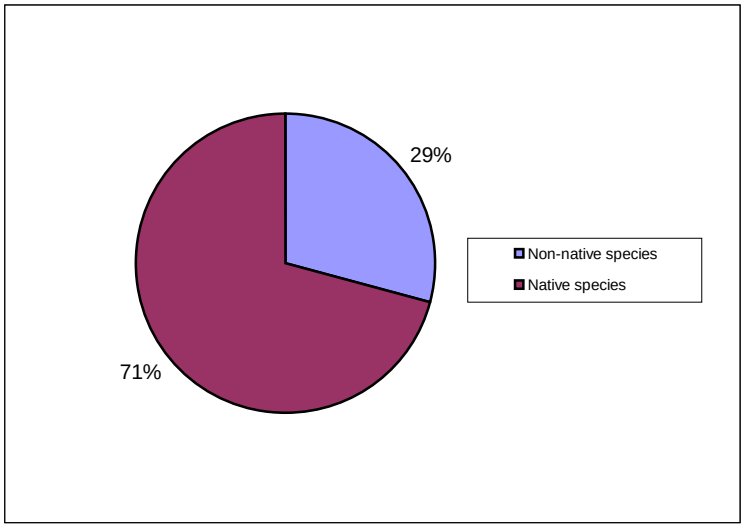


Figure 6. Proportion of native and non-native vascular plant species found in the 50 releve plots.

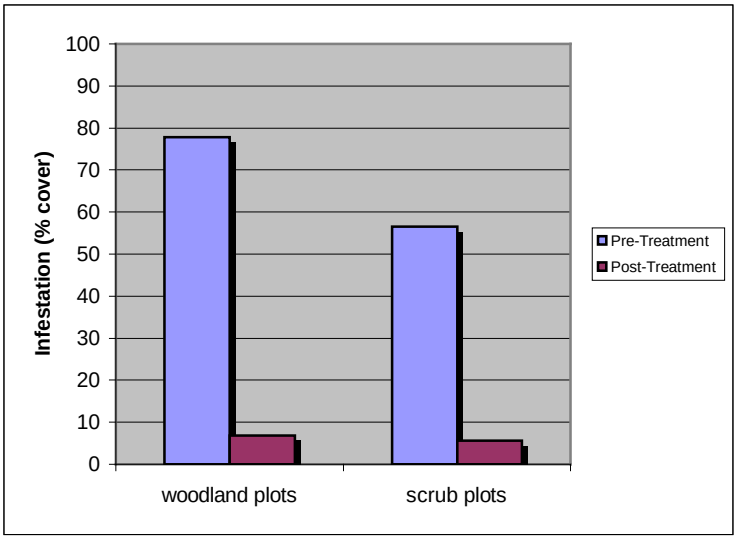


Figure 7. Infestation in 16 woodland and 12 scrub plots before and after treatment.

Effect of Initial Treatment and Re-Treatment Effort. Initial treatment of target vegetation was highly successful at reducing the relative cover of this vegetation, especially giant reed, in both woodland and scrub habitats in the project area (Figure 6). Woodland and scrub plots did not differ significantly in average pre- or post-treatment infestation ($p > 0.05$; two-tailed t-test). Infestation averaged 68% cover before initial treatment in the woodland and scrub treatment plots, compared to less than 6% cover after treatment (single-factor ANOVA, $p < 0.0001$) a highly significantly reduction in percent cover of the target exotics. However, treatment did not eliminate giant reed and/or the other target species from the project area. Live giant reed or other target vegetation was recorded in 82% of the 28 treatment plots.

Native Species Richness. Infestation by the target exotics significantly depressed native species richness (r = -0.738***) and native cover (r = -0.473***) in both the treatment and the control plots (Figures 8 and 9).

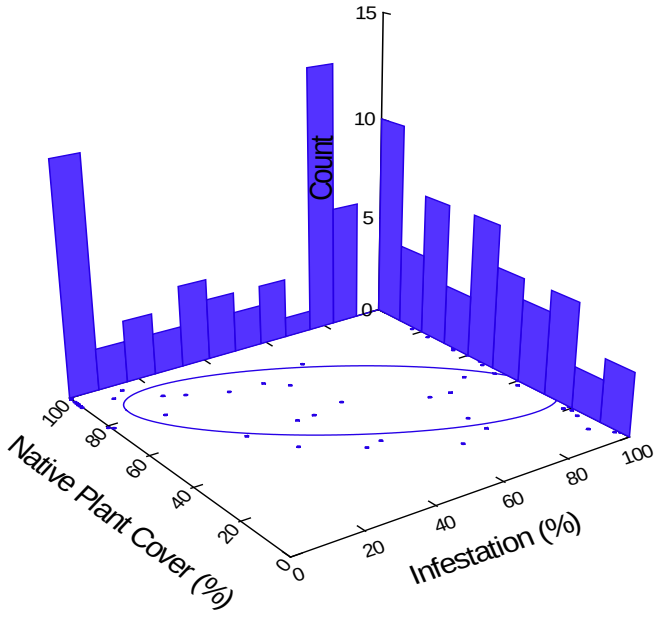


Figure 8. Relationship between infestation and native plant cover (all plots). Centroid captures 95% of variation (r = -0.738*).**

This inverse relationship was most strongly demonstrated in control plots where the relationship between these two cover categories could be directly observed without having to extrapolate infestation from dead, treated vegetation (Figure 9). Even in control plots where infestation was currently very high, native cover composed up to 20% of the plot because of stratified vegetation, particularly in woodland plots where a sparse native canopy was typically present above nearly homogeneous stands of giant reed.

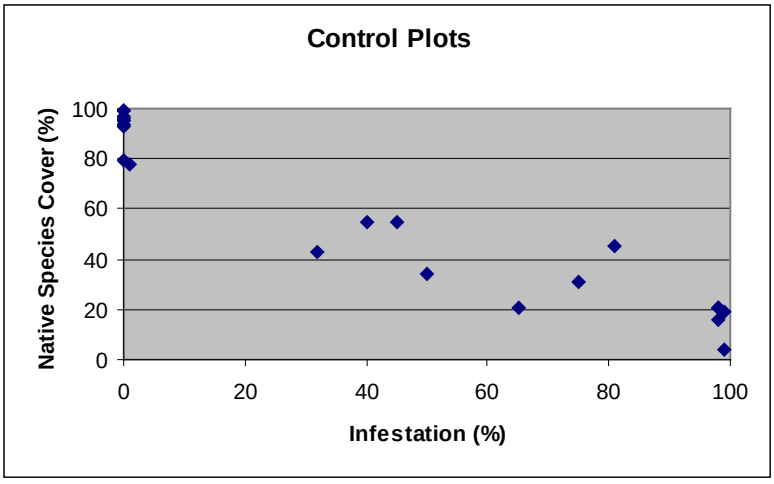


Figure 9. Infestation and native species cover in control plots (r = -0.953*).**

The same a significant inverse relationship between pre-treatment infestation and native plant cover was observed in the treatment plots (Figure 10). Consequently, native cover actually increased at the highest pre-treatment infestation rates, particularly in plots in scrub habitats, because these areas were all but cleared of vegetation during initial treatment.

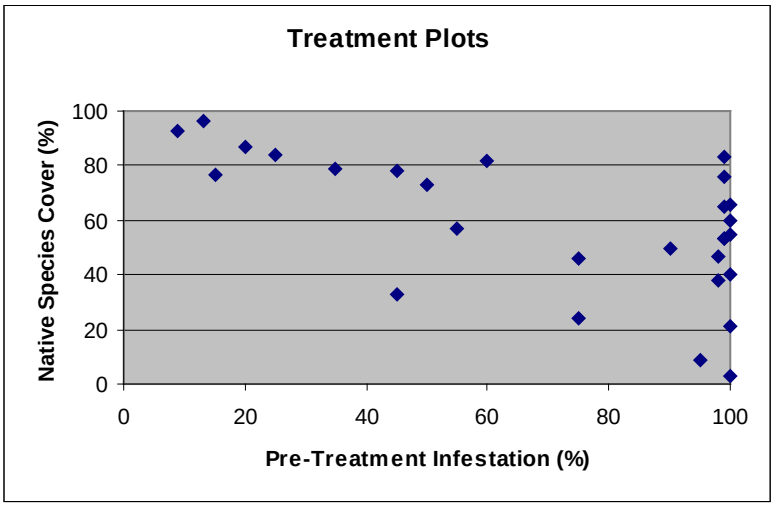


Figure 10. Infestation (pre-treatment) and native species cover in treatment plots (r = -0.600*).**
Note: pre-treatment infestation is actually an extrapolation of former infestation.

Treatment plots showed a highly significant increase in native species cover following treatment (mean 29.4% pre-treatment versus 58.2% post-treatment; single-factor ANOVA; $p << 0.001$) (Figure 11). Pre-treatment cover in the treatment plots was estimated by the amount of dead exotic vegetation (primarily giant reed) present in the plot. This is largely an estimate of pre-treatment infestation of giant reed based on the amount of shredded litter and/or cut stems in the plot. Pre-treatment and no treatment infestation was similar. Plots in uninfested areas had significantly higher native cover compared to treatment plots (mean: 92.5% versus 58.2%, respectively; $p < 0.001$). Spatial variation in native plant cover in treatment plots was significantly greater in treatment plots compared to uninfested plots ($F_{max} = 10.75$; $p < 0.0001$).

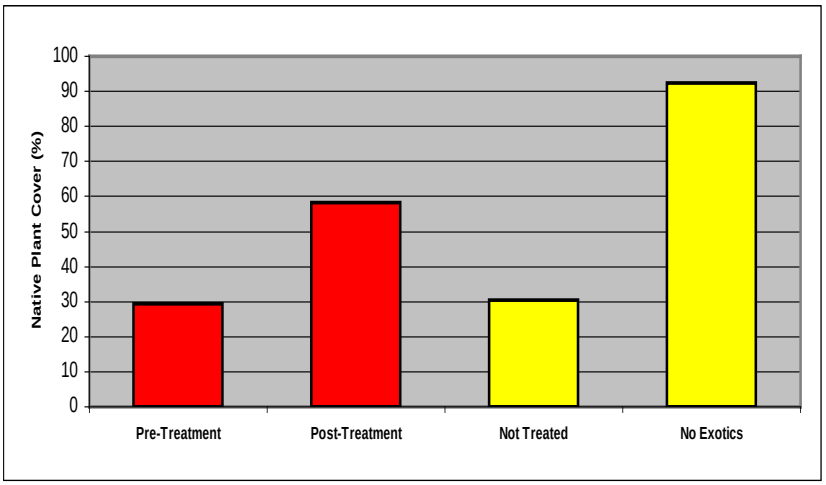


Figure 11. Native plant cover in treatment plots (red) before and after treatment versus control plots (yellow).

Native Species Richness. Total species richness was significantly lower and spatially less variable in uninfested woodland plots compared to uninfested floodplain scrub plots (mean: 12 species versus 29 species, respectively; $p < 0.0001$) (Figure 12).

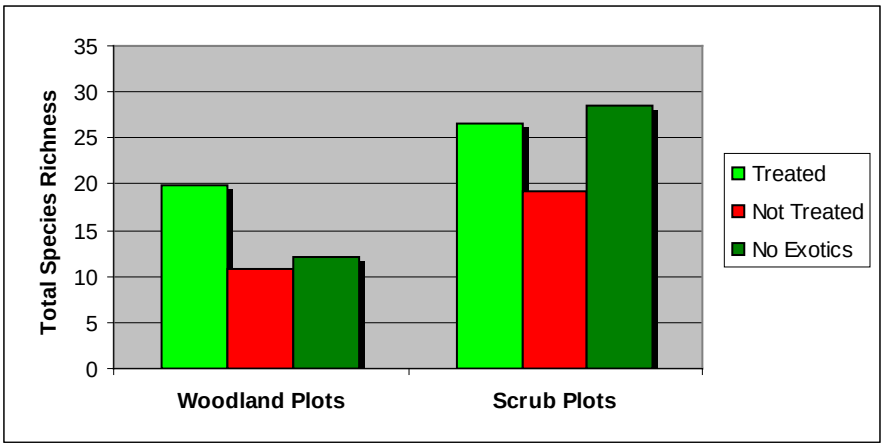


Figure 12. Total species richness in treated and control plots.

Overall, woodland plots had lower species richness than scrub plots across both treatment and control plots (Figure 12). Species richness in treatment plots in woodland and scrub habitats was significantly higher than untreated control plots and, in woodland plots, exceeded species richness in uninfested woodland.

Mean native species richness in the various treatment and control plots was surprisingly high, varying from 58% of total species richness in treated scrub plots to 85% of total species richness in uninfested scrub plots. Species richness in woodland and scrub treatment plots was dominated by native species, which comprised 65% and 58% of total

species richness, respectively. Native species richness as a proportion of total species richness did not differ significantly in treated and untreated woodland plots (65% and 63%, respectively), treated and untreated scrub plots (58% and 62%, respectively), or in uninfested woodland plots (68%), but the proportion of native species in uninfested scrub plots was significantly greater than any other group (85%).

Multivariate Analyses. Discriminant function analysis (DFA) was used to examine the robustness of a set of important predictor variables (canopy cover, pre-treatment infestation, native species richness, and native species cover) in classifying infestation categories (uniform, dispersed, and none). Despite high spatial variability in these metrics, this set of predictors correctly classified 80% of the plots (40 out of 50) into infestation categories, and had the highest classification success compared to other combinations of variables (Table 3) (e.g., these predictors were only able to correctly classify 38% of the plots into treatment categories). Collective variation in these variables was highly significant and directly related to intensity of infestation (i.e., F-matrix values are lowest with the "no infestation" category; highest with the "uniform infestation category").

Table 3. Jackknifed classification matrix from discriminant function analysis.

Infestation Category	Dispersed	Uninfested	Uniform	Plots Correctly Classified (%)
Dispersed	9	5	3	53
Uninfested	0	10	0	100
Uniform	2	0	21	91
Total	**11**	**15**	**24**	**80**

The centroids of the group means of these infestation categories are plotted on DFA axes 1 and 2. The 95% confidence intervals around these centroids do not overlap, indicating they are significantly different (Figure 13).

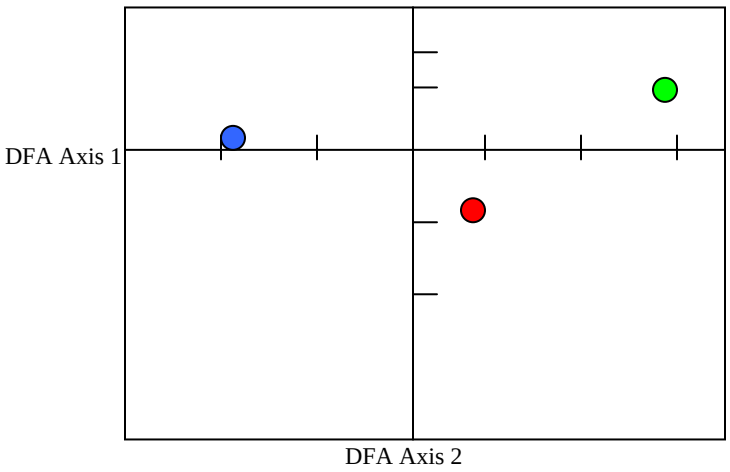


Figure 13. Group centroids plotted from canonical scores of group means. Tick marks on the axes represent one canonical unit. Blue = uniform infestation; red = no infestation; green = dispersed infestation.

Table 4 shows the combination of variables that explained the greatest amount of variation in the data set, as determined by factor analysis.

Table 4. Factor analysis component loadings.

Variable	Factor 1	Factor 2
% Native Cover	-0.873	-0.307
Pre-Treatment Infestation	0.798	0.418
% Live Giant Reed	0.749	0.039
Litter Cover	0.672	-0.340
Total Species Richness	-0.503	0.799
Total Variance Explained	**53.3%**	**20.5%**

Approximately 74% of the total variation in the data set could be explained using this combination of variables along two factors. Percent live giant reed in the plots and pre-treatment infestation of the plots are not significantly separable on these two factors, indicating that infestation and re-sprouting rate are directly related.

5.0 Discussion. By exposing extensive areas of floodplain substrates that formerly were all but covered with giant reed, particularly in Reaches 7a and 7b, initial treatment set the stage for a natural experiment of native and non-native vegetation colonization. The releve plots captured a large proportion of the total plant species richness within and beyond the project area and about 30% of these species are not native to California.

Plant communities typically contain many species, and the species vary greatly in their abundance from common to rare. Determining the distribution of abundances of different species is a fundamental task of plant and animal community ecology (MacArthur and Wilson, 1967; Pielou, 1977) and the species-abundance relationship is a fundamental attribute of plant and animal communities. Typically, one finds that singleton species (those represented by one individual) are numerous, often the most numerous. Species with successively more representatives, doubletons with 2, trebletons with 3, and so on, are usually progressively less numerous.

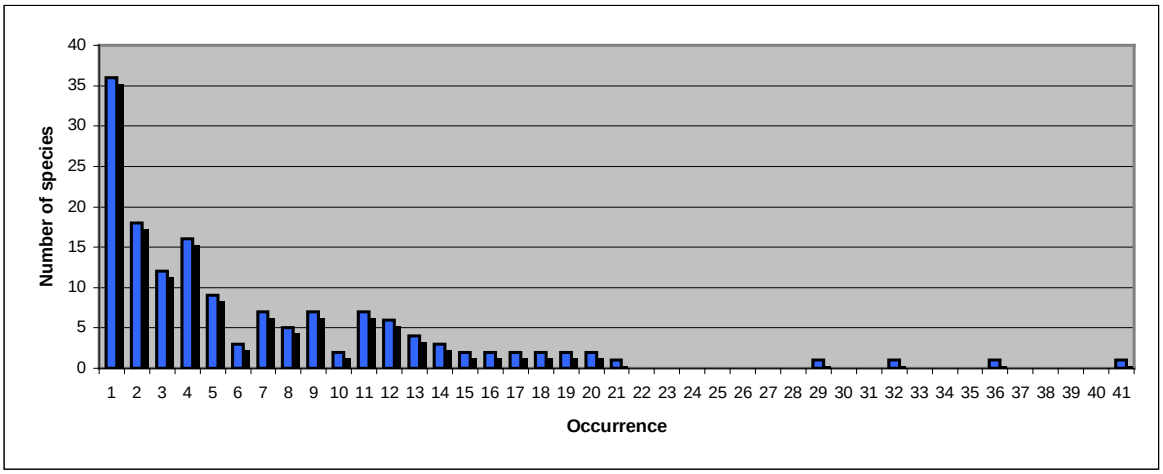


Figure 14. Species occurrence frequency among the 152 species found in the releve plots used in this study.

This study did not measure individual plant abundance in the plots, rather presence or absence and these data also follow this general pattern of many uncommon and a few common species (Figure 14). The underlying reasons for this pattern are complex, site-specific, and beyond this discussion. Thirty-six species occurred only once and 91 species, representing 60% of the total number of species observed in this study, occurred in five or fewer plots. On the other end of this abundance spectrum, five species (3% of total) occurred in 20 or more of the 50 releve plots and these are shown in Figure 15. The two most commonly encountered species in the plots are non-native species: smilo grass (*Pipatherum miliaceum*) and giant reed (*Arundo donax*).

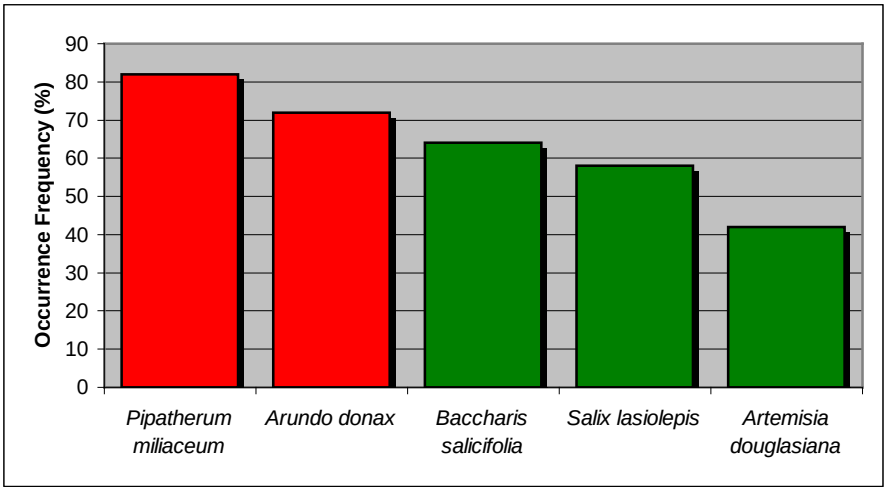


Figure 15. Top five recurring plant species in the plots.

Smilo is not only common throughout the Matilija Creek and Ventura River watersheds and occurred in over 80% of the plots, but also had relatively high cover values (mean 6.8%, 12.3%, range 0-75% cover), especially in plots established in floodplain scrub habitats that formerly were covered with giant reed. Live giant reed (re-sprouts) occurred in over 70% of the plots. Both of these species were spatially highly variable in occurrence and cover. The high recurrence of live giant reed in the plots is partly an artifact of study design (control plots are included in Figure 15), but also reflects its abundance in the project area as re-sprouting, live vegetation (82% of 28 treatment plots contained live giant reed that varied in cover from 0 to 25%). Despite non-natives comprising the two most commonly occurring species, native shrubs make up 10 of the 15 next most commonly encountered species in this study.

Giant reed re-sprouting was positively associated with pre-treatment infestation. Consequently, Reaches 7a and 7b support some of the highest re-sprout rates and cover of live giant reed in this study. Re-sprouting is recurring vegetatively and underscores the need for multi-year re-treatment efforts to continue. It is highly unlikely that giant reed can be completely eradicated from the project area, but it may be consigned to a rather minor component of riparian woodland and floodplain scrub habitat if periodic

control efforts continue until native vegetation has been established in areas formerly infested by this species. Giant reed thrives on disturbance and two disturbance factors: lowering water levels in Matilija Reservoir, coupled with occasional severe storms that mobilize floodplain substrates and remove native vegetation, allowed this species to form extensive, nearly monotypic stands of vegetation in Reaches 7a and 7b and contributed to the high level of infestation in the upper Ventura River below Matilija Dam.

The major finding of this study is that native species are recolonizing the woodland and scrub treatment plots at a 2:1 ratio over non-native species following treatment (65% cover and 58% cover, respectively). This result is surprising given that exposed, disturbed substrates typically favor non-native species that frequently out-compete native species in terms of reproductive output and growth rates. However, once giant reed was removed and controlled, these exposed substrates have been rapidly colonized by native plants that proliferated in the absence of competition with the exotics. One reason may be that, at least in the project area upstream of Matilija Reservoir, giant reed infestation was more or less restricted to the floodplain and along these reaches the floodplain is bordered by stream terraces that support intact, native riparian woodland and alluvial scrub habitats that provide a ready seed source for propagules to colonize areas once giant reed has been removed. Other non-native vegetation present in the plots is composed of species that do not appear to inhibit native species colonization or growth.

There is a clear trend in total and native species richness and cover: infestation by giant reed depresses total species richness and especially native species richness and cover (Figures 11 and 12). Treated woodland plots were more speciose than untreated woodland plots, but treated and untreated scrub habitats did not differ significantly in total species richness because this metric was so spatially variable (Figure 12). However, native plant cover dominated treated scrub habitat plots (and treated woodland plots).

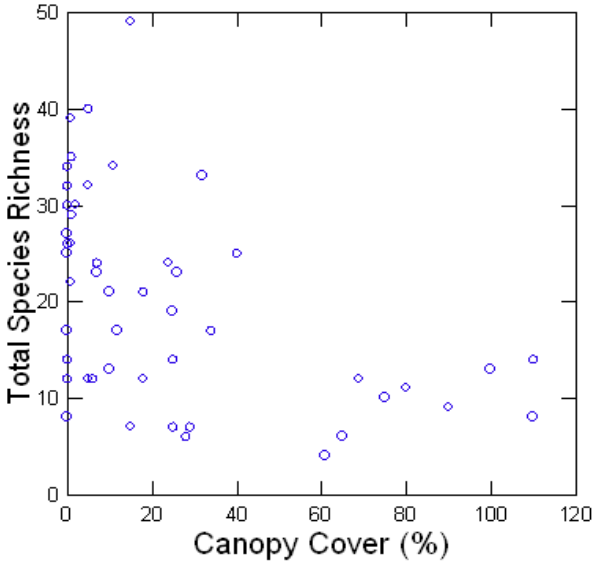


Figure 16. Relationship between species richness and canopy cover (r = -0.497).**

An important pattern observed among the 50 releve plots was the control that canopy cover had on species richness and composition and its implications for community structure and the nature of non-native plant infestation, especially giant reed (Figure 16). Although total species richness declines significantly with increased canopy cover, this inverse pattern is borne disproportionately by non-native vegetation ($r = -0.352^{**}$). Native species richness showed no relationship to canopy cover ($r = 0.108$). This means that the relative contribution of non-native vegetation to woodland communities depends strongly on canopy cover and where woodland canopies remain intact, non-native species remain a minor component of overall species richness. This was certainly the case in Reaches 7a and 7b where giant reed was able to thoroughly infest riparian woodland habitat following disturbance that destroyed or reduced tree canopy cover. Once established an uniform stands of vegetation, giant reed was able to maintain dominance by repressing native plant recruitment and survivorship.

The picture that emerges from this study is that removal and control of exotics opened up substrates that were rapidly colonized by a mixture of native and non-native species. Native colonists appear to be dominant, both in terms of species richness and percent cover in the treatment plots. Overall, removal and control of the target exotics appears to have been very successful as the first step in restoring these floodplain habitats to their former uninfested condition. Repression of giant reed to a minor component of woodland and scrub habitats in the project area appears to hinge on two factors: a) establishing a dense canopy of riparian trees in woodland habitats and; b) establishing dominance of native shrubs in scrub habitats. Future monitoring of these releve plots is necessary to document if the patterns reported herein persist.

6.0 Literature Cited

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Appendix 1. Plot Location and Characteristics.

Appendix 1. Plot Location and General Characteristics. The following table gives the project area reach of the releve plots or, if plots were located outside of the project area, the general location (maps of plot locations follow this table. UTM coordinates are taken from the data sheets for each plot. Photographs of plot conditions are found on a CD attached to this report.

Releve Field Number	General Location	Mapped Polygon Number and Infestation *	UTM Coordinates**	Stand	Treatment
MATI 0001	Reach 7a Plan Sheet 13	R7A-26 (50-100%)	286704 E 3819032 N	Woodland	Spray-Shred
MATI 0002	Reach 7a Plan Sheet 13	R7A-26 (50-100%)	286799 E 3819182 N	Scrub	Spray-Shred
MATI 0003	Reach 7a Plan Sheet 13	R7A-26 (50-100%)	286911 E 3819109 N	Scrub	Spray-Shred
MATI 0004	Reach 7a Plan Sheet 13	R7A-26 (50-100%)	286767 E 3819086 N	Woodland	Spray-Shred
MATI 0005	Reach 7a Plan Sheet 13	R7A-26 (50-100%)	286788 E 3819099 N	Woodland	Spray-Shred
MATI 0006	Reach 7a Plan Sheet 13	R7A-26 (50-100%)	286827 E 3819061 N	Scrub	Spray-Shred
MATI 0007	Reach 7a Plan Sheet 13	R7A-27 (50-100%)	286694 E 3819226 N	Scrub	Spray-Shred
MATI 0008	Reach 7a Plan Sheet 13	R7A-26 (50-100%)	287476 E 3819133 N	Scrub	Spray-Shred
MATI 0009	Reach 7a Plan Sheet 13	R7A-26 (50-100%)	287540 E 3819052 N	Woodland	Spray-Shred
MATI 0010	Reach 7a Plan Sheet 13	R7A-26 (50-100%)	287516 E 3819011 N	Woodland	Spray-Shred
MATI 0011	Reach 7a Plan Sheet 13	R7A-26 (50-100%)	287455 E 3819027 N	Woodland	Spray-Shred
MATI 0012	Reach 7b Plan Sheet 14	R7B-1 (50-100%)	285966 E 3819446 N	Woodland	Spray Shred
MATI 0013	Reach 7b Plan Sheet 14	R7B-1 (50-100%)	285912 E 3819457 N	Woodland	Spray Shred
MATI 0014	Reach 7a Plan Sheet 13	R7A-27 (50-100%)	286626 E 3819222 N	Scrub	Spray-Shred
MATI 0015	Reach 7a Plan Sheet 13	R7A-15 (11-24%)	286543 E 3819201 N	Scrub	Cut-Daub
MATI 0016	Reach 7b Plan Sheet 16	R7B-48 (< 1%)	282088 E 3820553 N	Scrub	None (Control)
MATI 0017	Reach 7b Plan Sheet 16	R7B-43 (1-10%)	282067 E 3820490 N	Scrub	None (Control)
MATI 0018	Reach 7b Plan Sheet 16	R7B-50 (< 1%)	282059 E 3820445 N	Scrub	None (Control)
MATI 0019	Reach 7b Plan Sheet 15	R7B-49 (< 1%)	284075 E 3820349 N	Woodland	Cut-Daub
MATI 0020	Reach 7a Plan Sheet 13	R7A-26 (50-100%)	287017 E 3819241 N	Woodland	Spray-Shred
MATI 0021	Reach 7a Plan Sheet 13	R7A-26 (50-100%)	287460 E 3819084 N	Woodland	Spray-Shred
MATI 0022	Reach 7b Plan Sheet 16	R7b-50 (< 1%)	281975 E 3820577 N	Scrub	None (Control)

MATI 0023	Reach 7b Plan Sheet 16	R7B-43 (1-10%)	281865 E 3820575 N	Scrub	Cut-Daub
MATI 0024	Reach 7b Plan Sheet 15	R7B-41 (1-10%)	284577 E 3820189 N	Scrub	None (Control)
MATI 0025	Reach 7a Plan Sheet 13	R7A-21 (25-49%)	287335 E 3819155 N	Woodland	Spray-Shred/C-D
MATI 0026	Reach 5a Plan Sheet 10	R5-22 (1-10%)	289486 E 3815362 N	Scrub	Cut-Daub
MATI 0027	Reach 5a Plan Sheet 10	R5-64 (11-24%)	289480 E 3815226 N	Scrub	Cut-Daub
MATI 0028	Reach 5a Plan Sheet 10	R5-42 (25-49%)	289417 E 3815211 N	Scrub	Cut-Daub
MATI 0029	Reach 7a Plan Sheet 13	R7A-32 (50-100%)	286411 E 3819167 N	Scrub	Spray-Shred/C-D
MATI 0030	OVLC parcel, S of San Antonio Creek and E of main stem Ventura River, E of Ventura River Trail	Downstream of Project Area (< 1%)	287981 E; 3806576 N	Woodland	None (Control)
MATI 0031	OVLC parcel, S of San Antonio Creek and E of main stem Ventura River, E of Ventura River Trail	Downstream of Project Area (0%)	287943 E 3806606 N	Woodland	None (Control)
MATI 0032	OVLC parcel, S of San Antonio Creek and E of main stem Ventura River, E of Ventura River Trail	Downstream of Project Area (75%)	287863 E 3806720 N	Woodland	None (Control)
MATI 0033	Main stem Ventura River floodplain, W of confluence San Antonio Creek	Downstream of Project Area (30%)	287772 E 3806753 N	Scrub	None (Control)
MATI 0034	Main stem Ventura River floodplain, W of confluence San Antonio Creek	Downstream of Project Area (50%)	287731 E 3806749 N	Scrub	None (Control)
MATI 0035	E edge main stem Ventura River, W of confluence San Antonio Creek	Downstream of Project Area (98%)	287721 E 3806796 N	Woodland	None (Control)
MATI 0036	W edge main stem Ventura River, S of confluence San Antonio Creek, W of Ventura River Trail	Downstream of Project Area (99%)	287870 E 3806703 N	Woodland	None (Control)
MATI 0037	Reach 5a Plan Sheet 10	R6-7 (1-10%)	289736 E 3816584 N	Woodland	Cut-Daub
MATI 0038	Reach 5a Plan Sheet 10	R6-7 (1-10%)	289746 E 3816591 N	Woodland	None (Control)
MATI 0039	Reach 5a Plan Sheet 10	R6-7 (1-10%)	289731 E 3816640 N	Woodland	Cut-Daub
MATI 0040	Reach 6b Plan Sheet 12	R6-15 (11-24%)	289021 E 3818099 N	Woodland	Cut-Daub
MATI 0041	Reach 6b Plan Sheet 12	R6-18 (25-49%)	289166 E 3818029 N	Woodland	Cut-Daub
MATI 0042	North Fork Matilija Creek at jct Hwy 33 x Matilija Cyn Rd	East of Project Area (0%)	288272 E 3819286 N	Woodland	None (Control)
MATI 0043	E side main stem Ventura River floodplain, W of Ventura River Trail,	Downstream of Project Area (98%)	288264 E 3803376 N	Woodland	None (Control)

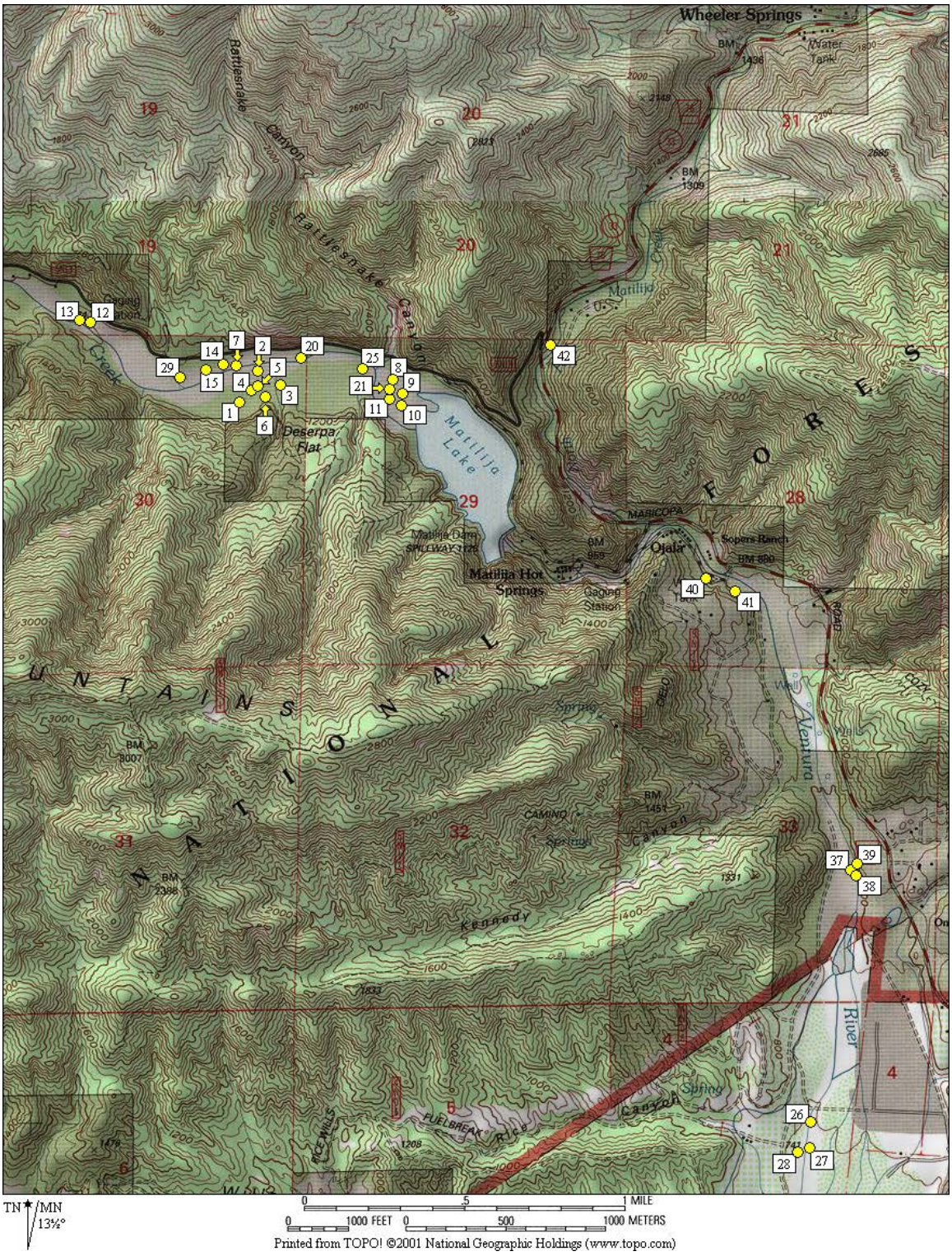
	downstream of Foster Park				
MATI 0044	E side main stem Ventura River floodplain, W of Ventura River Trail, downstream of Foster Park	Downstream of Project Area (99%)	288288 E 3803360 N	Woodland	None (Control)
MATI 0045	E side main stem Ventura River floodplain, W of Ventura River Trail, downstream of Foster Park	Downstream of Project Area (99%)	288143 E 3803437 N	Scrub	None (Control)
MATI 0046	E side main stem Ventura River floodplain, W of Ventura River Trail, downstream of Foster Park	Downstream of Project Area (65%)	288119 E 3803454 N	Scrub	None (Control)
MATI 0047	E side main stem Ventura River floodplain, W of Ventura River Trail, downstream of Foster Park	Downstream of Project Area (45%)	288087 E 3803476 N	Scrub	None (Control)
MATI 0048	E side main stem Ventura River floodplain, W of Ventura River Trail, downstream of Foster Park	Downstream of Project Area (0%)	288021 E 3803530 N	Woodland	None (Control)
MATI 0049	E side main stem Ventura River floodplain, W of Ventura River Trail, downstream of Foster Park	Downstream of Project Area (50%)	287990 E 3803522 N	Woodland	None (Control)
MATI 0050	E side main stem Ventura River floodplain, W of Ventura River Trail, downstream of Foster Park	Downstream of Project Area (40%)	288336 E 3803254 N	Scrub	None (Control)

* Polygon number is mapped on VCWPD plan maps dated 1 June 2007 (County of Ventura, 2007). "Infestation" is an estimate of total cover of target exotics in mapped polygon. Estimates were made prior to start of initial treatment, which began in September 2007 (Ecosystems Restoration Associates, 2007).

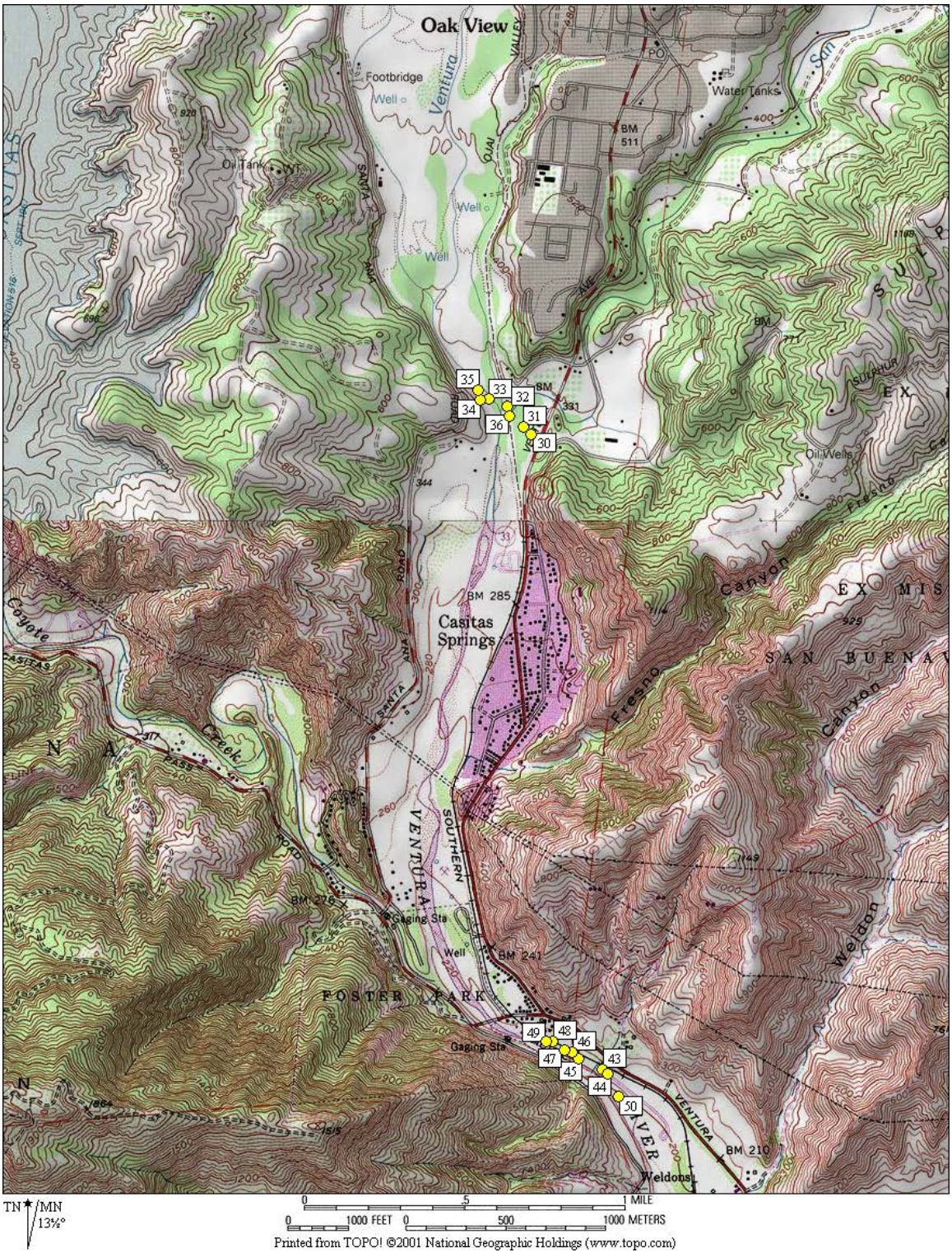
** GPS coordinates taken at SW corner of each releve plot in November-December 2009. GPS accuracy is +- 7 to 12 feet, generally +- 9 ft.



Map 1 of 3. Upstream end of releve plot locations, Project Area Reaches 7a and 7b.



Map 2 of 3. Releve plot locations in Project Area Reaches 5, 6, and 7a,b.



Map 3 of 3. Releve plot locations downstream of Project Area.

Appendix 2. Plot Summary Data.

Appendix 3. Plant Species Found in Plots.

Appendix 3. Plant Species Found in Releve Plots. The following list contains 152 non-native and native plant species were found in fifty 400m^2 releve plots measured between 4 November 2009 and 27 December 2009 along the main stem of Matilija Creek (26 plots), North Fork Matilija Creek (1 plot), and main stem Ventura River (23 plots).

Non-native species (n = 45 species or 30% of total sp richness):

Agrostis viridis
Arundo donax
Avena fatua
Bidens pilulosa
Brassica sp.
Bromus diandrus
Bromus madritensis subsp. *rubens*
Bromus mollis
Bromus sp.
Carduus pycnocephala
Centaurea solstitialis
Chenopodium album
Cirsium vulgare
Conium maculatum
Cynodon dactylon
Cynosurus cristatus
Erodium botrys
Euphorbia lathyris
Foeniculum vulgare
Galium aparine
Genista monspessulanus
Gnaphalium luteo-album
Hirschfeldia incana
Lactuca serriola
Malva nicaaensis
Marrubium vulgare
Melilotus alba
Nicotiana glauca
Picris echioides
Pipatherum miliaceum
Polypogon monspeliensis
Ricinus communis
Salsola tragus
Senecio mikanioides
Senecio vulgaris
Silybum marianum
Sonchus oleraceus
Taraxacum officinale
Vicia sp.
Vinca sp.
Vitis vinifera
Vulpia myuros
Washingtonia robusta

Native species (n = 107 species or 70% of total sp richness):

Achillea millefolium
Adenostoma fasciculatum
Agrostis exarata
Alnus rhombifolia
Ambrosia acanthicarpa
Ambrosia psilostachya
Arctostaphylos glauca
Artemisia californica
Artemisia douglasiana
Artemisia dracunculus
Aspidotis californica
Astragalus sp.
Baccharis pilularis
Baccharis salicifolia
Boykinia occidentalis
Brickellia californica
Calystegia macrostegia
Ceanothus crassifolius
Ceanothus megacarpus
Cercocarpus betuloides
Claytonia perfoliata
Clematis lasiantha
Conyza canadensis
Cyperus eragrostis
Datura wrightii
Dicentra ochroleuca
Encelia californica
Epilobium canum

Epilobium ciliatum
Equisetum sp.
Ericameria cuneata
Eriodictyon crassifolium
Eriodictyon traskiae
Eriogonum fasciculatum
Eriophyllum confertiflorum
Erodium macrophyllum
Euthamia occidentalis
Filago californica
Fraxinus dipetala
Galium angustifolium
Garrya veatchii
Geranium sp.
Gnaphalium californicum
Gutierrizia californica
Hazardia squarrosa
Heteromeles arbutifolia
Heterotheca sessiliflora
Hoita macrostachya
Juglans californica
Juncus xiphioides
Lepidospartum squamatum
Leptodactylon californicum
Lessingia filaginifolia
Leymus condensatus
Lotus purshianus
Lotus scoparia
Lupinus hirsutissimus
Lupinus sp.
Malacothamnus fasciculatus
Malacothrix saxatilis
Malosma laurina
Marah macrocarpus
Mentzelia laevicaulis
Mimulus aurantiacus
Nassella sp.
Paeonia californica
Pellaea mucronata
Pellaea andromedifolia
Pentagramma triangularis
Phacelia ramosissima
Platanus racemosa
Populus balsamifera
Populus fremontii
Prunus ilicifolia
Quercus agrifolia
Quercus chrysolepis
Rhamnus californica
Rhamnus crocea
Rhus integrifolia
Rhus ovata
Rhus trilobata
Ribes sanguineum
Ribes speciosum
Rubus ursinus
Rumex sp.
Salix lasiolepis
Salvia apiana
Salvia columbariae
Salvia leucophylla
Salvia mellifera
Sambucus mexicana
Scrophularia californica
Solanum douglasii
Solanum umbelliferum
Solanum xanti
Stachys albens
Stephanomeria cichoriacea
Toxicodendron diversilobum
Trifolium sp.
Turricula parryi
Typha latifolia
Umbellularia californica
Unid. native shrub A
Unid. native shrub B
Urtica holosericea
Venegasia carpesioides
Verbena lasiostachys
Xanthium strumarium
Yucca whipplei

Appendix 4. Releve Field Data Sheets

Southern California Steelhead Recovery Plan Summary



Adult Female Steelhead, Mission Creek, Santa Barbara County

National Marine Fisheries Service
Southwest Regional Office
Long Beach, CA

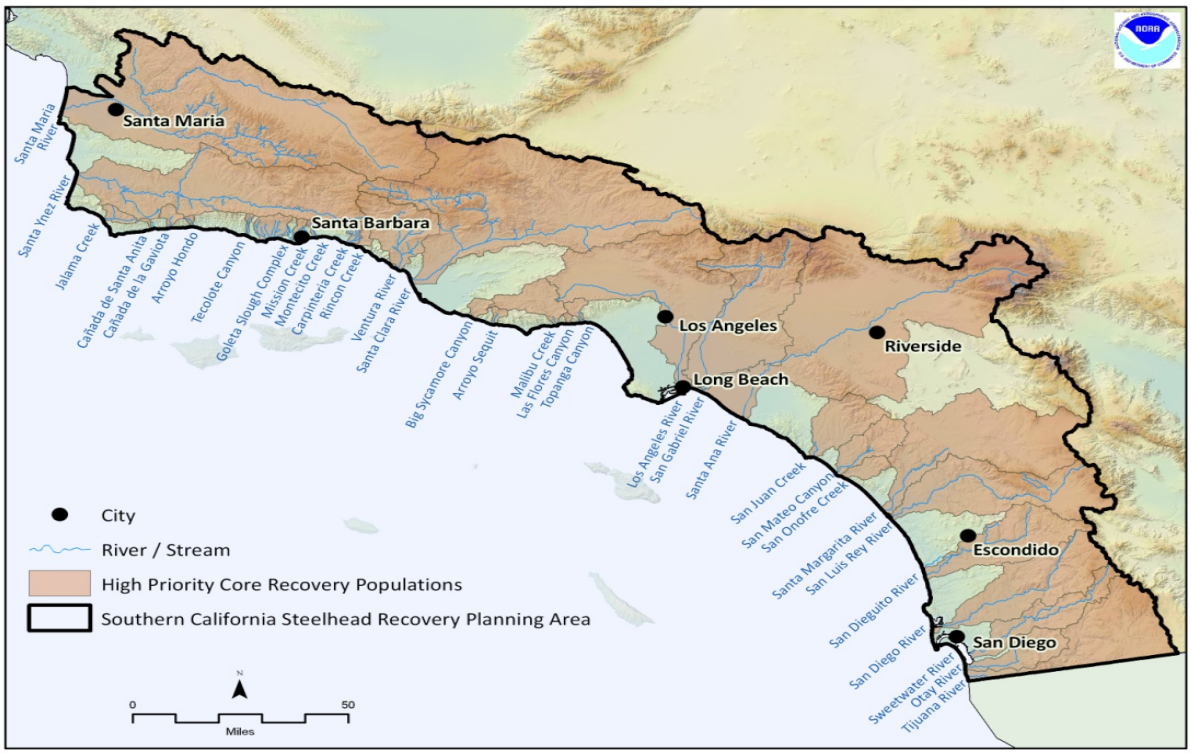
January 2012

Introduction

Steelhead are the anadromous, or ocean-going, form of the species *Oncorhynchus mykiss*. Steelhead are one of six Pacific salmon species that are native to the west coast of North America, and are currently the only species of this group that naturally reproduces within the coastal watersheds of southern California. Because steelhead employ several different life-history strategies that exploit all portions of a river system, they serve as an indicator of the health of southern California watersheds. Southern California steelhead populations have declined precipitously, largely due to extensive watershed development.

Following a comprehensive status review of all West Coast steelhead populations by the National Marine Fisheries Service (NMFS), southern California steelhead were listed as an endangered species under the Endangered Species Act (ESA) on August 18, 1997; the range of the listed steelhead was extended to the U.S.-Mexico Border in 2002. Following a status review in 2005, a final listing determination was issued on January 5, 2006 for the Southern California Steelhead Distinct Population Segment (DPS); critical habitat was also designated within 32 DPS watersheds.

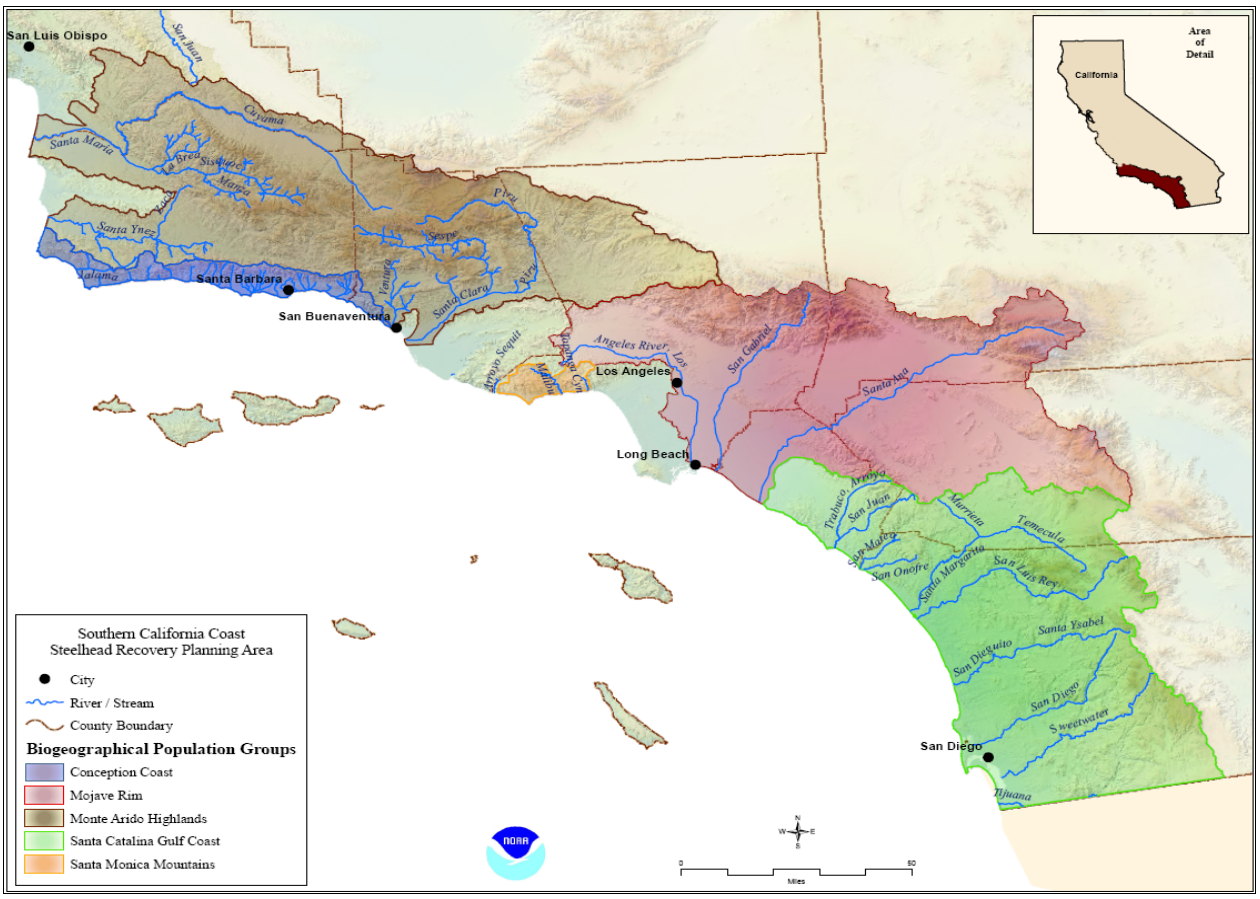
The Southern California Steelhead (SCS) Recovery Planning Area extends from the Santa Maria River to the Tijuana River at the U.S.-Mexico border. It includes both those portions of coastal watersheds that are at least seasonally accessible to steelhead entering from the ocean, and the upstream portions of watersheds that are currently inaccessible to steelhead due to man-made barriers but were historically used by steelhead. Major steelhead watersheds in the northern portion of the SCS Recovery Planning Area include the Santa Maria, Santa Ynez, Ventura, and Santa Clara Rivers, and Malibu and Topanga Creeks. Major steelhead watersheds in the southern portion of the SCS Recovery Planning Area include the San Gabriel, Santa Margarita, San Luis Rey, San Dieguito, and Sweetwater Rivers, and San Juan and San Mateo Creeks.



The Southern California Steelhead Recovery Planning Area.

The Southern California Steelhead DPS encompasses all naturally-spawned anadromous *O. mykiss* between the Santa Maria River (inclusive) and the U.S.-Mexico border, whose freshwater habitat occurs below artificial or natural impassible upstream barriers, as well as *O. mykiss* residing above impassible barriers that are able to emigrate into waters below barriers and exhibit an anadromous life-history.

The SCS Recovery Planning Area is divided into five Biogeographic Population Groups (BPGs): Monte Arido Highlands, Conception Coast, Santa Monica Mountains, Mojave Rim and Santa Catalina Gulf Coast. Each BPG is characterized by a unique combination of physical and ecological characteristics that present differing natural selective regimes for steelhead populations utilizing the individual watersheds. The separate watersheds comprising each BPG are generally considered to support individual *O. mykiss* populations (*i.e.*, one watershed = one steelhead population). Thus, single BPGs encompass multiple watersheds and multiple *O. mykiss* populations.



The Southern California Steelhead Recovery Planning Area Biogeographic Population Groups.

The basic goal of the Southern California Steelhead Recovery Plan is to recover anadromous steelhead and ensure the long-term persistence of self-sustaining wild populations of steelhead across the DPS – and ultimately to remove southern California steelhead from the Federal List of Endangered and Threatened Wildlife. The Recovery Plan proposes to accomplish this goal by addressing factors limiting the species ability to survive and naturally reproduce in the wild within a set of core watershed populations distributed across the SCS Recovery Planning Area.

Environmental Setting

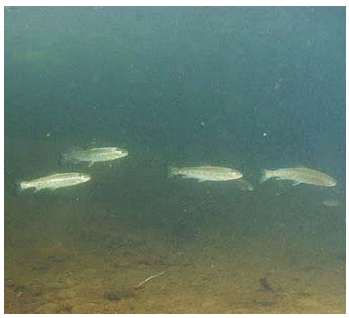
The SCS Recovery Planning Area is dominated by a series of steep mountain ranges and coastal valleys and terraces. Watersheds within the region fall into two basic types: those characterized by short coastal streams draining mountain ranges immediately adjacent to the coast and those watersheds containing larger river systems that extend inland through gaps in the coastal ranges. The SCS Recovery Planning Area has a Mediterranean climate, with long dry summers and brief winters with short, sometimes intense cyclonic winter storms. Significant portions of the upper watersheds within the SCS Recovery Planning Area are contained within four U.S. National Forests (Los Padres, Angeles, San Bernardino, and Cleveland National Forests).

Steelhead Biology and Ecology

Steelhead exhibit an anadromous life-history: juveniles born and reared in freshwater undergo a physiological change (smoltification) that allows them to migrate to and mature in saltwater before returning to their natal rivers or streams (streams where they were spawned) to reproduce and complete their life cycle. After maturing in the marine environment for two to four years, returning adults may migrate from several to hundreds of miles upstream to reach their spawning grounds. Once in spawning habitat, a female will excavate a nest, termed a "redd", in streambed gravels where she deposits her eggs. After fertilization by the male, hatching time varies from about three weeks to two months, with the young fish emerging two to six weeks later. Adult anadromous steelhead do not necessarily die after spawning and may return to the ocean, sometimes repeating their spawning migration one or more times.



Juvenile *O. mykiss* (~10 cm)
Santa Ana Creek



Smolt *O. mykiss* (~16 cm)
Carpinteria Creek



Adult *O. mykiss* (~76 cm)
Mission Creek

Within this basic life-history pattern, individuals may exhibit great variation in the time and location spent at each life-history stage. *O. mykiss* exhibit three basic life-history strategies: fluvial-anadromous (migration between freshwater and saltwater), lagoon-anadromous (migration to and from a brackish lagoon) and freshwater residency (remain in freshwater). The diversity of these life-history strategies has allowed *O. mykiss* to take advantage of different habitats and to persist in the highly variable and challenging southern California environment. Anadromous steelhead reach a larger size and produce more eggs per individual than typical freshwater resident *O. mykiss*; they can also spawn in non-natal streams and thus re-colonize watersheds whose populations have been extirpated. Lagoon-reared juveniles can attain a larger size in a single rearing season than freshwater-reared individuals, which enhances their survival in the ocean. However, freshwater-reared individuals, referred to as rainbow trout, may exhibit higher survival rates than ocean-reared individuals during poor ocean conditions, that can persist for multiple decades. Fish that exhibit any one of these life-history strategies can produce progeny that exhibit one or more of the other life-history strategies. The switching of life-history strategies is an important adaptive response to the highly variable environments characteristic of southern California watersheds.

Southern California Steelhead

For millennia, steelhead have been an integral part of southern California watershed ecosystems. The subsistence role of steelhead in pre-European settlement Native American cultures, however, is not as well understood as other marine species, and continues to be a subject of archeological and ethnographic research.



Ventura River Steelhead Anglers, 1909



Santa Ynez River Steelhead Angler, 1942

Up until the mid-1900s recreational steelhead angling was prevalent during the early to mid-1900s, and both steelhead and their progeny were sought out by recreational anglers - the ocean going steelhead pursued during the winter and the freshwater juveniles during the spring and summer angling seasons.

Following the dramatic rise in southern California's human population after WW II, and the associated land and water development in coastal watersheds, steelhead populations rapidly declined from an estimated 32,000 - 46,000 fish per year to less than 500 returning adults. While the steelhead populations declined sharply, most coastal watersheds retained populations of the non-anadromous form of the species, with many populations trapped behind dams and other impassible barriers.

Factors Leading to Federal Listing

There is no single factor responsible for the decline of southern California steelhead; however, the destruction and modification of habitat has been identified as one of the primary causes of the decline of the Southern California Steelhead DPS.

Approximately half of the population of the State of California currently lives and works within the SCS Recovery Planning Area, placing extraordinary pressure on natural resources. As a result, anadromous *O. mykiss* in southern California face significant threats from water and land management practices that have degraded or curtailed freshwater and estuarine habitats, reducing the capability of the anadromous form of *O. mykiss* to persist within many watersheds.

Water withdrawals and diversions for agriculture, flood control, domestic water supply and hydropower purposes have greatly reduced or degraded historically accessible habitat. Dams and other water control structures have blocked access to historically important spawning and rearing areas; modified flow regimes necessary for migration, spawning and rearing; increased downstream water temperatures; degraded riparian habitats; and reduced gravel recruitment essential to support spawning and invertebrate food sources for rearing juveniles.



Rincon Creek Estuary and Urban Development



Matilija Dam, Matilija Creek

Land-use and flood control activities associated with urban development, mining, agriculture, ranching, and recreation have significantly altered the quantity and quality of steelhead habitat in multiple ways. These include: alteration of stream banks; increases in ambient stream water temperatures; degradation of water quality through municipal and industrial waste discharges; removal of riparian vegetation resulting in increased stream bank erosion, loss of channel complexity, pool habitat, and increased sedimentation into spawning and rearing areas; and fragmentation of remaining habitats. The substantial increase of impermeable surfaces (including roads) as a result of urbanization has also altered the natural flow regimes of rivers and streams, particularly in their lower reaches. A significant percentage of estuarine habitats have been lost across the DPS due to urban development, including recreational development; the remaining wetland areas remains at risk of further loss or degradation.



Agricultural Development



Sedimentation Following Wildfires



Channel Modification

Other factors contributing to the decline of southern California steelhead populations and leading to the listing of the species as endangered include impacts from recreational activities (*e.g.*, off-road vehicles, summer dams); the introduction and spread of non-native species which can compete directly or indirectly for habitat space, serve as vectors for disease, or increase predation; and the inadequacy of existing planning or regulatory and enforcement mechanisms at the local, state, and federal levels.

The natural environmental variability of the SCS Recovery Planning Area has both masked and exacerbated the problems associated with degraded and altered riverine and estuarine steelhead habitats. Floods and persistent drought conditions have periodically reduced naturally limited spawning, rearing, and migration habitats. Projected impacts of future climate change pose additional challenges to southern California steelhead.

Steelhead Recovery Goals, Objectives, and Criteria

The Recovery Plan is a guidance document for achieving recovery goals that include viability criteria for populations of *O. mykiss* and the DPS as a whole. The basic goal of the Southern California Steelhead Recovery Plan is to prevent the extinction of anadromous steelhead by ensuring the long-term persistence of viable, self-sustaining, wild populations of steelhead across the DPS. It is also the goal of the Recovery Plan to re-establish a sustainable southern California steelhead sport fishery.

The Recovery Plan outlines the following objectives that address factors limiting the species' ability to survive and naturally reproduce in the wild:

- ***Prevent steelhead extinction by protecting existing populations and their habitats.***
- ***Maintain current distribution of steelhead and restore distribution to some previously occupied areas.***
- ***Increase abundance of steelhead to viable population levels, including the expression of all life-history forms and strategies.***
- ***Conserve existing genetic diversity and provide opportunities for interchange of genetic material between and within viable populations.***
- ***Maintain and restore suitable habitat conditions and characteristics to support all life-history stages of viable populations.***

Biological viability criteria are identified for individual populations and the DPS as a whole. A *viable population* is defined as a population having a negligible (< 5%) risk of extinction due to threats from demographic variation, non-catastrophic environmental variation, and genetic diversity changes over a 100-year time frame. A *viable DPS* is comprised of a sufficient number of viable populations widely distributed throughout the DPS but sufficiently well-connected through ocean and freshwater dispersal to maintain long-term (1,000-year) persistence and evolutionary potential of the DPS.

The population-level viability criteria apply to core populations in all of the BPGs. These criteria include population characteristics such as mean annual run-size, persistence during varying ocean conditions, spawner density, and the anadromous fraction of the individual populations. Because of the uncertainty regarding important aspects of the biology and ecology of southern California steelhead further research is needed to refine the population-level criteria in all BPGs, as well as the role of each of the BPGs.

The DPS-level viability criteria identify a minimum number of populations which must be restored to viability and the minimum spatial distribution between populations in each BPG: Monte Arido – 4 populations, Conception Coast - 3 populations, Santa Monica Mountains – 2 populations, Mojave River – 3 populations, and Santa Catalina Gulf Coast -8 populations).

This redundancy ensures that there are a sufficient number of populations within the BPGs and across the DPS to provide resiliency in the face of environmental fluctuations, and also that a variety of habitat types and environmental conditions are represented to promote the continued evolution of the species. Some of these populations may be comprised of multiple watersheds if further research indicates that they act as trans-basinal populations.

Summary of DPS-Wide Recovery Actions

Recovery of the Southern California Steelhead DPS will require recovery of a number of viable populations (or sets of interacting trans-basinal populations) within each of the five BPGs to conserve the natural diversity (genetic, phenotypic, and behavioral), spatial distribution, and resiliency of the DPS as a whole. Core populations in all BPGs must be restored to viability before the DPS as a whole can be recovered and delisted.

There are two types of developments and activities that pose the principal threats to the species: 1) impassible barriers to fish passage; and 2) water storage and withdrawal, including groundwater extraction. The Recovery Plan provides additional information on these and other threats and related recovery actions necessary to recover steelhead within individual watersheds and the DPS as a whole.

The Recovery Plan highlights a number of high priority DPS-wide recovery actions, including:

- ***Physically modify passage barriers such as dams and diversion facilities to allow natural rates of migration to upstream spawning and rearing habitats.***

- ***Coordinate with the California Department of Fish and Game and State Water Resources Control Board to ensure the effective implementation of California Fish and Game Code Sections 5935-5937 (provision of fishway and fish flows associated with dams and diversions).***

- ***Extend California Water Code Section 1294.4 (dealing with instream flows to protect instream beneficial uses, including native fishes), to southern California.***

- ***Enhance protection of natural in-channel and riparian habitats, including appropriate management of flood-control activities, off-road vehicle use, and in-river sand and gravel mining practices.***

- ***Reduce water pollutants such as fine sediments, pesticides, herbicides, and other non-point source waste discharges.***

- ***Assess the condition of and restore estuarine habitats through the control of fill, waste discharges, and establishment of buffers; control artificial breaching and/or draining of coastal estuaries.***

- ***Conduct research on the relationship between resident and anadromous forms of O. mykiss, and the population dynamics regarding distribution, abundance, residualization, dispersal, and recolonization rates.***

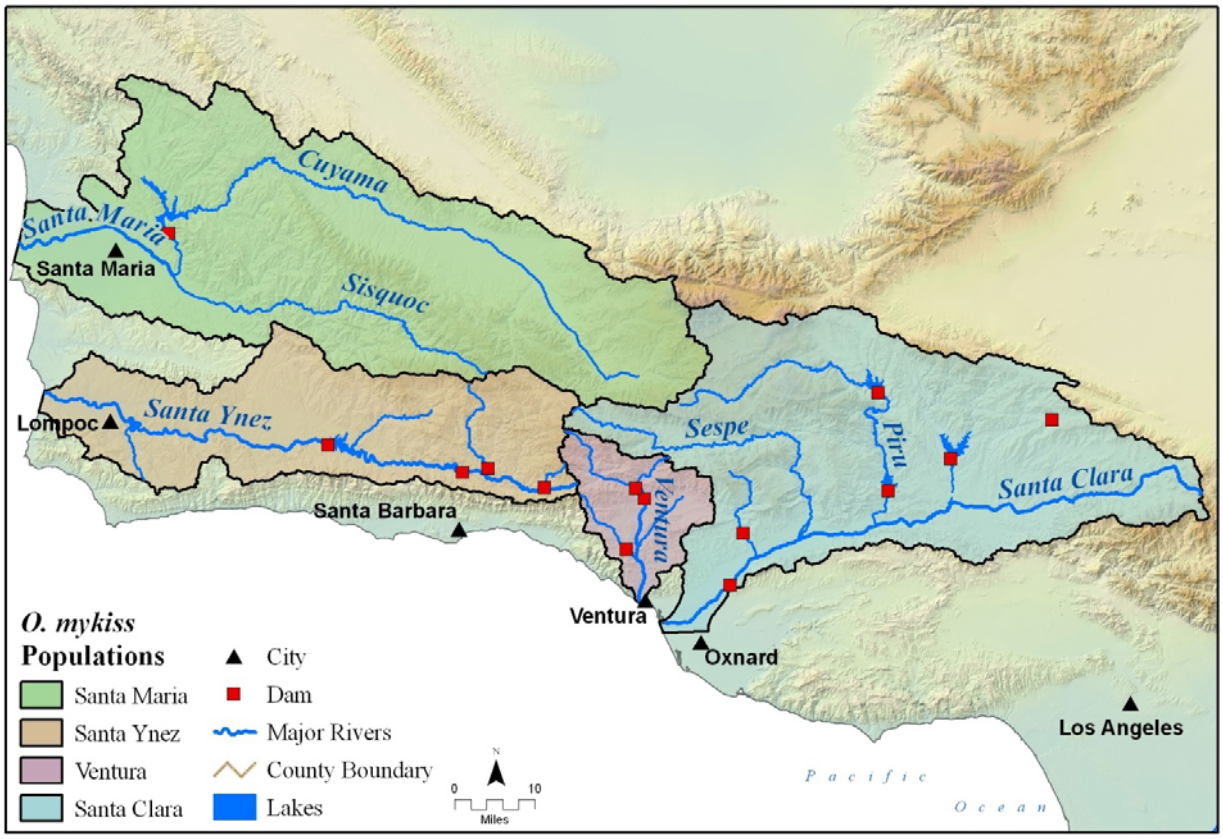
- ***Survey and monitor the distribution and abundance of non-native plant and animal species that degrade natural habitats or compete with native species; reduce and/or control such non-native invasive species.***

- ***Incorporate appropriate elements of the Recovery Plan into the state-sponsored and funded Integrated Regional Water Management Plans (IRWMP).***

- ***Finalize and implement the Statewide Coastal Monitoring Plan for anadromous salmonids.***

As part of an adaptive management program, population and habitat responses to recovery actions will be evaluated through on-going research and monitoring.

Monte Arido Highlands
Biogeographic Population Group



The Monte Arido Highlands BPG encompasses four medium to large coastal watersheds and eight sub-watersheds that drain the western half of the Transverse Range in southern San Luis Obispo, Santa Barbara, Ventura, and eastern Los Angeles counties. These watersheds are highly disparate in terms of slope, aspect, and size, but share one common feature: the interior portions are mountainous and include high peak elevations, ranging between 5,700 and 8,600 feet above sea level. Each of these watersheds flows across a coastal terrace in its lower elevation, but the Santa Maria, Santa Ynez, and Santa Clara rivers traverse broad coastal plains before entering the Pacific Ocean. Overall, stream lengths tend to be long, due to multiple tributaries and topographic relief in the interior watersheds. The Santa Maria River watershed (Cuyama River sub-watershed) extends the furthest inland—almost 90 miles between the mouth and the limits of the upper watershed.



Santa Maria River



Adult Steelhead, Santa Clara River



Bradbury Dam, Santa Ynez River

Threat Source Rankings: Monte Arido Highlands BPG Component Watersheds (north to south)													
Threat Sources	Santa Maria River	Cuyama River	Sisquoc River	Santa Ynez River	Ventura River	Coyote Creek	Matilija Creek mainstem	North Fork Matilija Creek	San Antonio Creek	Santa Clara River	Santa Paula Creek	Sespe Creek	Piru Creek
Dams and Surface Water Diversions													
Groundwater Extraction													
Agricultural Development													
Urban Development													
Recreational Facilities													
Non-Native Species													
Levees and Channelization													
Flood Control													
Wildfires*													
Mining and Quarrying													
Roads													
Urban Effluents													
Agricultural Effluents													
Culverts & Road Crossings													

Key: Red = Very High threat; Yellow = High threat; Light green = Medium threat; Dark green = Low threat
Threat cell colors represent threat rating from Conservation Planning (CAP) Workbooks.

*Wildfires were not identified during the CAP Workbook analyses as one of the top five threats in several of these watersheds, but recent fires in coastal watersheds indicates that future wild fires could result in significant habitats impacts.

Priority Recovery Actions

- Develop and implement operating criteria to ensure the pattern and magnitude of water releases from dams, including Twitchell, Bradbury, Gibraltar, Juncal, Casitas, Matilija, Robles Diversion, Santa Felicia, Pyramid, Vern Freeman Diversion, and Castaic dams, provide the essential habitat functions to support the life-history and habitat requirements of adult and juvenile *O. mykiss*.

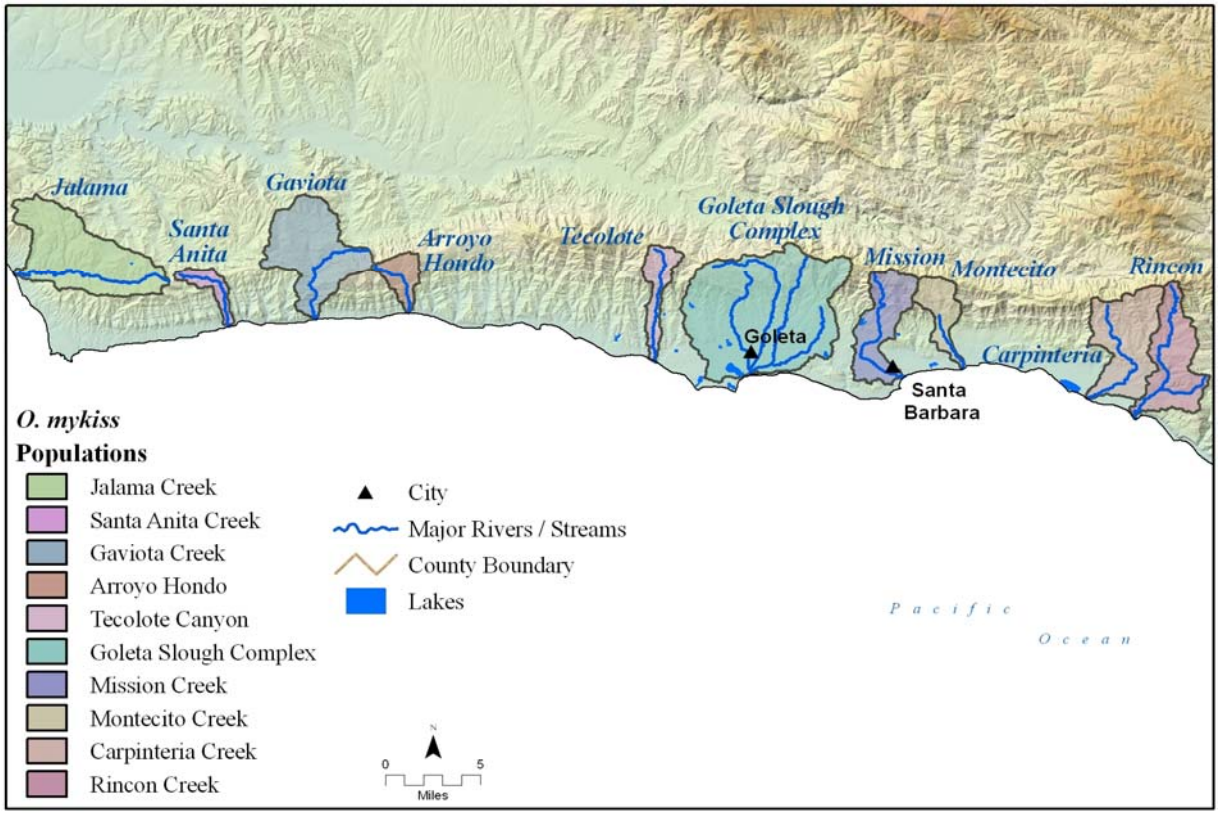
- Develop and implement plans to physically modify Twitchell, Bradbury, Gibraltar, Mono, Juncal, Casitas, Matilija, Robles Diversion, Santa Felicia, Pyramid, Vern Freeman Diversion, and Castaic dams to allow natural rates of adult and juvenile *O. mykiss* migration between the estuary and upstream spawning and rearing habitats, and passage of smolts and kelts downstream to the estuary and ocean.

- Develop and implement a groundwater monitoring program to guide management of groundwater extractions within steelhead bearing watersheds to ensure surface flows provide essential support for all *O. mykiss* life-history stages, including adult and juvenile *O. mykiss* migration, spawning, incubation, and rearing habitats.

- Develop and implement plans to physically modify the lower Santa Paula Creek flood control channel to allow natural rates of migration of adult and juvenile *O. mykiss* between n the estuary and upstream spawning and rearing habitats, and passage of smolts and kelts downstream to the estuary and ocean.

- Develop and implement restoration and management plans for the estuaries associated with steelhead bearing watersheds. To the maximum extent feasible, the plan should restore the physical configuration, size and diversity of the wetland habitats, eliminate exotic species, control artificial breaching of the sand bar, and establish effective buffers to restore estuarine functions and promote *O. mykiss* use (including rearing and acclimation) of the estuaries.

Conception Coast
Biogeographic Population Group



The Conception Coast BPG encompasses eight small coastal watersheds that drain a 50-mile long stretch of the south-facing slopes of the Santa Ynez Mountains in southern Santa Barbara County and extreme southwestern Ventura County. The Santa Ynez Mountains are an east-west trending spur of the Transverse Range that creates some of the steepest watersheds in any of the five BPGs in the SCS Recovery Planning Area. Peak elevations reach 4,300 feet within a few miles of the Pacific Ocean. These watersheds are relatively homogeneous in slope, aspect, and size, with steep upper watersheds and lower watersheds that cut across a relatively narrow coastal terrace. Stream lengths are relatively short in this BPG; the Gaviota Creek watershed penetrates the furthest inland (about seven miles). Rainfall amounts in the upper watersheds can be five to six times higher than on the coastal terrace during the same storm event, and the steep topography creates extremely "flashy" flows within these watersheds.



Gaviota Creek



Maria Ygnacio Creek



Adult Steelhead, Carpinteria

Threat Source Rankings: Conception Coast BPG Component Watersheds (north to south)										
Threat Source	Jalama Creek	Canada de Santa Anita	Gaviota Creek	Arroyo Hondo	Tecolote Creek	Goleta Slough	Mission Creek	Montecito Creek	Carpinteria Creek	Rincon Creek
Roads										
Culverts & Crossings										
Groundwater Extraction										
Levees and Channelization										
Urban Development										
Wildfires*										
Recreational Facilities										
Non-Point Pollution										
Flood Control										
Mining and Quarrying										
Agricultural Development										
Dams and Surface Water Diversions										

Key: Red = Very High threat; Yellow = High threat; Light green = Medium threat; Dark green = Low threat
Threat cell colors represent threat rating from Conservation Action Planning (CAP) Workbooks.

*Wildfires were not identified during the CAP Workbook analyses as one of the top five threats in several of these watersheds, but recent fires in coastal watersheds indicates that future wildfires could result in significant habitats impacts.

Priority Recovery Actions

- Develop and implement a plan to physically modify channelized reaches of lower Mission Creek, and upstream road crossings, to allow natural rates of migration of adult and juvenile *O. mykiss* between the estuary and upstream spawning and rearing habitats, and passage of smolts and kelts downstream to the estuary and ocean.

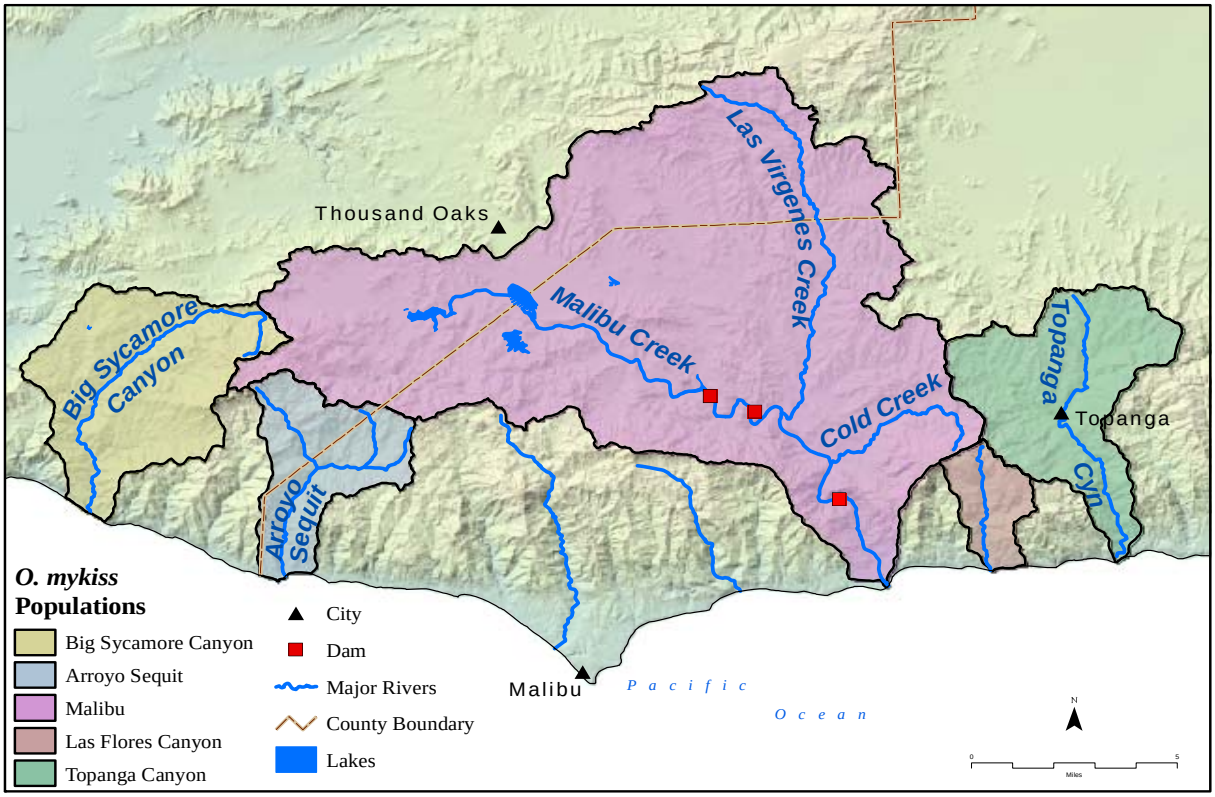
- Develop and implement a plan to physically modify upstream debris basins and other fish passage barriers within steelhead bearing watersheds to allow natural rates of adult and juvenile *O. mykiss* of migration between the estuary and upstream spawning and rearing habitats, and passage of smolts and kelts downstream to the estuary and ocean.

- Develop and implement a plan to physically modify the Highway 101 and railroad culvert over lower Rincon Creek, and upstream road crossings to allow natural rates of adult and juvenile *O. mykiss* migration between the estuary and spawning and rearing habitats, and passage of smolts and kelts downstream to the estuary and ocean.

- Develop and implement a groundwater monitoring program to guide management of groundwater extractions within steelhead bearing watersheds to ensure surface flows provide essential support for all *O. mykiss* life-history stages, including adult and juvenile *O. mykiss* migration, spawning, incubation, and rearing habitats.

- Develop and implement restoration and management plans for estuaries associated with steelhead bearing watersheds. To the maximum extent feasible, the plans should restore the physical configuration, size and diversity of the wetland habitats, eliminate exotic species, control artificial breaching of the sand bar, and establish effective buffers to restore estuarine functions and promote *O. mykiss* use (including rearing and acclimation) of the estuaries).

Santa Monica Mountains
Biogeographic Population Group



The Santa Monica Mountains BPG consists of five coastal watersheds located in southern Ventura and western Los Angeles counties which drain the east-west coastal Santa Monica Mountains. Similar to the Conception Coast BPG, it is comprised of a series of short, nearly parallel streams that drain steep south-facing slopes, but with an average elevation of less than 2,500 feet. These watersheds are relatively homogeneous in slope, aspect, and size, with steep upper watersheds and lower watersheds that cut across a relatively narrow coastal terrace. Malibu Creek is the largest of the five watersheds, encompassing approximately 110 square miles, and penetrates through a break in the Santa Monica Mountains to drain a portion of its north-facing slopes and the south-facing slopes of the Simi Hills. There are also a number of smaller watersheds within this BPG (*e.g.*, Trancus, Zuma, Solstice, and Las Flores Canyon) which may also be used by steelhead when water conditions are periodically favorable. Calleguas Creek and the Los Angeles River, to the east and west of the BPG, drain the northern slopes of the Santa Monica Mountains.



Malibu-Los Angeles



Adult Steelhead, Malibu Creek



Rindge Dam, Malibu Creek

Threat Source Rankings: Santa Monica Mountains BPG Component Watersheds (west to east)					
Threat Sources	Big Sycamore Canyon Creek	Arroyo Sequit	Malibu Creek	Las Flores Canyon Creek	Topanga Canyon Creek
Roads					
Recreational Facilities					
Culverts and Road Crossings					
Wildfires*					
Urban Development					
Levees and Channelization					
Dams and Surface Water Diversions					
Non-Native Species					
Upslope/Upstream Development					
Urban Effluents					

Key: Red = Very High threat; Yellow = High threat; Light green = Medium threat; Dark green = Low threat
Threat cell colors represent threat rating from Conservation Action Planning (CAP) Workbooks.

*Wildfires were not identified during the CAP Workbook analyses as one of the top five threats in several of these watersheds, but recent fires in coastal watersheds indicates that future wildfires could result in significant habitats impacts.

Priority Recovery Actions

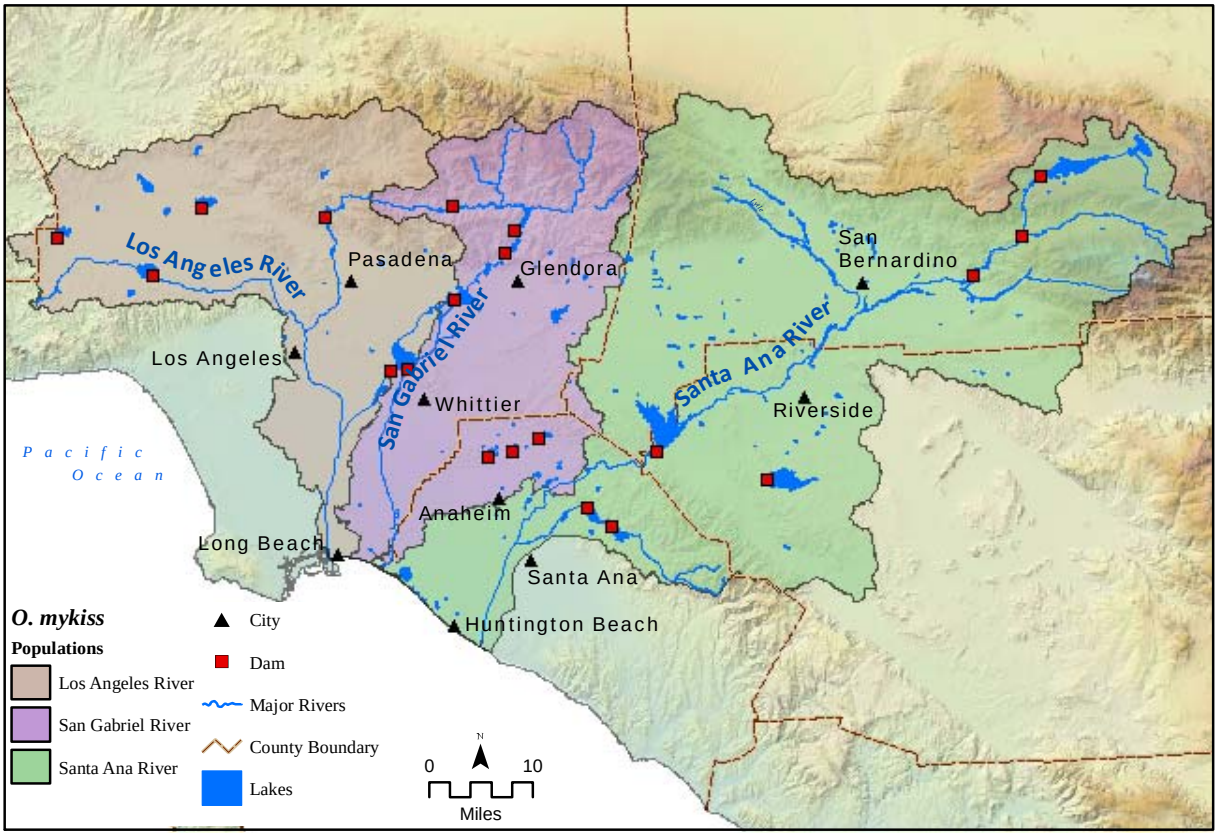
- Develop and implement plans to remove Rindge and Malibu dams, and physically modify road crossings and other fish passage barriers to allow natural rates of adult and juvenile *O. mykiss* migration between the estuary and upstream spawning and rearing habitats, and passage of smolts and kelts downstream to the estuary and the ocean.

- Develop and implement plan to replace the U.S. 101 culvert over Topanga Creek with a full span bridge and remove fill from the Topanga Creek Estuary to allow natural rates of adult and juvenile *O. mykiss* migration to upstream spawning and rearing habitats, and passage of smolts and kelts downstream to the estuary and ocean.

- Develop and implement restoration and management plans for estuaries associated with steelhead bearing watersheds. To the maximum extent feasible, the plans should restore the physical configuration, size and diversity of the wetland habitats, eliminate exotic species, control artificial breaching of the sand bar, and establish effective buffers to restore estuarine functions and promote *O. mykiss* use (including rearing and acclimation) of the estuaries.

- Develop and implement an integrated wildland fire and hazardous fuels management plan, including monitoring, remediation and adaptive management, to reduce potentially catastrophic wildland fire effects to adult and juvenile *O. mykiss* and their habitat and preserve natural ecosystem processes (including sediment transport and deposition).

Mojave Rim
Biogeographic Population Group



The Mojave Rim BPG encompasses three large coastal watersheds that drain the northern slopes of the Santa Monica Mountains and the southern slopes of the San Gabriel and San Bernardino mountains in southern Los Angeles County, southwestern San Bernardino, and western Riverside and Orange counties: the Los Angeles River, San Gabriel River, and the Santa Ana River. The upper portions of each of these watersheds include steep, mountainous terrain (within the Angeles and San Bernardino National Forests) and the lower watersheds cut across the Los Angeles Basin—an extensive coastal plain, with comparatively few, small tributaries.



Morris Dam, San Gabriel River



East Fork San Gabriel River



Santa Ana River Estuary

Threat Source Rankings: Mojave Rim BPG Component Watersheds (west to east)								
Threat Sources	Los Angeles River mainstem	Arroyo Seco	San Gabriel River mainstem	West Fork San Gabriel River	East Fork San Gabriel River	Santa Ana River mainstem	Lytle Creek	Mill Creek
Dams and Surface Water Diversions								
Flood Control								
Groundwater Extraction								
Levees and Channelization								
Urban Development								
Recreational Facilities								
Culverts and Road Crossings								
Agricultural Development								
Upslope/Upstream Development								
Wildfires*								

Key: Red = Very High threat; Yellow = High threat; Light green = Medium threat; Dark green = Low threat
Threat cell colors represent threat rating from Conservation Action Planning (CAP) Workbooks.

* Wildfires were not identified during the CAP Workbook analyses as one of the top five threats in several of these watersheds, but recent wildfires indicates that future wildfires could result in significant habitats impacts; additionally, the presence of non-native species is not reflected in the CAP Workbook analyses, but non-native species is a potential threat in this BPG.

Priority Recovery Actions

- Develop and implement operating criteria to ensure the pattern and magnitude water releases from dams, including Morris, San Gabriel, Cogswell, Santa Fe, Prado, Seven Oaks, and Bear Valley dams, provide the essential habitat functions to support the life-history and habitat requirements of adult and juvenile *O. mykiss.*

- Develop and implement a plan to physically modify dams, including Morris, San Gabriel, Cogswell, Santa Fe, Prado, Seven Oaks, and Bear Valley dams, to allow adult and juvenile *O. mykiss* natural rates of migration between the estuary and upstream spawning and rearing habitats, and passage of smolts and kelts downstream to the estuary and ocean.

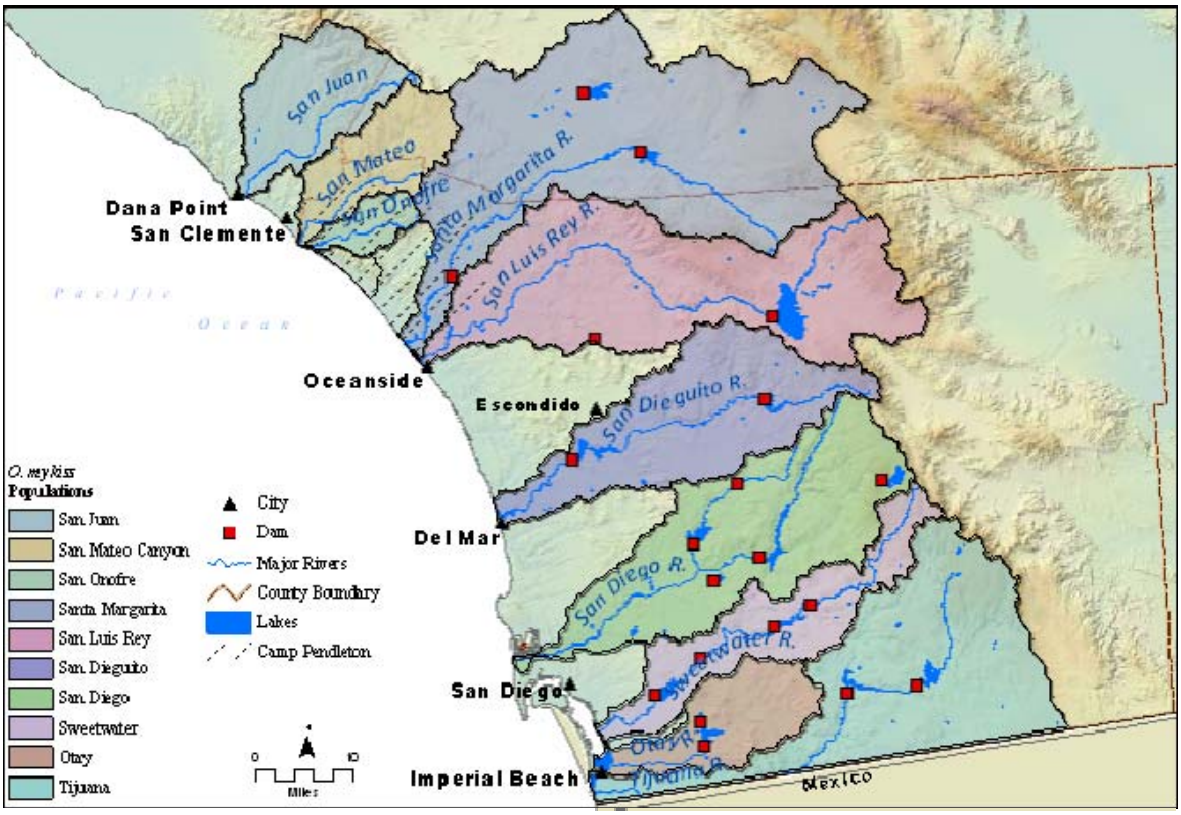
- Develop and implement a plan to physically modify or remove fish passage barriers at debris basins, diversions, roads, and highways to allow adult and juvenile *O. mykiss* natural rates of migration between the estuary and upstream spawning and rearing habitats, and passage of smolts and kelts downstream to the estuary and ocean.

- Develop and implement restoration and management plans for steelhead bearing watersheds. To the maximum extent feasible, plans should restore the physical configuration, size and diversity of the wetland habitats, eliminate exotic species, control artificial breaching of the sand bar, and establish effective buffers to restore estuarine functions and promote *O. mykiss* use (including rearing and acclimation) of the estuaries.

- Develop and implement an integrated wildland fire and hazardous fuels management plan, including monitoring, remediation and adaptive management, to reduce potentially catastrophic wildland fire effects to adult and juvenile *O. mykiss* and their habitat and preserve natural ecosystem processes (including sediment transport and deposition).

- Develop and implement flood control maintenance plan for steelhead bearing watersheds to minimize the frequency and intensity of disturbance of instream habitats and riparian vegetation of the mainstem and tributaries to protect all *O. mykiss* life-history stages, including adult and juvenile migration, spawning, incubation and rearing, and their associated habitats.

Santa Catalina Gulf Coast
Biogeographic Population Group



The Santa Catalina Gulf Coast BPG encompasses ten coastal watersheds of moderate size that drain the western slopes of the Santa Ana Mountains and Peninsular Range in southwestern Orange and Riverside counties southward through San Diego County to the United States-Mexico border. The upper portions of almost all of these watersheds include steep, mountainous regions and the lower watersheds cut across coastal terraces. Two watersheds, the Sweetwater River and Otay River, drain into San Diego Bay; the other eight watersheds drain directly into the Pacific Ocean. The component watersheds vary greatly in size and numerous tributaries contribute to the large total stream length for this BPG (4,235 miles). Because of low rainfall, many of the drainages in this BPG are naturally seasonal or have extensive dry reaches during years of below-average precipitation, particularly in their lower reaches.



Arroyo Trabuco Creek



O. mykiss, Pine Valley Creek



San Mateo Creek

Threat Source Rankings: Santa Catalina Gulf Coast Component Watersheds (north to south)										
Threat Sources	San Juan Creek/ Trabuco Creek	San Mateo Creek	San Onofre Creek	Santa Margarita River	San Luis Rey River	San Dieguito River	San Diego River	Sweetwater River	Otay River	Tijuana River
Groundwater Extraction										
Dams and Surface Water Diversions										
Urban Development										
Agricultural Development										
Levees and Channelization										
Culverts & Road Crossings										
Recreational Facilities										
Non-Native Species										
Roads										
Flood Control Maintenance										
Upslope/Upstream Development										
Agricultural Effluents										
Wildfires*										

Key: Red = Very High threat; Yellow = High threat; Light green = Medium threat; Dark green = Low threat
Threat cell colors represent threat rating from the Conservation Action Planning (CAP) Workbooks.

* Wildfires were not recognized during the CAP Workbook analyses as one of the top five threats in these watersheds, but recent fires indicate that future wildfires could result in significant habitat impacts.

Priority Recovery Actions

- Develop and implement plans to physically modify or remove fish passage barriers at dams, debris basins, diversions, roads, and highways to allow adult and juvenile *O. mykiss* natural rates of migration between the estuary and upstream spawning and rearing habitats, and passage of smolts and kelts downstream to the estuary and ocean.

- Development and implement operating criteria to ensure the pattern and magnitude of water releases from Pilgram, Turner, Lower and Upper Stehly, Agua Tibia, Henshaw, Eagles Nest, and O'Neill Diversion dams provide the essential habitat functions to support the life-history and habitat requirements of adult and juvenile *O. mykiss*.

- Develop and implement watershed–wide plans for steelhead bearing watersheds to identify and determine the type, distribution, and density of non-native species; assess their impacts on all *O. mykiss* life-history stages; and eliminate or control non-native species to protect all *O. mykiss* life history stages.

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- Develop and implement restoration and management plans for estuaries in steelhead bearing watersheds. To the maximum extent feasible, the plan should restore the physical configuration, size and diversity of the wetland habitats, eliminate exotic species, control artificial breaching of the sand bar, and establish effective buffers to restore estuarine functions and promote *O. mykiss* use (including rearing and acclimation) of the estuaries.

Summary

An array of natural and anthropogenic factors has reduced both the population size and historical distribution of steelhead within the SCS Recovery Planning Area, placing severe pressure on the species' ability to survive. However, steelhead are resilient fish and despite encroaching agricultural and urban development, they continue to persist in small numbers throughout the SCS Recovery Planning Area. The Southern California Steelhead Recovery Plan outlines a strategy for species' recovery by identifying core watersheds, threats to these watersheds and recovery actions to address those threats. The Recovery Plan also identifies a research program to address the biology and ecology of southern California steelhead necessary to refine the viability recovery criteria, and a monitoring program to assess the effectiveness of recovery actions and the status of individual populations and the DPS as a whole.

Many of the recovery actions identified in this Recovery Plan address watershed-wide processes (*e.g.*, wild-fire cycle, erosion and sedimentation, runoff, and non-point waste discharges) which will benefit a wide variety of other native species (including other state and federally listed species, or species of special concern) by restoring natural ecosystem functions.

Restoration of steelhead habitats in coastal watersheds will also provide substantial benefits for human communities. These include, but are not limited to, improving and protecting the water quality of important surface and groundwater supplies, reducing damages from periodic flooding resulting from floodplain development, and controlling invasive exotic animal and plant species which can threaten water supplies and increase flood risks. Restoring and maintaining ecologically functional watersheds also enhances important human uses of habitats occupied by steelhead; these include such activities as outdoor recreation, environmental education (at primary and secondary levels), field-based research on the physical and biological processes of coastal watersheds, aesthetic enjoyment, and the preservation of important tribal and cultural heritage values. Investment in the recovery of southern California steelhead will provide economic benefits, including stimulating the economy directly through the employment of a restoration workforce, and the expenditure of wages and restoration dollars for the purchase of goods and services. In addition, viable salmonid populations provide ongoing direct and indirect economic benefits as a natural resource base for angling, outdoor recreation, and tourist related activities. Recovering and delisting the Southern California Steelhead DPS will also reduce the regulatory obligations imposed by the ESA, and allow land and water managers greater flexibility to optimize their activities, and reduce costs related to ESA protections.

Recovery of viable, self-sustaining populations of southern California steelhead will require a shift in societal attitudes, understanding, priorities, and practices, and ultimately the re-integration of the species into a highly altered landscape that is home to more than 22 million people. These changes are necessary to both ensure sustainable communities in southern California and to restore the habitat upon which viable steelhead populations depend.

Recovery of southern California steelhead depends most fundamentally on a shared vision of the future. A shared vision for the future can align interests and encourage cooperation that, in turn, has the potential to improve rather than undermine the adaptive capacity of natural public resources such as functioning watersheds and river systems. The on-going cooperation and dedication of many stakeholders from both public and private sectors will therefore be essential to achieve the recovery of southern California steelhead.

Southern California Steelhead Recovery Plan may be obtained from**:**

National Marine Fisheries Service
Office of Protected Resources
501 W. Ocean Blvd., Suite 4200
Long Beach, CA 90802
562-980-4000

Or can be downloaded from the NMFS Recovery Planning website:

http://swr.nmfs.noaa.gov/pr/recovery/plans.htm

Final | June 2013

2013 Comprehensive Water Resources Report









Prepared for: Ventura Water

Prepared by: RBF Consulting,
a Company of Michael Baker Corporation

2013 COMPREHENSIVE WATER RESOURCES REPORT

Final Report

Prepared for:
Ventura Water
501 Poli Street
Ventura, CA 93002



Prepared by:
RBF Consulting, a Michael Baker Company
5051 Verdugo Way, Suite 300
Camarillo, CA 93012

Contact: Kevin Gustorf, P.E.
(949) 472-3429

RBF CONSULTING
A Baker Company

June 10, 2013

EXECUTIVE SUMMARY

Introduction

On July 26, 2010 Public Works conducted a workshop with City Council that included information on the City's current water supply issues. It was presented that with continued years of drought, tightening water restrictions and environmental responsibilities, Ventura's water supply was being impacted by several factors. These factors included and continue to include the following:

- The City's historical water rights to the Ventura River may be significantly limited as concern for the health of the endangered Southern California Steelhead and its habitat ecosystem restrict how much and at what time of the year this water source is available. Storm events over the past 15 years have restricted our ability to withdraw historical amounts from this source.
- City allocation from two groundwater basins, Oxnard Plain Basin and Santa Paula Basin, are increasingly regulated and monitored. Studies being conducted by the oversight agencies have indicated that potential overdraft and water quality issues may occur in the near future.
- The Mound Groundwater Basin has experienced water quality degradation and projections for reliable supply may be lower than originally anticipated.

A recommendation from the workshop was to provide a comprehensive evaluation of current and projected water supply needs.

In addition, as a part of this year's City Council Priority Projects, the Community Development (Planning) Department and Ventura Water have focused their time and energy on streamlining and documenting the development review process as it pertains to water and wastewater services. More specifically, we are working to:

- Ensure transparency and consistency to our customers,
- Create equity in assigning costs; and
- Protect the reliability of our water and wastewater infrastructure.

In order to provide a comprehensive evaluation of the City's current and projected water supply needs, there has been interdepartmental coordination to provide input and expertise on what development has taken place since the 2005 General Plan, the pace of proposed development and what water demands those developments may require. This Report will review previously developed water demand projections, anticipated water supplies and approved development projects and compare them to where

the City is today for each of these three categories. City staff is collaboratively looking forward to help plan the City's water resources to accommodate future development in the most responsible manner for its customers.

Purpose

The main purpose of this report is twofold. The report will identify water demand and water supply conflicts in various reports and will evaluate how current and future anticipated water demands match current and future anticipated water supply. City staff recognize the need to develop a process that tracks proposed development projects, consistently calculates the anticipated increase in water demand associated with each proposed development project, and the evaluates the impact on the current water supply. This Comprehensive Water Resources Report ("Report") is intended to be a tool in the development review process as it pertains to water supply and demand.

Previous Documents

As described in Section 1.B, one of the purposes of this Report is to identify the water demand and water supply discrepancies between the various previous reports published by the City, specifically the 2005 General Plan, 2010 Urban Water Management Plan and the 2011 Water Master Plan. A more detailed comparison is included in Section 1.D, and a summary of the year 2025 comparison is provided in Table ES-1.

Table ES-1
Year 2025 - Water Demand and Supply Projections from Previous Documents

Document	2025 Water Demand		2025 Water Supply	
	(AFY)	Notes	(AFY)	Notes
2005 General Plan Documents	27,421	Based on anticipated growth rate in General Plan (population x per capita use)	28,262	• All supply sources producing at maximum amounts. • Saticoy County Yard Well at 2,262 AFY. • No recycled water included.
2010 Urban Water Management Plan	24,270	Based on population projection x per capita use	24,700	• All supply sources producing at maximum amounts, except Casitas. • Casitas at 6,200 AFY (estimated in-District demand). • Saticoy County Yard Well at 0. • Recycled water at 700 AFY.
2011 Water Master Plan	22,708	Based on existing water consumption plus estimated demands calculated using demand factors (gpm/ac)	18,760 - 25,800	• Casitas: 4,960 AFY (current in-District demand) to 8,000 AFY (max). • Ventura River: 4,200 AFY (historical average) to 6,700 AFY (historical operational capacity). • Mound GW Basin: 2,500 AFY to 4,000 AFY (past 5-year low/high). • No recycled water included. • Oxnard GW Basin and Santa Paula Basin at max. • Saticoy County Yard Well at 0.

Current Water Supply

The City's potable water supply is derived from local groundwater basins, Lake Casitas and sub-surface water from the Ventura River. The City also has a 10,000 acre-foot per year allocation from the California State Water Project. To date the City has not received any of this water because there are no facilities to get the water to the City. There are presently five local water sources that provide water to the City water system:

- Casitas Municipal Water District (Casitas)
- Ventura River Foster Park Area (Foster Park)
    - Surface Water Intake
    - Upper Ventura River Groundwater Basin/Subsurface Intake and Wells
- Mound Groundwater Basin (Mound Basin)
- Oxnard Plain Groundwater Basin (Fox Canyon Aquifer)
- Santa Paula Groundwater Basin (Santa Paula Basin)

The City also provides recycled water from the Ventura Water Reclamation Facility (VWRF). The City's current reliable water supply is 19,600 AFY, although it could drop as low as 18,000 AFY at any time.

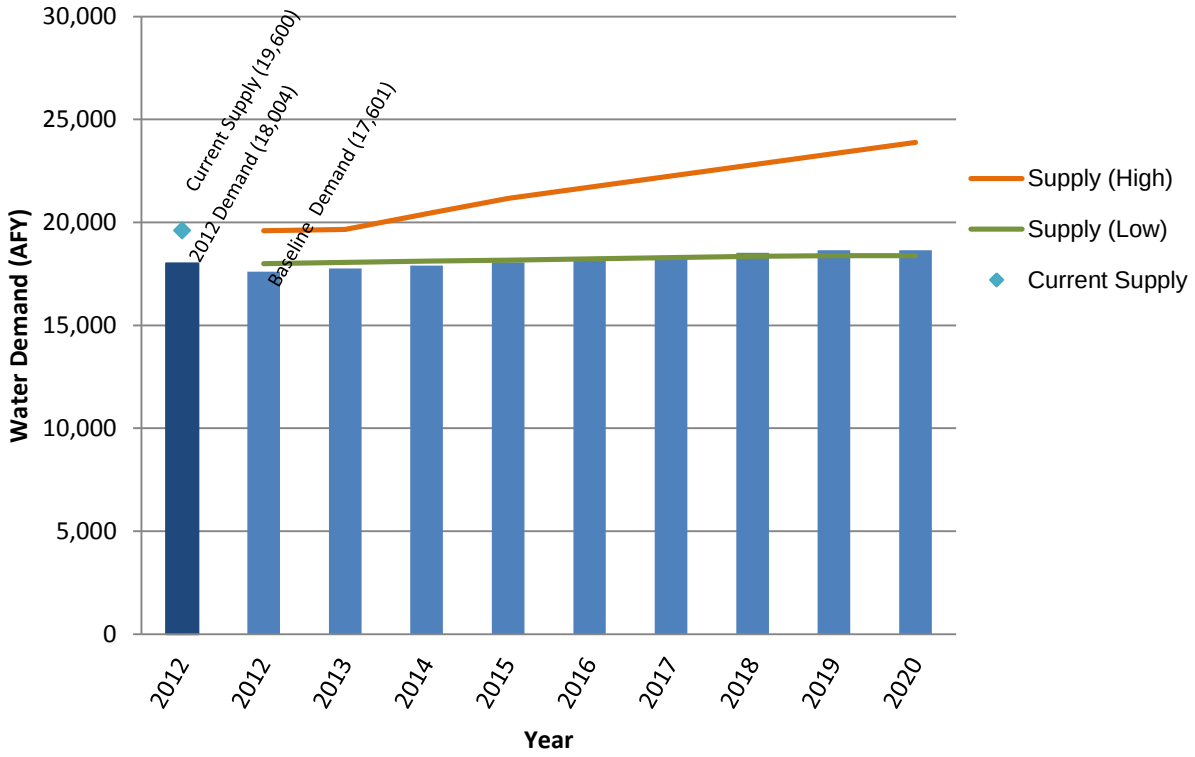
Estimated Water Demand

The City's total water consumption for the most recent complete calendar year (2012) was 18,004 AFY. Historical water consumption data was evaluated for the previous 10-year period to develop a baseline water demand condition. Based on a review of historical consumption data, it was determined that the most recent 5-year average of the annual water consumption would be used to establish the baseline water demand. This Report will utilize a baseline water demand of 17,601 AFY.

There are currently 47 projects that have received City approval for development. Of those 47 projects, a few are in construction, while the majority are approved for development. Utilizing water demand factors developed specifically for the City, based on historical data, it is estimated that the approved projects will require an additional 1,042 AFY of water supply, resulting in a total projected water demand of 18,643 AFY. Using an assumed absorption rate of 350 dwelling units per year (and an equivalent absorption rate for the non-residential development), it is estimated that the City will reach the projected demand condition in year 2019.

Figure ES-1 provides a graphical representation of the current water consumption, projected water demand through year 2020, and the anticipated water supply range over the same time period.

Figure ES-1
Demand vs. Supply Projection



Conclusions & Recommendations

Based on the City's current available water supply of 19,600 AFY, the City can meet the demands of the existing and approved development projects (18,643 AFY). However, at any time the available water supply could drop to an annual average of 18,000 AFY. In the circumstances where the water supply drops to the low end of the range, the supply is slightly (1%-2%) larger than the demand through year 2016, after which the water supply is less than the anticipated demand beginning in year 2017.

The results of this Report indicate that the spread between the current water demand and the current water supply is very tight, and in some conditions the supply could be less than the demand. This presents challenges for the City moving forward in the ability to allocate water supply to development projects that will generate additional water demands. The recommendations for the City moving forward include:

1. Track the total water consumption on an annual basis.
2. Re-calculate the 3-year, 5-year and 10-year water consumption averages on an annual basis.
3. Update the water supply portfolio on an annual basis.
4. Update the existing land use data on an annual basis. This can be done through a system that tracks the development projects as the transition from "Under Construction" to "Existing," and "Approved" to "Under Construction."
5. All future development projects should be evaluated based on current supply and demand conditions.
6. Use the City-specific water usage factors to calculate the water demand of all development projects as the projects proceed through the City process prior to approval.
7. Continue to develop water supply through demand side management, securing water rights, establishing an in-lieu fee ordinance, and continue to integrate new water supply sources into the City's portfolio.

Due to the wide range of demand and supply estimates in this initial analysis, it is clear that a thoughtful and multi-faceted approach to managing and planning for Ventura's water supply will be absolutely critical in the coming years to support economic growth and quality of life.

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APPENDIX

Demand Factors from Other Agencies:

LAFCo 13-01S Sphere of Influence Report

2005 General Plan Tables & Figures

2005 General Plan FEIR Tables

2010 UWMP Tables

2011 Water Master Plan Tables

LAFCo MSR Report

2005 General Plan FEIR Water Demand Factors (email correspondence)

2005-2012 Built Projects – Background Data

1. INTRODUCTION

A. INTRODUCTION

On July 26, 2010 Public Works conducted a workshop with City Council that included information on the City's current water supply issues. It was presented that with continued years of drought, tightening water restrictions and environmental responsibilities, Ventura's water supply was being impacted by several factors. These factors included and continue to include the following:

- The City's historical water rights to the Ventura River may be significantly limited as concern for the health of the endangered Southern California Steelhead and its habitat ecosystem restrict how much and at what time of the year this water source is available. Storm events over the past 15 years have restricted our ability to withdraw historical amounts from this source.
- City allocation from two groundwater basins, Oxnard Plain Basin and Santa Paula Basin, are increasingly regulated and monitored. Studies being conducted by the oversight agencies have indicated that potential overdraft and water quality issues may occur in the near future.
- The Mound Groundwater Basin has experienced water quality degradation and projections for reliable supply may be lower than originally anticipated.

A recommendation from the workshop was to provide a comprehensive evaluation of current and projected water supply needs.

In addition, as a part of this year's City Council Priority Projects, the Community Development (Planning) Department and Ventura Water have focused their time and energy on streamlining and documenting the development review process as it pertains to water and wastewater services. More specifically, we are working to:

- Ensure transparency and consistency to our customers,
- Create equity in assigning costs; and
- Protect the reliability of our water and wastewater infrastructure.

In order to provide a comprehensive evaluation of the City's current and projected water supply needs, there has been interdepartmental coordination at the City to provide input and expertise

on what development has taken place since the 2005 General Plan, the projects currently approved for development within the City and the potential for additional development through 2025. The City provided data to better determine the water demands those developments may require. This Report will review previously developed water demand projections, anticipated water supplies and approved development projects and compare them to where the City is today. City staff is collaboratively looking forward to help plan the City's water resources to accommodate future development in the most responsible manner for its residents.

B. PURPOSE OF REPORT

The main purpose of this report is twofold. The report will identify water demand and water supply conflicts in various reports and will evaluate how current and future anticipated water demands match current and future anticipated water supply. The City recognizes the need to develop a process that tracks proposed development projects, consistently calculate the anticipated increase in water demand associated with each proposed development project, and then evaluate the impact on the current water supply. This Comprehensive Water Resources Report ("Report") is intended to be a tool in the development review process as it pertains to water supply and demand.

Over the past several years, the City has prepared various documents that address water demand and water supply. More specifically, there are three documents that have been used as a reference document for both historical figures and future projections. The three documents are:

- 2005 General Plan, 2005 General Plan FEIR and 2007 Supplement
- 2010 Urban Water Management Plan (amended in 2011)
- 2011 Water Master Plan

Each of these reports was completed at a different time, with different data available and for a specific purpose and/or audience. An agency's water demands will vary from year to year depending upon a number of variables. In addition, the water supply availability will vary from year to year, especially in southern California, where in recent years the delivery and availability of both imported water supplies and groundwater have been legally challenged. Therefore, the information provided in each of these reports pertaining to water demand and water supply will show differences. Subsection D includes pertinent information on each of the three previous report, such as: the purpose of the report; the resources utilized for the report; the water demand

factors utilized and the estimated water demands based on those factors in each report and the anticipated current and future water supply in each report.

C. STUDY AREA

The City of San Buenaventura is located 62 miles north of Los Angeles and 30 miles south of Santa Barbara along the California coastline. The City is located within the County of Ventura, and bound by the City of Oxnard to the south, by unincorporated Ventura County to the east and north, and by the Pacific Ocean to the west. The northwest portion of the City is bound by the Ventura River, while the southern portion is bound by the Santa Clara River. The Ventura Freeway (101) bisects the City in the north-south direction, while the Santa Paula Freeway (126) runs east to west through the center of the City. The Ojai Freeway (33) runs along the northwestern edge of the City. The City currently occupies an estimated 21 square miles and has an estimated population of 109,000 persons. Exhibit 1-1 identifies the City of San Buenaventura boundary, the Sphere of Influence and General Plan boundary.

Ventura Water provides potable water service to a population of approximately 113,500 persons and has approximately 32,000 service connections. The City's existing water service area includes all portions within the City limits, as well as portions of unincorporated Ventura County that meet the City's policy for water connections outside City limits (Municipal Code Section 22.110.055).

Ventura Water also operates the Saticoy Country Club (SCC) water system, which consists of residences and country club facilities that are located east of the City. They have their own stand-alone system, which includes two groundwater wells, a booster pump station and two storage tanks. The ownership responsibility for the system is shared between the City and SCC (1/3 and 2/3, respectively). The SCC system has a separate Domestic Water Supply Permit from the California Department of Public Health.

On January 16, 2013, the Ventura County Local Agency Formation Commission (LAFCo) adopted resolution LAFCo 13-01S, which updated the City of Ventura Sphere of Influence (see Appendix). The Sphere of Influence (SOI) included in this Report depicts the updated SOI.

MATCHLINE

Avenue Water Treatment Plant

Ventura River

33

101

Two Trees

City Hall

Public Works Maintenance Facility

City of Ventura

126

County Government Center

101

Santa Clara River

Pacific Ocean

Ventura Water Reclamation Facility

101

City of Oxnard



VENTURA WATER

City Overview

Legend

- Location Sites
- Ventura City Limit
- General Plan Boundary
- City Sphere of Influence

0 0.5 1
Miles

Source: Eagle Aerial, 2010

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Exhibit 1-1

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D. DOCUMENT COMPARISON

1. 2005 General Plan, General Plan FEIR and 2007 Supplement

State law requires each California city to adopt a comprehensive, long-term General Plan for the physical development of the community that guides local decision-making by expressing community goals about the future distribution and character of land uses and activities. The General Plan serves as a long-term guide, establishing policies for day-to-day land use decisions over a 20-year planning horizon. The General Plan is a policy document that sets over-arching goals for the future development of the City and specifies policies and actions to achieve these over-arching goals.

The 2005 General Plan Final Environmental Impact Report (FEIR) provides an analysis of the potential environmental impacts associated with the potential development identified in the General Plan.

The City prepared a supplement to the FEIR in 2007 to address the impact of an additional 329,000 square feet of non-residential development in the Ventura Harbor area.

Land Use

Chapter 3 of the City's 2005 General Plan defines the City's plan for growth over the 20-year planning horizon (through 2025). Specifically, Table 3-2 of the General Plan provides the estimated amount of development that could reasonably be expected to occur within the City and the Sphere of Influence by 2025, and together with Figure 3-1 provides a picture of where such change might occur. The 2007 FEIR Supplement included an additional potential of 329,000 square feet of non-residential development in the 20-year planning horizon.

Water Supply

Chapter 4.13 of the 2005 General Plan FEIR addresses the impacts of the General Plan on the public utilities, which includes the water system. Table 4.13-7 summarizes the City's historic and projected water supply. The source used in preparation of Table 4.13-7 is the City's 2004 Biennial Water Supply Report, which provides projections for the

City's future water supply and demand based on current information at the time (thru 2003).

Water Consumption (Demands)

Table 4.13-8 summarizes the City's historical and projected water consumption. The source used in preparation of Table 4.13-8 is the City's 2004 Biennial Water Supply Report. Projected demands are based on the post-mandatory water conservation demand factor of 0.179 AFY/capita, the 2000 U.S. Census and the City growth rate of 0.9%. However, the table only projects out to Year 2020. In order to identify the water demand projections for Year 2025, you must utilize the projected water demands developed in Table 4.13-15 (5,806 AFY) in conjunction with the calculated demand increase (115 AFY) identified in the 2007 FEIR Supplement. The demand projections in Table 4.13-15 are based on a set of water demand factors to be discussed later in this Section.

2. 2010 Urban Water Management Plan

An Urban Water Management Plan (UWMP) is a long-term planning tool that provides water purveyors and their customers a broad perspective on water supply issues. The UWMP is a management tool, providing the framework for action, but not functioning as a detailed project development plan. Preparation of the UWMP is a requirement of the California Urban Water Management Planning Act. UWMP's must be prepared every five years. The primary goals of the UWMP are to: 1) plan the water supply over a 20-year period, 2) identify and quantify water supply for future demands in normal, single-dry and multiple-dry year conditions, and 3) implement conservation and efficient water use practices in urban settings.

Land Use

The UWMP does not evaluate land use. The UWMP projects water demands based on population projections. The population projections are based on historical data provided by the California Department of Finance (2000 Benchmark). Future projections are based on the 0.88 percent annual growth rate as identified in the City's 2005 General Plan, and are shown in Table 2-1 of the 2010 UWMP.

Water Supply

Table 3-1 in the 2010 UWMP provides a summary of the existing and projected water supply. The water supply data are based on historical production data and estimates of current water supply sources available and operational constraints.

Water Consumption (Demands)

Table 2-5 in the 2010 UWMP provides a summary of the past, current and projected water demands. The 2005 and 2010 water demand data are the actual metered demands based on billing records. The water demand projections are based on the per capita water demand factor of 168 gallons per capita day, multiplied by the population growth projections identified in Table 2-1 of the UWMP.

3. 2011 Water Master Plan

A Water Master Plan (WMP) is a document that is typically prepared every 5-10 years. They are not mandated by state law, but most water purveyors prepare a WMP to document the plan for improvement or expansion of the existing water distribution system. The master plan provides a comprehensive evaluation of the water system infrastructure to determine the systems' capacity to meet the current and future water demand, and evaluates the operational efficiency of the system. The primary focus of a master plan is to evaluate the capacity of the system facilities (pipelines, pump stations, reservoirs, wells, etc.) to provide a safe and reliable water supply to the customers at minimum specified criteria. The criteria will include system pressure, pipe velocity, fire flow availability, reservoir storage, pump capacity, etc., which are based on guidelines provided by the American Water Works Association (AWWA), Environmental Protection Agency (EPA), and California Department of Public Health (DPH). The primary goal of a WMP is to develop a capital improvement program that identifies specific projects, costs and priorities for system improvements.

Land Use

The 2011 Water Master Plan utilized the land use data provided in Table 3-1 of the 2005 General Plan to establish the existing land use condition. The future "near-term" land use conditions were based on the City's 2006 Pending Project list. The ultimate land use condition was based on the remaining vacant land as identified in the 2005 General Plan,

less the proposed projects listed on the 2006 Pending Project list. The figures are summarized in Tables II-1 thru II-4 in the 2011 Water Master Plan.

Water Supply

The summary of the current (2010) water supplies are identified in Table V-14. The current water supply is shown as a historical supply projection range from 18,760 – 25,800 AFY.

Water Consumption (Demands)

The existing water demands identified in the 2011 Water Master Plan are based on actual billing records taken from a two-year period from January 2004 through December 2005. The actual billing records, coupled with the existing land use identified in the 2005 General Plan were used to develop "actual" water demand factors. The actual demand factors were increased by approximately 10% to account for water loss. The demand factors were applied to the 2006 Pending Project list and then to the remaining vacant land to calculate the future water demands.

The water supply and water demand figures provided within each document are summarized on Table 1-1. The table includes the source of the data used to develop the figures presented within each document, and the various factors and methods used to come up with the projections. As you will note, the water supply projections in the 2005 General Plan documents are the most optimistic and the water demand projections in the 2005 General Plan documents are the most conservative. This is likely due to the fact that these projections were made based on actual data available through Year 2003, and obviously could not factor in the economic conditions of later in the decade, nor the drought and water supply limitations of the same time frame.

It is prudent to point out that comparing the demand and supply projections within each of these three documents is not an "apples to apples" comparison, as each document was prepared at a different time using actual data from different time periods, incorporating current information regarding water supply sources at that specific time, using different methodologies (land use based vs. population based) to calculate future projections, using different demand factors and making different assumptions.

E. DEMAND FACTOR COMPARISON (from previous documents)

Demand factors are used to calculate the future water demand projections. Demand factors are either land use based (per area (acre/ksf) or per dwelling unit) or population based (per capita). Demand factors are typically derived from actual water consumption data, and a safety factor is applied for planning purposes. Demand factors were used in each of the three documents described above to arrive at the future demand projections presented within each report. As briefly described above and shown in Table 1-1, the demand factors and methodologies used within each document vary. Since each document uses different methodologies and demand factors, an "apples to apples" comparison is difficult. Table 1-2 lists the demand factors used within each report. In an attempt to show an "apples to apples" comparison, the residential demand factors have been converted to similar units and are shown on Table 1-3.

The Appendix includes water usage factors from other local agencies with similar characteristics – population, climate and water supply sources. These include Simi Valley, Thousand Oaks, Irvine Ranch Water District and Santa Margarita Water District.

Table 1-1
Summary of Previous Documents

Total Water Supply (AFY)							
Document	**2000**	**2005**	**2010**	**2015**	**2020**	**2025**	**Data Source & Factors**
2005 General Plan, GP FEIR and 2007 Supplement	*21,566* [1]	26,300	28,262	28,262	28,262	28,262	Table 1 of the 2004 Biennial Water Supply Report - Based on actual water production data thru 2003 - Future projections based on assumptions and limitations for each supply source known at the time (2004) - [1] Figure includes 1,129 AFY for raw water and oil operation use - Figures do not include recycled water
2010 Urban Water Management Plan	n/a	n/a	20,600	22,000	24,600	24,700	Table 3-2 of the 2010 UWMP - Water production data for 2010 is based on annual average data from 2000 - 2009 as presented in Table V-14 of the 2011 WMP - Future projections based on assumptions and limitations for each supply source known at the time (2011) - Figures do not include raw water and oil operation use - Figures include 700 AFY of recycled water annually
2011 Water Master Plan	n/a	n/a	n/a	n/a	n/a	18,760 - 25,800	Tables ES-2, V-1, V-2, V-7, V-10, V-13 and V-14 of 2011 WMP - Based on actual water production data thru 2009 - Future projections based on assumptions and limitations for each supply source known at the time (2011) - Figures do not include raw water and oil operation use - Figures do not include recycled water

Total Water Demand / Consumption (AFY)							
Document	**2000**	**2005**	**2010**	**2015**	**2020**	**2025**	**Data Source & Factors**
2005 General Plan, GP FEIR and 2007 Supplement	*20,437*	20,594	21,724	22,918	24,181	27,421 [2]	Tables 2, 3 and 4 of the 2004 Biennial Water Supply Report - Based on actual water consumption data thru 2003 - Historical population based on 2000 U.S. Census - Growth rate in City = 0.9%, outside City = 0.6% - Water Use Factor = 0.179 AFY/capita - [2] Year 2025 projections based on demand factors provided for FEIR
2010 Urban Water Management Plan	n/a	*20,808*	*17,351*	22,286	23,256	24,270	Table 2-5 of the 2010 UWMP - Based on actual water consumtion data through 2010 - Historical population based on California Department of Finance Table E-4 Population Estimates for Cities, Counties and the State (2000 Benchmark) - Growth rate in City = 0.88%, outside City = 0.1258% in connections - Water Use Factor = 168 gpcd = 0.188 AFY/capita
2011 Water Master Plan	n/a	*16,190*	17,896	n/a	n/a	22,708	Table IV-5 and Figure IV-2 of the 2011 WMP - Based on actual billing records from 2004-2005. - Near-term projections (allocated to 2010) based on actual billing data from 2004-2005, calculated demand factors from the same period applied to the 2006 Pending Projects list. - Long-term projections (allocated to Year 2025) based on applying the calculated demand factors to the remaining developable land as identified in the 2005 GP, excluding the land accounted for in the 2006 Pending Projects list.

Table 1-2
Summary of Water Demand Factors in Previous Documents

General Plan FEIR, August 2005

Land Use Description	Density (DU/Acre)	Demand Factor [1]	Unit
Residential	n/a	450	gpd/du
Retail	-	250	gpd/ksf
Office	-	250	gpd/ksf
Industrial	-	315	gpd/ksf
Hotel	-	500	gpd/ksf

[1] Provided in email corrspondence from Chandra Chandrashaker, City CD, (January 8, 2013). Only used to calculate the year 2025 projections.

Note: Future projections through year 2020 based on population data and 0.179 AFY/capita factor

2010 Urban Water Management Plan

Land Use Description	Density (DU/Acre)	Demand Factor [1]	Unit
Single-Family	n/a	0.33	AFY/Acct
Multi-Family	n/a	1.71	AFY/Acct
Commercial	-	1.69	AFY/Acct
Industrial	-	10.87	AFY/Acct
Institutional/Governmental	-	2.80	AFY/Acct
Landscape	-	4.86	AFY/Acct
Petroleum Recovery	-	465	AFY/Acct
Other	-	0.83	AFY/Acct

[1] Adapted from 2005 data in Tables 2-5 and 2-6 of the 2010 UWMP.

Note: Future projections based on population data and 168 gpcd factor = 0.188 AFY/capita

Water Master Plan, March 2011

Land Use Description [1]	Density (DU/Acre) [1]	Demand Factor [2]	Unit
Neighborhood Low (NL)	0-8	1.20	gpm/acre
Neighborhood Medium (NM)	9-20	2.00	gpm/acre
Neighborhood High (NH)	21-54	5.00	gpm/acre
Commerce (C)	-	1.60	gpm/acre
Industry (I)	-	1.60	gpm/acre
Public and Institutional (PI)	-	0.75	gpm/acre
Parks and Open Space (POS)	-	0.10	gpm/acre
Downtown Specific Plan	21-54	2.55	gpm/acre

[1] Source: 2005 General Plan

[2] Per Table III-1 of WMP. Factors are calculted based on 2004-2005 billing data, and 2005 General Plan land use data.

Table 1-3
Comparison of Residential Water Demand Factors in Previous Documents

Comparison of Residential Demand Factors					
2005 General Plan FEIR		**2010 UWMP [2]**		**2011 Water Master Plan [1]**	
Residential	450 gpd/du	Single-Family	293 gpd/du	Low (NL)	432 gpd/du
				Medium (NM)	199 gpd/du
		Multi-Family	1530 gpd/du	High (NH)	192 gpd/du

[1] Assumes the average density (du/acre)

[2] Assumes 1 account = 1 du

F. CURRENT PLANNING DATA

The Community Development Department (City Planning Department) maintains a database of all projects that are in the planning, design or construction phase. These projects are known as the "Pending Projects." The pending projects database is updated constantly as new projects are proposed or existing projects are modified.

The Community Development Department provided actual development data ("Built" projects) for the period from 2005 – 2012, and data on all projects that are under construction or have received all planning approvals ("Approved" projects) for development, as of December 31, 2012. This Report will take into account the actual development data provided by the City for years 2005-2012 to determine the current land use condition (as of December 31, 2012), as well as consider the impacts of those projects that are under construction or have received all planning approvals. Projects listed in the Pending Project database that had not received all approvals from the City as of December 31, 2012 were not considered in the future water demand projections for this Report.

G. 2012 LAFCo MUNICIPAL SERVICE REVIEW

It should be noted that in 2012, the Ventura Local Agency Formation Commission (LAFCo) completed the Municipal Service Review for nine Ventura County cities, including the City of San Buenaventura. LAFCos exist for each county in California. LAFCos are responsible for achieving three primary objectives: encouraging the orderly formation and expansion of local government agencies; preserving agricultural land and open space resources; and discouraging urban sprawl. To accomplish these objectives, LAFCos are responsible for coordinating logical and timely changes in local government boundaries, conducting special studies that review ways to reorganize and streamline government structure and preparing a sphere of influence for each city and special district over which they have authority.

LAFCos are required to review, and as necessary, update the sphere of influence for each city or special district every five years. Prior to updating a sphere of influence, LAFCo is required to conduct a Municipal Service Review (MSR). MSRs consist of written determinations relating to seven different factors, one of which is the "present and planned capacity of public facilities, adequacy of public services, and infrastructure needs or deficiencies related to … municipal and industrial water… within or contiguous to the sphere of influence."

The MSR for the City of San Buenaventura (City) was accepted by the LAFCo Board on November 14, 2012. LAFCos findings regarding the potable water system concluded the City's current potable water demand is 88 percent of the supply, with approved development projects it increases to 94 percent of the supply, with proposed development projects it increases to 96 percent of the supply, and in drought conditions the normal water demand exceeds supply.

A copy of the MSR for the City is included as an Appendix.

H. REFERENCE DOCUMENTS

The following documents were used as reference for the preparation of this Comprehensive Water Resources Report. Specific excerpts and data sources from these documents used in the preparation of this Report are included in the Appendix.

2004 Biennial Water Supply Report

2005 Ventura General Plan (August 2005), City of San Buenaventura.

2005 Ventura General Plan Final EIR, Volumes I and II (August 2005), City of San Buenaventura.

2007 General Plan FEIR Supplement

2010 Urban Water Management Plan (June 2011), Kennedy/Jenks Consultants.

Water Master Plan (March 2011), RBF Consulting.

Municipal Service Reviews for Nine Ventura County Cities (November 14, 2012), Ventura Local Agency Formation Commission (LAFCo).

2. LAND USE

A. EXISTING LAND USE

For the purposes of this Report, the "existing" land use picture is considered the year-end of 2012. In order to determine the existing land use make-up within the City's water service area as of year-end 2012, the land use data published in the 2005 General Plan was used as a starting point. Table 3-1 of the 2005 General Plan (see Appendix) identifies the existing land uses (as of year-end 2004) in dwelling-unit count and square-footage. Table 2-1 herein provides a summary of the existing development as of year-end 2004 within the General Plan land use categories. Exhibit 2-1 (a copy of Figure 3-5 from the General Plan) depicts the land use designations throughout the City as identified in the 2005 General Plan.

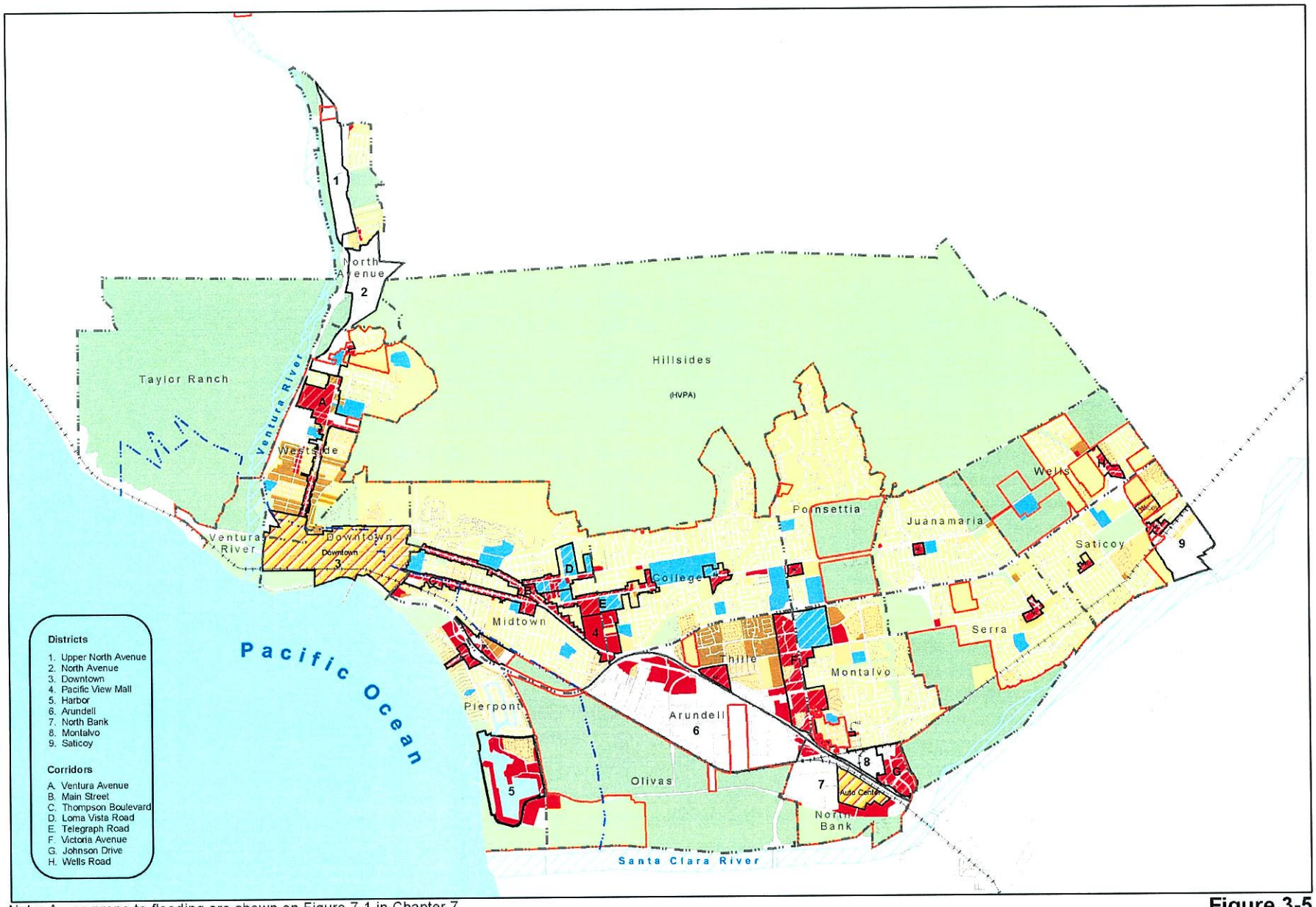
In order to depict the land use condition of the present day "existing" condition, data for all projects built from 2005-2012 was tabulated and summarized. The City Planning Department provided a listing of all projects "built" from 2005-2012, including back-up data (see Appendix). Minor modifications and adjustments were made based on supplemental data provided by Ventura Water staff. In addition, square footages for parking garages were eliminated from the list since the land use does not consume water. The summary of the "Built" projects is included in Table 2-2. It should be noted that the land uses were broken down into two (2) non-residential categories and two (2) residential categories, which is a more consolidated breakdown of the land use designations than shown in the 2005 General Plan.

Table 2-3 provided a summarized total of the existing (year-end 2012) land use within the City service area. It should be noted that Table 2-3 has been further consolidated into one (1) non-residential category. This was done because the break-down of the non-residential land uses in Table 2-2 was not broken down into detailed categories that matched the 2005 General Plan.

Table 2-1
Existing Land Uses per 2005 General Plan [1]

Planning Designation	Allowed Density (du/acre)	Existing Development as of 2004		
		Single Family (Units)	Multi Family (Units)	Non-Residential (SF)
Neighborhood Low	0-8	19,425	3,335	49,386
Neighborhood Medium	9-20	1,163	8,965	149,513
Neighborhood High	21-54	814	2,468	194,143
Commerce		257	490	4,995,248
Industry		29	31	8,299,840
Public and Institutional		4	0	54,422
Park and Open Space		6	0	15,491
Agriculture		4	0	19,550
Downtown Specific Plan	21-54	332	1,543	1,795,401
Harbor District		0	310	350,160
Total		**22,034**	**17,142**	**15,923,154**

[1] Source: Table 3-1 of 2005 Ventura General Plan



Note: Areas prone to flooding are shown on Figure 7-1 in Chapter 7.

Figure 3-5

GENERAL PLAN DIAGRAM

Neighborhood
- Low (up to 8 du/ac)
- Medium (9-20 du/ac)
- High (21-54 du/ac)

- Commerce
- Industry
- Public and Institutional
- Agriculture
- Parks and Open Space
- Specific Plan Area
- Corridors, Neighborhood Centers (NC)
- Districts

- City Limits
- Planning Communities
- California Coastal Zone Boundary

This map is a product of the City of San Buenaventura, California. Although reasonable efforts have been made to ensure the accuracy of this map, the City of San Buenaventura cannot guarantee its accuracy.

Table 2-2
Summary of "Built" Projects 2005-2012

	Non-Residential			Residential		
	RETAIL/OFFICE (SF)	INDUSTRIAL (SF)	TOTAL NON-RESIDENTIAL (SF)	SINGLE-FAMILY (UNITS)	MULTI-FAMILY (UNITS)	TOTAL RESIDENTIAL (UNITS)
DISTRICTS						
Upper North Avenue	0	18,619	18,619			
North Avenue	0	0	0			
Downtown Specific Plan	55,891	0	55,891	14	184	198
Pacific View Mall	14,624	0	14,624			
Harbor	201	0	201			
Arundell	105,412	71,890	177,302			
North Bank	97,774	500,132	597,906			
Montalvo	0	270	270			
Saticoy	438	0	438			
Subtotal (Districts)	***274,340***	***590,911***	***865,251***	***14***	***184***	***198***
CORRIDORS						
Ventura Avenue	7,086	0	7,086		24	24
Main Street	2,072	0	2,072		10	10
Thompson Boulevard	18,784	0	18,784			
Loma Vista	19,541	0	19,541		4	4
Telegraph Road	5,503	0	5,503		4	4
Victoria Avenue	64,775	163,328	228,103			
Johnson Drive	840	0	840			
Wells Road	2,816	0	2,816			
Subtotal (Corridors)	***121,417***	***163,328***	***284,745***	***0***	***42***	***42***
SPHERE OF INFLUENCE(SOI/Other Infill/Neighborhood Centers)						
101/126 Agriculture	0	0	0			
Wells/Saticoy	0	0	0			
Pierpont	0	0	0			
Other Neighborhood Centers (includes Seaward/Allessandro+College/ Day+Gateway Plaza+Victoria Plaza+Bristol+Kimball/Telegraph+Petit/Telephone+Telephone/ Cachuma+Saticoy)	27,032	0	27,032			
Second Units	0	0	0		26	26
Underutilized	0	0	0			
Vacant	0	0	0			
Subtotal (SOI/Other Infill/NC)	***27,032***	***0***	***27,032***	***0***	***26***	***26***
PLANNING COMMUNITIES (Not Included within District/Corridor/Center-above)						
Downtown	0	0	0	3	2	5
Ventura Ave/Westside	0	0	0			
Midtown	0	0	0	49	11	60
College (Telegraph/Loma Vista)	10,931	0	10,931	10	2	12
Telephone Road Corridor	0	0	0			
Montalvo/Victoria	56,933	0	56,933	123	104	227
Saticoy/East End	6,320	0	6,320	95	453	548
Arundell	0	0	0			
Olivas	658	0	658			
Pierpont	26,436	0	26,436	27	4	31
Serra	3,744	0	3,744	191	95	286
Juanamaria	689	0	689	1	3	4
Poinsettia	1,499	0	1,499	8		8
Thille	13,370	0	13,370		364	364
Wells	87,618	0	87,618		60	60
Westside	9,216	0	9,216	22	19	41
Subtotal (Planning Communities)	***217,414***	***0***	***217,414***	***529***	***1,117***	***1,646***
TOTAL	640,203	754,239	**1,394,442**	543	1,369	**1,912**

Source: Development data provided by City 02/14/2013.
Note: Figures include the built projects only.

Table 2-3
Summary of Existing Land Use - December 2012

	Residential Single-Family (units)	Residential Multi-Family (units)	Non-Residential (sf)
Existing (as of 2005 General Plan) [1]	22,034	17,142	15,923,154
Constructed (Built Projects 2005 - 2012) [2]	543	1,369	1,394,442
Total Existing Land Use (through 2012)	**22,577**	**18,511**	**17,317,596**

[1] Per Table 2-1
[2] Per Table 2-2

B. FUTURE LAND USE

The City maintains a database of projects that are in a phase of the planning process. The database includes all projects from those that are in the conceptual phase to those that are in construction. For the purposes of this Report, the priority was to determine those projects that the City has made commitments to, and to determine the water resources required to meet the anticipated water demand of the projects.

1. Under Construction and Approved Projects

The City Planning Department provided a listing of all the development projects within the City that are "In Planning Process," "In Plan Check," "Under Construction," or have "All Planning Approvals." The list was narrowed down to those projects that are either "Under Construction," or have "All Planning Approvals." Some modifications and adjustments were made based on review and data provided by Ventura Water staff. The Under Construction and Approved Projects are shown on Table 2-4. Table 2-4 provides specific data about each project, including the project number, type, name, status, description and land use details. The table also identifies if the project is located within the boundary of the Casitas Municipal Water District. Exhibit 2-2 identifies the location of each Project that is "Under Construction" or has "All Planning Approvals."

2. Future Potential (per 2005 General Plan)

Table 3-2 of the 2005 General Plan (see Appendix) identifies the predicted development intensity and pattern that was anticipated to occur within the General Plan boundary through the planning horizon of year 2025. As mentioned previously, the City provided information as to the development areas that have been constructed, are currently under construction, or are approved for development since the 2005 General Plan through the end of year 2012. Table 2-5 provides a summary of the 2005 General Plan predicted development, a summary of the projects constructed from 2005-2012, a summary of the projects that are under construction or approved, and calculates the remaining developable land through the 2025 planning horizon. It should be noted that the residential unit count is not divided up by the density.

Table 2-4
Summary of Approved and Under Construction Projects - December 2012

						Non-Residential								Residential			
Project ID	Project Type	Project Name	Project Status	Located in Casitas Municipal Water District (Y or N)	Description of Project	Commercial (SF)	Hotel (SF)	Industrial (SF)	Institutional (SF)	Office (SF)	Total (SF)	Hospital (beds)	Hotel (Rooms)	Single-Family (Units)	Multi-Family (Units)	Total (Units)	Area (ac)
PROJ-00687	Mixed Use	CAFE SCOOP - STAJEN	All Planning Approvals	YES	Mixed Use - Condominiums/Commercial	4,873	0	0	0	0	4,873	0	0		10	10	0.5
PROJ-00756	Mixed Use	ANASTASI DEV.	All Planning Approvals	NO	Mixed Use - Commercial/Residential	20,230	0	0	0	0	20,230	0	0		138	138	5.6
PROJ-01009	Industrial	SALLY CRAIN	All Planning Approvals	NO	Warehouse building	0	0	40,000	0	0	40,000	0	0			0	2.5
PROJ-01181	Institutional	HARRY LYONS SCHOOL	All Planning Approvals	YES	Public pool & aquatic center	0	0	0	5,960	0	5,960	0	0			0	1.3
PROJ-01520	Mixed Use	V2V VENTURES	All Planning Approvals	YES	Mixed Use - Condominiums/Commercial	2,500	0	0	0	0	2,500	0	0		29	29	1.1
PROJ-02225	Mixed Use	CENTRAL COAST INVESTORS	All Planning Approvals	YES	Mixed Use - Condominiums/Commercial	4,500	0	0	0	0	4,500	0	0		43	43	1.1
PROJ-02284	Residential	HILTY APARTMENTS	All Planning Approvals	YES	Apartments	0	0	0	0	0	0	0	0		16	16	0.4
PROJ-03031	Residential	ALDEA HERMOSA - CITY VENTURES	Under Construction	NO	47 single family residences with 9 residential 2nd units	0	0	0	0	0	0	0	0	28		28	7.4
PROJ-03198	Residential	REXFORD	All Planning Approvals	YES	Condominiums	0	0	0	0	0	0	0	0		25	25	0.5
PROJ-03232	Residential	CITRUS PLACE - PHASE 2 & 3	All Planning Approvals	NO	59 Single Family Residences; 60 Condominiums	0	0	0	0	0	0	0	0	59	60	119	9.4
PROJ-03614	Mixed Use	V2V VENTURES	All Planning Approvals	YES	Mixed Use - Condominiums/Commercial	6,175	0	0	0	0	6,175	0	0		34	34	0.3
PROJ-03617	Industrial	FPA LAND DEV/VICTORIA CORP C	All Planning Approvals	NO	8 industrial office buildings	0	0	234,200	0	0	234,200	0	0			0	11.9
PROJ-03676	Mixed Use	PALM & POLI ASSOC	All Planning Approvals	YES	Mixed Use - Condominiums/Commercial	1,200	0	0	0	0	1,200	0	0		16	16	0.4
PROJ-03743	Mixed Use	CANNERY ROW LLC	Under Construction	YES	Mixed Use - Condominiums/Commercial	2,156	0	0	0	0	2,156	0	0		78	78	1.4
PROJ-03826	Residential	UC HANSEN TRUST SP	All Planning Approvals	NO	131 Single family; 34 Condominiums; 24 farmworker apartments	0	0	0	0	0	0	0	0	131	58	189	35.7
PROJ-03829	Residential	WESTWOOD/PARKLANDS	All Planning Approvals	NO	216 detached homes; 110 attached homes	0	0	0	0	0	0	0	0	216	110	326	58.5
PROJ-03864	Commercial	VOOV	All Planning Approvals	NO	New 2-story office building.	0	0	0	0	6,400	6,400	0	0			0	0.6
PROJ-03865	Residential	MATILIJA	All Planning Approvals	YES	Condominiums	0	0	0	0	0	0	0	0		28	28	0.9
PROJ-04110	Residential	RISI	All Planning Approvals	YES	Condominiums	0	0	0	0	0	0	0	0		6	6	0.2
PROJ-04154	Residential	CENTEX	All Planning Approvals	YES	120 Single Family Residence, 36 Condominiums	0	0	0	0	0	0	0	0	120	36	156	25.3
PROJ-04182	Mixed Use	NEW URBAN VENTURES	All Planning Approvals	YES	Mixed Use - Condominiums/Commercial	1,779	0	0	0	0	1,779	0	0		80	80	2.7
PROJ-04263	Residential	SANTA CLARA ST URBAN RENEWAL	All Planning Approvals	YES	Condominiums	0	0	0	0	0	0	0	0		21	21	0.4
PROJ-04282	Commercial	GHITTERMAN	Under Construction	NO	New 2 story office building.	0	0	0	0	4,829	4,829	0	0			0	0.2
PROJ-04284	Mixed Use	MAIN/CENTRAL	All Planning Approvals	YES	Mixed Use - Condominiums/Commercial	2,500	0	0	0	0	2,500	0	0		14	14	0.6
PROJ-04291	Residential	LA BARRANCA	All Planning Approvals	NO	10 Single Family Lots	0	0	0	0	0	0	0	0	10		10	3.8
PROJ-04296	Residential	GOLDBERG	All Planning Approvals	YES	5 Condominiums	0	0	0	0	0	0	0	0		5	5	0.2
PROJ-04300	Commercial	VENTURA EAST VILLAGE	All Planning Approvals	NO	14,000 sq.ft. market; 15,500 sq.ft. drugstore; 2,911 sq.ft. drive-thru restraunt	32,411	0	0	0	0	32,411	0	0			0	5.0
PROJ-04315	Residential	MATLIJA INVESTMENT GROUP	All Planning Approvals	YES	15 Condonimiums	0	0	0	0	0	0	0	0		15	15	0.6
PROJ-04326	Mixed Use	SONDERMANN-RING/VTA HARBOR	All Planning Approvals	NO	313 apartments (incl. 30 live/work lofts); 21,300 sq ft commercial/retail; 104 public boating slips; 8,600 sq ft recreation/management building; 1,850 linear foot public promenade.	21,300	0	0	0	8,600	29,900	0	0		313	313	26.9
PROJ-04333	Industrial	GORBANOV	All Planning Approvals	NO	New two story industrial building	0	0	3,241	0	0	3,241	0	0			0	0.4
PROJ-04543	Mixed Use	RENAISSANCE HOLDINGS	All Planning Approvals	YES	Mixed Use - Condominiums/Commercial	3,582	0	0	0	0	3,582	0	0		25	25	0.8
PROJ-04590	Residential	HUGHES	All Planning Approvals	YES	3 Condominiums	0	0	0	0	0	0	0	0		3	3	0.2
PROJ-04623	Mixed Use	JENVEN VILLAGE LLC	All Planning Approvals	NO	Mixed Use - Condomiums/Commercial	23,691	0	0	0	0	23,691	0	0		83	83	3.1
PROJ-04691	Residential	CHAPMAN, MIKE	Under Construction	YES	7 Apartments	0	0	0	0	0	0	0	0		7	7	0.5
PROJ-1126	Residential	HEMLOCK APARTMENTS	All Planning Approvals	YES	23 Apartments	0	0	0	0	0	0	0	0		23	23	0.6
PROJ-1128	Commercial	CHICK-FIL-A	Under Construction	NO	Fast food restaurant with a drive-thru	4,356	0	0	0	0	4,356	0	0			0	1.0
PROJ-1200	Mixed Use	LOGUE FAMILY	All Planning Approvals	YES	Mixed Use - Condominiums/Commercial	7,300	0	0	0	0	7,300	0	0		105	105	5.9
PROJ-1678	Institutional	CMH - NEW HOSPITAL	Under Construction	YES	Construction of a hospital building (320,000 sq ft and 230 beds), adaptive resuse of existing hospital facilities (121,000 sq ft for non-essential hospital support services) and 104,000 sq ft for new backfill medical office reuse), new street extensions.	0	0	0	320,000	0	320,000	230	0			0	1.9
PROJ-2008	Residential	ISLAND VIEW APARTMENTS - WESTWOOD COMMUNITIES	All Planning Approvals	NO	Apartment complex	0	0	0	0	0	0	0	0		154	154	3.8
PROJ-2695	Commercial	CBCFCU	Under Construction	NO	Two story bank	0	0	0	0	7,434	7,434	0	0			0	0.6
PROJ-3678	Institutional	CITY HALL - CARPORTS	All Planning Approvals	YES	Installation of solar panels on top of new parking canopy structures on behind City Hall	0	0	0	0	0	0	0	0			0	2.8
PROJ-3784	Commercial	MARRIOT RESIDENCE INN	All Planning Approvals	NO	128 room Residence Inn	0	87,000	0	0	0	87,000	0	128			0	3.7
PROJ-3996	Commercial	MJL CAPITAL PARTNERS - GP/Z AMENDMENT	All Planning Approvals	NO	General Plan Amendment to modify the existing General Plan Land Use designation from Neighborhood Low to Commerce and change the existing zone designation from Single Family Residential (R-1) to Limited Commercial (C-1).	0	0	0	0	0	0	0	0			0	0.5
PROJ-4154	Residential	EAST VILLAGE RESIDENTIAL - CEDC	All Planning Approvals	NO	Low Income Apartments	0	0	0	0	0	0	0	0		50	50	2.5
PROJ-4222	Residential	PARKLANDS APARTMENTS	All Planning Approvals	NO	Apartments with Community Building	0	0	0	7,115	0	7,115	0	0		173	173	7.1
PROJ-4627	Commercial	VALERO	All Planning Approvals	YES	New automatic carwash and canopy	912	0	0	0	0	912	0	0			0	0.6
PROJ-4677	Residential	WESTSIDE RENAISSANCE - DYER SHEEHAN	All Planning Approvals	YES	Affordable senior apartments	0	0	0	0	0	0	0	0		50	50	2
TOTAL						**139,465**	**87,000**	**277,441**	**333,075**	**27,263**	**864,244**	**230**	**128**	**564**	**1,808**	**2,372**	**243.3**

Source: City of Ventura, with updates based on 04/12/2013 discussions.

Table 2-5
Summary of Predicted, Actual and Remaining Development

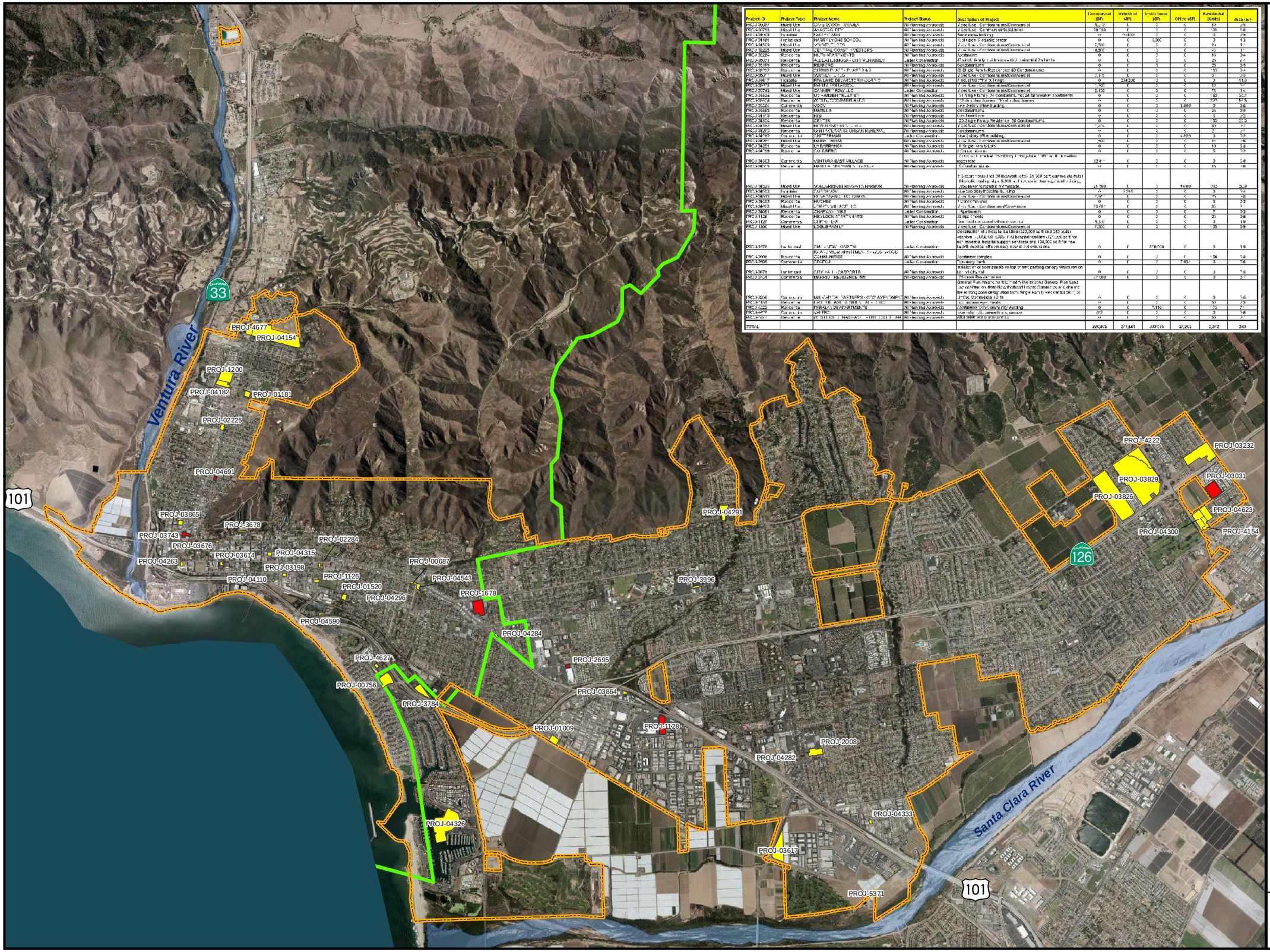
	Residential Development (units)	Non-Residential				
		Retail (sf)	Office (sf)	Industrial (sf)	Hotel (sf)	Total (sf)
2005 General Plan Prediction [1]	8,318	1,241,377	1,213,214	2,235,133	530,000	5,219,724
Actual Development (Built 2005-2012) [2]	1,912	320,102	320,102	754,239	0	1,394,442
Remaining Developable Land (as of end 2012)	***6,406***	***921,276***	***893,113***	***1,480,894***	***530,000***	***3,825,282***
Approved & Under Construction Projects [3]	2,372	139,465	27,263	610,516	87,000	864,244
Remaining Developable Land (through 2025)	**4,034**	**781,811**	**865,850**	**870,378**	**443,000**	**2,961,038**

[1] Source: Table 3-2 of 2005 General Plan.

[2] Per Table 2-2. The "Retail/Office" square footage listed in Table 2-2 was split evenly for the purposes of this table.

[3] Per Table 2-4. Square footage for the "Institutional" Category was added to the "Industrial" category.

Project ID	Project Type	Project Name	Project Status	Description of Project	Commercial (SF)	Industrial (SF)	Hotel/Inn (SF)	Office (SF)	Residential (Units)	Acres
PROJ-3687	Mixed Use	[illegible]	All Planning Approvals	Zone Use - Commercial/Commercial	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
PROJ-03751	Mixed Use	[illegible]	All Planning Approvals	Zone Use - Commercial/Residential	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
PROJ-03804	Industrial	[illegible]	All Planning Approvals	New manufacturing	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
PROJ-04181	Institutional	[illegible]	All Planning Approvals	Addition to existing school	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
PROJ-04053	Mixed Use	[illegible]	All Planning Approvals	Zone Use - Commercial/Commercial	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
PROJ-3225	Mixed Use	[illegible]	All Planning Approvals	Zone Use - Commercial/Commercial	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
PROJ-3226	Residential	[illegible]	All Planning Approvals	Condominiums	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
PROJ-03001	Recreational	[illegible]	Under Construction	Golf course, driving range, clubhouse, and related facilities	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
PROJ-03189	Residential	[illegible]	All Planning Approvals	Condominiums	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
PROJ-03753	Residential	[illegible]	All Planning Approvals	19 SFR on North Ridge (see PD Condominiums	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
PROJ-3767	Mixed Use	[illegible]	All Planning Approvals	Zone Use - Commercial/Commercial	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
PROJ-3767	Hospital	[illegible]	All Planning Approvals	Medical office building	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
PROJ-03773	Mixed Use	[illegible]	All Planning Approvals	Zone Use - Commercial/Commercial	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
PROJ-3793	Mixed Use	[illegible]	Under Construction	Zone Use - Commercial/Commercial	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
PROJ-3824	Residential	[illegible]	All Planning Approvals	21 Single Family Residence Condominiums; 24 Townhouse Condominiums	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
PROJ-3850	Recreational	[illegible]	All Planning Approvals	Private clubhouse - Private clubhouse	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
PROJ-3854	Commercial	[illegible]	All Planning Approvals	New Safety office building	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
PROJ-3865	Residential	[illegible]	All Planning Approvals	Condominiums	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
PROJ-3873	Residential	[illegible]	All Planning Approvals	Condominiums	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
PROJ-3876	Residential	[illegible]	All Planning Approvals	22 Single Family Residence; 36 Condominiums	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
PROJ-3897	Mixed Use	[illegible]	All Planning Approvals	Zone Use - Commercial/Residential	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
PROJ-3898	Residential	[illegible]	All Planning Approvals	Condominiums	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
PROJ-3899	Residential	[illegible]	All Planning Approvals	8 Single Family Lots	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
PROJ-3908	Residential	[illegible]	All Planning Approvals	8 Condominiums	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
PROJ-3930	Commercial	VENTURA EAST VILLAGE	All Planning Approvals	Residential Project (Multiple Properties - RFS to Hamilton Associates)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
PROJ-3939	Residential	[illegible]	All Planning Approvals	65 Condominiums	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
PROJ-3955	Mixed Use	[illegible]	All Planning Approvals	15 commercials lot 30 Network office 21,300 sq ft marine oriented retail 84 units, ranging in size from 1,000 sq ft to 3,000 sq ft, and 2 story, 30,000 sq ft public boat dry storage facility	21,300	[illegible]	[illegible]	9,000	210	[illegible]
PROJ-3958	Recreational	[illegible]	All Planning Approvals	New 200 slip Marina	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
PROJ-3959	Mixed Use	[illegible]	All Planning Approvals	Zone Use - Commercial/Commercial	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
PROJ-3961	Residential	[illegible]	All Planning Approvals	4 Condominiums	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
PROJ-3962	Residential	[illegible]	All Planning Approvals	4 Condominiums	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
PROJ-3963	Mixed Use	[illegible]	All Planning Approvals	Zone Use - Commercial/Commercial	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
PROJ-3981	Residential	[illegible]	Under Construction	7 Apartments	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
PROJ-4115	Residential	[illegible]	All Planning Approvals	28 Age Units	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
PROJ-4164	Commercial	[illegible]	Under Construction	New facility and office expansion	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
PROJ-4206	Mixed Use	[illegible]	All Planning Approvals	Zone Use - Commercial/Commercial	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
PROJ-4472	Institutional	[illegible]	Under Construction	Construction of hospital building 323,000 sq ft and 220 beds (phase 1 of 2) (Total Community Hospital master plan 424,000 sq ft for new acute inpatient hospital, open pavilion and 134,000 sq ft for new health medical office/clinic, future shell expansion)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
PROJ-4508	Residential	[illegible]	All Planning Approvals	Continuing care complex	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
PROJ-4508	Commercial	[illegible]	Under Construction	Cemetery park	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
PROJ-4579	Institutional	[illegible]	All Planning Approvals	Installation of solar panels on top of new parking canopy structures on [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
PROJ-4704	Commercial	[illegible]	All Planning Approvals	35 room Boutique Hotel	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
PROJ-4706	Residential	[illegible]	All Planning Approvals	General Plan Amendment to modify the existing Seaside Park Land Use Policy from Non-Residential to Community Commercial and the existing zone designation from Single Family Residential (R-1) to [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
PROJ-4707	Residential	[illegible]	All Planning Approvals	10 Condominiums	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
PROJ-4708	Residential	[illegible]	All Planning Approvals	Condominium Conversion of existing building	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
PROJ-4709	Residential	[illegible]	All Planning Approvals	Demolition of 6 units and construction of 6 new units	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
PROJ-4867	Residential	[illegible]	All Planning Approvals	Add one unit to existing [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
TOTAL					2,000,000	2,711,441	3,337,076	2,000,000	2,362	249



VENTURA WATER

Pending Projects Approved and Under Construction

(as of December 2012)

Legend

- Ventura City Limit

Project Status

- All Planning Approvals
- Under Construction

0 0.5 1

Miles

Source: Eagle Aerial, 2010

RBF CONSULTING A Baker Company

Exhibit 2-2

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3. WATER DEMANDS

A. EXISTING DEMAND CONDITION

According to the 2010 UWMP, the City serves almost 32,000 service connections and approximately 113,500 persons. Per-capita water usage has shown a marked decline in recent decades from 277 gallons per capita per day (gpcd) to 161 gpcd. This decrease is a result of lower water use by a few large use customers and concerted water conservation efforts pursuant to the State of California's mandated landscape ordinance and Senate Bill 7 also known as the Water Conservation Act of 2009. However, the City's water consumption target, which must be achieved by 2020, must further reduce the per-capita consumption by another 12 percent to achieve the target of 142 gpcd.

City staff provided a summary of the meter consumption data for the entire service area for the calendar years (CY) 2003 - 2012 (Historical Water Consumption). Table 3-1 summarizes the total water consumption for each consumption category within the City's water service area for the most recent complete year of data, CY 2012. As shown in Table 3-1, the total water consumption for CY 2012 was 18,004 AFY, including the 6.5% water loss factor. The annual water consumption figures for the past ten years are provided in subsection 3.D.

Table 3-1

Summary of Existing Water Consumption for CY 2012

City Consumption Category	Water Consumption (HCF) [1]	Water Consumption (gpm)	Water Consumption (gpd)	Water Consumption (AFY)	Water Consumption + 6.5% Loss (AFY)
Single Family	3,212,783	4,572.23	6,584,005	7,376	7,855
Multi Family	1,708,860	2,431.94	3,501,993	3,923	4,178
Commercial/Retail/Industrial/Hotel	1,491,845	2,123.10	3,057,260	3,425	3,647
Public/Institutional (Municipal/Church/School)	250,903	357.07	514,179	576	613
Hospitals	96,261	136.99	197,269	221	235
Parks/Landscape/Irrigation	398,875	567.65	817,421	916	975
Other [2]	204,439	290.94	418,960	469	500
Total	**7,363,966**	**10,479.92**	**15,091,086**	**16,905**	**18,004**

[1] Source: HCF Consumption Data Tables (2003-2012) provided by Ventura Water.

[2] "Other" category includes all other accounted-for water such as construction water, water/sewer system maintenance, measured leakage. In addition, this includes 'grandfathered' users with water entitlements requiring special service conditions.

B. CONSUMPTION AND USAGE FACTORS

Future water demands are calculated using available land use data and corresponding water demand factors. Recently, the City has been utilizing the water demand factors identified in the 2005 General Plan FEIR to calculate future water demands. However, City staff recognize that the demand factors identified in the FEIR are very conservative, planning-level factors. City staff felt it prudent to develop more accurate water demand factors based on recent, historical billing data.

Utilizing land use information provided by the City and quantified in Section 2, water consumption factors were calculated for each consumption category based upon the CY 2012 consumption data provided by the City (Historical Water Consumption). The consumption factor calculations excluded the water consumption data for any specialized, or non-typical, land uses so as not to skew the factors. A consumption factor was calculated for each of the water consumption categories, provided adequate consumption data and land use data was available. Due to an apparent inconsistency in the reported building area, the calculated factor for the "Public/Institutional" category was significantly higher than industry norms. Therefore, for the purposes of this Report one factor was calculated for the "Non-Residential" customers, which included the "Commercial/Retail/Industrial/Hotel" category and the "Public/Institutional" category. Table 3-2 provides detail for how each of the categories consumption factor was calculated. Please note, the calculations in Table 3-2 are considered "raw factors," and do not factor in water loss or contingency.

The raw consumption factors were used as a basis to calculate a "Usage Factor," or planning-level consumption factor. The usage factors adjust the consumption factors to include a 6.5% water loss factor, per the 2010 UWMP, and a 20% contingency (factor of safety) for planning purposes. Table 3-3 provides a summary of the water usage factors recommended for use in calculating all future water demands for projects where development densities are known.

Table 3-2

Calculation of Raw Consumption Factors for CY 2012

City Consumption Category	Water Consumption (HCF) [1]	Water Consumption (gpm)	Water Consumption (gpd)	Water Consumption (AFY)	Units [2]	ksf or acre [2]	Raw Consumption Factor
Single-Family Res.	3,212,783	4,572.2	6,584,005	7,376	22,577		**292 gpd/du**
Multi-Family Res.	1,708,860	2,431.9	3,501,993	3,923	18,511		**189 gpd/du**
Commercial/Retail/Industrial/Hotel	1,491,845	2,123.1	3,057,260	3,425		17,318	**206 gpd/ksf [3]**
Public/Institutional	250,903	357.1	514,179	576			
Hospital/Assisted Living	96,261	137.0	197,269	221	465		**424 gpd/bed**
Park/Landscape/Irrigation [4]	398,875	567.7	817,421	916		522	**1,566 gpd/acre**
TOTAL	**7,159,527**	**10,189.0**	**14,672,127**	**16,436**	-	-	-

[1] Per Table 3-1

[2] Per Table 2-3.

[3] "Public/Institutional" was consolidated with "Commercial/Retail/Industrial" because gross square footages could not be accurately broken out for the two categories.

Table 3-3
Summary of Planning-Level Water Consumption Factors

	Water Demand Factor Classification	Raw Consumption Factor (CY 2012) [1]	Adjustment for Water Loss (+6.5%) [3]	Adjustment for Planning Purposes (+20%) [4]
Residential	Residential (0-8 du/ac)	292 gpd/du	311 gpd/du	370 gpd/du
	Residential (9-20 du/ac)	189 gpd/du	201 gpd/du	250 gpd/du
	Residential (21+ du/ac)	189 gpd/du	201 gpd/du	250 gpd/du
Non-Residential	Commercial/Retail/Industrial/Hotel Public/Institutional	206 gpd/ksf [2]	220 gpd/ksf	265 gpd/ksf
	Hospital/Assisted Living	424 gpd/bed	452 gpd/bed	545 gpd/bed
	Park/Landscape/Irrigation	1,566 gpd/acre	1,668 gpd/acre	2,000 gpd/acre

[1] Per Table 3-2.

[2] "Public/Institutional" was consolidated with "Commercial/Retail/Industrial" because gross square footages could not be accurately broken out for the two categories.

[3] Per 2010 UWMP.

[4] Value rounded-up to nearest 5.

C. USAGE FACTOR COMPARISON

The water usage factors calculated for the City were compared with other southern California water agencies with similar characteristics – population, climate, water supply sources. These included local agencies such as the City Simi Valley and the City of Thousand Oaks, as well as two other southern California agencies that have performed extensive research into calculating usage factors, the Irvine Ranch Water District and the Santa Margarita Water District. When compared to the other agency's factors, the low and medium density residential factors and the parks/irrigation factor calculated for Ventura are on the low side. The high density residential factor and the non-residential factor are both on the high side. Although the factors are either on the low or high side when compared to other agencies, this is likely due to the way Ventura classifies the consumption categories for billing purposes. Overall, the demand factors calculated for the City are within reason when compared to neighboring agencies. The comparison of water usage factors is shown on Table 3-4.

Table 3-4
Water Consumption Factor Comparison

Water Demand Factor Classification		Southern California Agencies				
		City of Ventura [5]	City of Thousand Oaks [1]	VCWWD No. 8 (Simi Valley) [2]	Santa Margarita Water District [3]	Irvine Ranch Water District [4]
Low Density Residential	*Low Density Residential (2-4.5 du/ac)*	-	405 gpd/du	840 gpd/du	-	-
	Residential (0-8 du/ac)	370 gpd/du	-	420 gpd/du	450 gpd/du	405 gpd/du
Medium Density Residential	*Medium Density Residential (4.5-15 du/ac)*	-	310 gpd/du	-	-	-
	Residential (9-20 du/ac)	250 gpd/du	-	-	300 gpd/du	310 gpd/du
High Density Residential	*High Density Residential (15-30 du/ac)*	-	180 gpd/du	-	-	-
	Condominium	-	-	259 gpd/du		-
	Multi-Family Apartment	-	-	222 gpd/du		-
	Residential (21+ du/ac)	250 gpd/du	-	-	175 gpd/du	200 gpd/du
Commercial/Industrial/Retail	Commercial/Retail/Industrial/Hotel	265 gpd/ksf			225 gpd/ksf	
	Public/Institutional					
	Hospital/Assisted Living	545 gpd/bed	-	1.85 gpm/ac	-	230 gpd/ksf
	Commercial	-	130 gpd/ksf	2.00 gpm/ac	225 gpd/ksf	220 gpd/ksf
	Industrial	-	60 gpd/ksf	-	-	-
	Industrial - Light	-	-	2.00 gpm/ac	-	60 gpd/ksf
	Industrial - Heavy	-	-	-	-	5000 gpd/ksf
	Institutional	-	45 gpd/ksf	-	-	-
	School	-	15 gpd/ksf	1.20 gpm/ac	15 gpd/stu	15 gpd/ksf
Parks / Irrigation	Park/Landscape/Irrigation	2,000 gpd/acre	-	-	3.5 AF/ac	3,400 gpd/acre
	Parks, Golf Courses, Open Space, Recreation Areas	-	3,400 gpd/acre	-	-	-
	Open Space, Community Park (Passive) Recreation Facility	-	-	-	100 gpd/acre	-
	Community Park (Active)	-	-	-	200 gpd/acre	-
	Community Facility	-	-	-	2,500 gpd/acre	-

[1] Table III-1, City of Thousand Oaks Water Master Plan, March 2005.

[2] Table III-1, Ventura County Waterworks District No. 8 Water Master Plan, February, 2010.

[3] Table IV-1, Santa Margarita Water District, I.D. Nos. 4C, 4E, 5 & 6 Plan of Works, April, 2012.

[4] Table 3-1, Irvine Ranch Water District, Water Resoruces Master Plan, November 16, 1999.

[5] Table 3-3 herein.

D. HISTORICAL WATER CONSUMPTION (BASELINE DEMAND CONDITION)

To calculate the total near-term water demand, the projected demands must be added to a baseline demand condition. The baseline demand should consider the historical water usage of the entire service area over an extended duration, in order to account for the year-to-year anomalies that can occur. City-wide water demands will vary from year to year based on several factors, including climate, water rates, the local economy, and environmental restrictions among other factors. To determine a recommended baseline, the historical water data was gathered for the past 10-year period. Ventura Water staff provided historical water consumption data for CY 2003 through 2012. Table 3-5 provides a summary of the City-wide water consumption for each year from 2003 to 2012. The consumption numbers are also depicted graphically on Figure 3-1.

As noted in the table, the average annual water consumption for Years 2003-2007 (19,507 AFY) was significantly higher than the average annual consumption for Years 2008-2012 (17,601 AFY). The drop in consumption is likely due to several factors, including improvements to the City's distribution system to control water loss, more aggressive water conservation measures, less construction activity, and a weaker economy. Some of the water use reduction trends may revert back to previous habits, however some will remain. With the State's passing of SB x7-7, all agencies are required to maintain a reduced urban water use target. This bill will result in water municipalities maintaining aggressive water conservation programs.

The historical data was used to develop the baseline demand condition, which is identified in Table 3-5. The City experienced a steady decline in total water consumption from its' peak year of 2007 (19,931 AFY) to the low year of 2011 (16,550 AFY). However, the City experienced an 8.8% increase in water consumption year-over-year from 2011 to 2012. This is indicative of a strengthening economy. Over the most recent 5-year period, the average annual water consumption was 17,601 AFY, with the lowest year approximately 6.0% lower than the average and the highest year approximately 13.2% above the average. Over the 10-year period, the average annual water consumption was 18,554 AFY, with the lowest year approximately 10.8% lower than the average and the highest year approximately 7.4% above the average.

For the purposes of establishing a baseline average annual water demand for the existing condition, it is recommended to use the 10-year average from the preceding ten years of data to capture the various factors influencing water consumption over the recent period. Due to the prolonged economic downturn, the significant restrictions placed on the imported water supply to southern California, and the recent drought conditions, it was determined that a longer period was

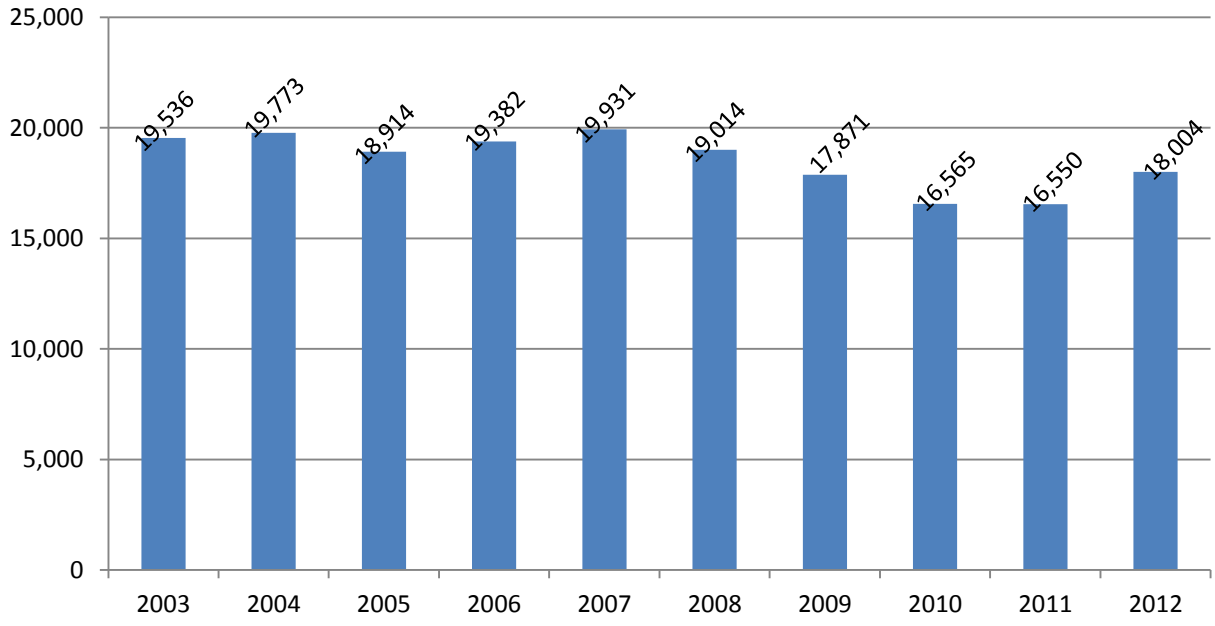
necessary to determine the baseline demand condition that is more reflective of a typical demand year. However, the City has identified a large industrial water user that has been significantly reducing their potable water consumption since the early 2000s. The City expects their reduced dependence on the potable water system to be permanent condition; therefore the City feels more comfortable using the most recent 5-year average as the baseline demand condition. Therefore, the baseline water demand established for this Report is 17,601 AFY.

Table 3-5
Historical Annual Water Consumption

Calendar Year	Consumption [1] (AFY)	Averages		
		3-year	5-year	10-year
2003	19,536			
2004	19,773			
2005	18,914		*19,507*	
2006	19,382			
2007	*19,931*			18,554
2008	19,014			
2009	17,871			
2010	16,565		**17,601**	
2011	*16,550*	17,040		
2012	18,004			

[1] Provided by Ventura Water. Includes 6.5% water loss factor.

Figure 3-1
Historical Annual Water Consumption (AFY)



E. FUTURE DEMAND PROJECTIONS (Approved Projects Only)

This Report will focus only on the near-term demand growth projections. The near-term growth consists of the proposed development projects that have been approved by the City but are not yet connected to the City's water system. This includes projects that are currently under construction, or were under construction in December 2012, and projects that have all City approvals, but have yet to begin construction (Table 2-4).

The future average annual water demand for the near-term growth projects were calculated utilizing the City-specific usage factors calculated above (Table 3-3). The factors were applied to each project in Table 2-4, per the detailed land use breakdown. Table 3-6 summarizes the calculations for the future demand potential. The increased water demand using the City-specific factors is predicted to be 1,042 acre-feet/year (AFY). Table 3-6 also identifies the portion of the near-term demands, 390 AFY, that are predicted to be within the service area of the Casitas Municipal Water District. The projected demands are considered a fully-committed allocation of the water supply.

Under the baseline demand condition, and utilizing the City-specific water usage factors developed herein for the approved development projects, the total near-term water demands are predicted to be 18,643 AFY, as shown on Table 3-7.

In order to estimate the growth of the future water demands, and absorption rate of 350 dwelling units per year (units/year) was utilized (and an equivalent absorption rate for the non-residential development). Based on historical growth data provided by the City, an estimated annual growth of 350 units/year is considered conservative. Assuming the 350 units/year growth rate, the City can expect the projected water demand for the under construction and approved projects to be fully vested by Year 2019, per Table 3-8.

Table 3-6
Total Estimated Demands for Under Construction and Approved Projects

Water Demand Factor Classification	Quantity [1]	Usage Factor [2]	Estimated Average Water Demand		Quantity [4]	Estimated Average Water Demand (within Casitas Boundary)	
Residential (0-8 du/ac)	564 du	370 gpd/du	208,680 gpd	234 AFY	120 du	44,400 gpd	50 AFY
Residential (9-20 du/ac)	1,808 du	250 gpd/du	452,000 gpd	506 AFY	669 du	167,250 gpd	187 AFY
Residential (21+ du/ac)							
Commercial/Retail/Industrial/Hotel Public/Institutional	544 ksf [3]	265 gpd/ksf	144,225 gpd	162 AFY	43 ksf [3]	11,511 gpd	13 AFY
Park/Landscape/Irrigation	0 ac	2,000 gpd/ac	-	-	0 ac	-	-
Hospital/Assisted Living	230 bed	545 gpd/bed	125,350 gpd	140 AFY	230 bed	125,350 gpd	140 AFY
Total			***930,255 gpd***	***1,042 AFY***		***348,511 gpd***	***390 AFY***

[1] Per Table 2-4

[2] Per Table 3-3

[3] Excludes 320,000 SF for the Hospital. Hospital demand calculated "per bed" since an appropriate factor was developed. Includes Hotel SF.

[4] Within Casitas Boundary, per Table 2-4 (included in the total).

Table 3-7
Projected Total Water Demands Including Under Construction and Approved Projects - Various Baselines

Baseline Demand Condition	Baseline Water Demand	Projected Water Demand [1] 1,042 AFY
1-Year: 2012	18,004 AFY	19,046 AFY
3-Year Average: 2010-2012	17,040	18,082
5-Year Average: 2008-2012	**17,601**	**18,643**
10-Year Average: 2003-2012	18,554	19,596
Past 5-Year Period: Annual High Year	19,014	20,056
Past 10-Year Period: Annual High Year	19,931	20,973

[1] Based on Calculated Consumption (Usage) Factors

Table 3-8
Projected Water Demand Growth per Absorption Rate

Year	Total Units [1]	Absorption Rate [2]	Projected Water Demand [3]
2012			***17,601 AFY***
2013		350	17,755
2014		350	17,908
2015		350	18,062
2016		350	18,216
2017		350	18,370
2018		350	18,523
2019		272	18,643
2020			18,643
Totals	**2,372**	2,372	**18,643 AFY**

[1] Per Table 2-4.

[2] Based on City's experience with peak rates of construction activity of approximately 350 units per year. Absorption rate of Commercial, Retail, Industrial, Hotel and Public/Institutional assumed to correlate with the estimated DU absorption rate.

[3] Projections based on Baseline Demand Condition, per Table 3-7.

4. WATER SUPPLY

A. INTRODUCTION

The City's potable water supply is derived from local groundwater basins, Lake Casitas and sub-surface water from the Ventura River. The City also has a 10,000 acre-foot per year allocation from the California State Water Project. To date the City has not received any of this water because there are no facilities to get the water to the City. There are presently five local water sources that provide water to the City water system:

- Casitas Municipal Water District (Casitas)
- Ventura River Foster Park Area (Foster Park)
    - Surface Water Intake
    - Upper Ventura River Groundwater Basin/Subsurface Intake and Wells
- Mound Groundwater Basin (Mound Basin)
- Oxnard Plain Groundwater Basin (Fox Canyon Aquifer)
- Santa Paula Groundwater Basin (Santa Paula Basin)

The City also provides recycled water from the Ventura Water Reclamation Facility (VWRF). The six current water supply sources are presented in the following section. Please refer to Exhibit 4-1 for the locations and boundaries of the City's current supply sources.

VENTURA WATER

Supply Sources



Legend

- Casitas Turnout
- Well
- City of Ventura Treatment Plant or Conditioning Facility
- Groundwater Basins
- Regional Water District Boundaries
- Ventura City Limit

0 0.5 1
Miles

Source: Eagle Aerial, 2010

RBF CONSULTING
A Baker Company

Exhibit 4-1

M:\Mdata\10104392\January_2013\EX4_1_SupplySources_L11x17.mxd 2/19/2013-- DJ

B. CURRENT WATER SUPPLY SOURCES

1. Casitas Municipal Water District (Casitas)

The City purchases treated water from Casitas Municipal Water District to provide water supply to a portion of the City. In the western portion of the City approximately 30 percent of the City's water accounts are located within the Casitas service area. Storm water runoff from local watersheds is stored in Lake Casitas, located approximately 10 miles northwest of the City, then treated and delivered to customers by Casitas. Casitas supplies potable water to agricultural, domestic, municipal, and industrial users within its service area. The Casitas service area includes the Ojai Valley, the western part of the City, and the coastal area between the City and Santa Barbara County. Use of Casitas water is restricted to areas within its boundaries.

The "'safe yield" of Lake Casitas is defined to be the amount of water that can be removed from the lake each year without excessive risk that the lake will become dry. The safe yield of Lake Casitas is currently estimated to be 21,920 acre-feet per year (AFY), based on the critical historical dry period from 1944 to 1965. Studies by Casitas' engineering department have shown that this period represents the most critical dry spell for the lake's watershed of all the years which historical data is available.

To maintain the future operation of Lake Casitas at safe yield, Casitas established an allocation program for its customers in 1992. The City's allocation can be as high as the in-District demand for Stage I (wet or average year or 8,000 AFY), or reduced to 7,090 AFY for Stage 2 (dry conditions). This amount is incrementally reduced during Stages 3 and 4 dry weather conditions and results in 4,960 AFY for Stage 5 (extremely dry conditions). Stage 2 is initiated when Lake Casitas storage drops below 95,000 AF and Stage 5 is initiated when levels drop below 65,000 AF. The lower allocation remains in effect until the storage is recovered to 90,000 AF. A possible future impact to the multistage allocation system may be the operation of the fish ladder at the Robles Diversion. Casitas is currently reviewing its allocation program and this may limit the amount of water available to the City.

In July 1995, the City signed the present operating agreement with Casitas establishing the City's minimum annual purchase at 6,000 AFY, which is subject to the allocation program described above during drought periods. However, due to recent demand reductions within the Casitas boundary City customers are currently using approximately 5,000 AFY. The City is presently renegotiating the water supply agreement with Casitas. While additional supply (up to 8,000

AFY) may be available to the City in future years, the present annual supply used within the Casitas district boundary of the City service system is approximately 5,000 AFY. Therefore the City's current reliable water supply from Casitas is 5,000 AFY.

2. Ventura River Surface Water Intake and Upper Ventura River Groundwater Basin/Subsurface Intake and Wells (Foster Park)

Surface water from the Ventura River is collected via surface diversion, subsurface collector, and shallow wells and delivered to the Avenue Treatment Plant through the City's Foster Park facilities. Production from this source is a function of several factors including diversion capacity, local hydrology, environmental impacts, and the storage capacity of the Ventura River alluvium and upstream diversions.

The Ventura River water source is dependent upon local hydrology. Currently, the surface intake structure at Foster Park is unused due to the natural channeling of the active river channel bypassing the structure. Each year the flows can change the position of the active river channel in relation to the intake structure. According to a model of the Ventura River developed in 1984 and modified in 1992, the Upper Ventura River Basin fills after one or more years of above average rainfall. Once full, it takes three successive years of drought, with below average rainfall to deplete the river basin subsurface storage and cause river water production to drop until the drought ends. More recent ongoing studies are looking at the interaction between groundwater diversion and surface water flow in the Foster Park reach.

The Foster Park facilities produce groundwater throughout the year. However, due to storm flows, the wells are subject to inundation and erosion. The early 2005 winter storms destroyed Nye Well 1A and damaged Nye Wells 2, 7 and 8. The pipeline between Nye Wells 7 and 8 along the west bank of the river and the pipeline that crosses the river from Nye Well 8 to the intake pipeline for the Avenue Treatment Plant were also damaged during the storms. Nye Wells 7 and 8 were repaired in late 2006, the pipeline across the river was repaired in late 2007 and the pipeline repair between Nye Wells 7 & 8 was completed in early 2009. To date, Nye Well 2 has not been repaired.

With input from resource agencies and consultants in 2008, the City began conducting studies of the Ventura River flow conditions and is presently operating the Foster Park facilities in an environmentally responsible manner. Presently the City operations staff has voluntarily adopted a

well production schedule that limits its pumping based on annual rainfall conditions. The City intends to work with experts to ascertain a pumping regime that will balance production demands with environmental concerns and is presently studying the relationship between groundwater production and surface flows.

Estimations of approximately 6,000 AFY on average is available based on this operational scenario and is comparable to the 50-year average historical City production records between 1960 and 2009. However, current operational constraints allow a diversion efficiency of up to 70 percent (average 4,200 AFY) to be obtained under the City's operations schedule, which can be considered reliable for planning purposes and is roughly equal to the annual average for the last 10 years. Therefore the City's current reliable water supply from the Ventura River / Foster Park is 4,200 AFY. This supply number may further be drastically reduced by proposed regulatory and environmental constraints.

3. Mound Groundwater Basin (Mound Basin)

The Mound Groundwater Basin has historically provided water for overlying beneficial uses and satisfies agricultural, municipal, and industrial demands. Historical use has been documented to temporarily exceed the yield of the basin and result in water levels that have fallen below sea level and created a threat of seawater intrusion. To abate this threat the City abandoned its historical coastal well facilities and located groundwater extraction near the center of the Mound Basin. A report (Fugro, 1997) compiled as part of a 1996 study of the basin indicated that historical data supports a basin yield of at least 8,000 AFY during drought conditions as long as pumpage is reduced during wet years to allow water levels to recover.

The 1983 to 1996 average annual production from the Mound Basin was approximately 5,000 AFY (Fugro, 1997). While the resulting water levels in the basin over that time period reportedly ranged from significantly below sea level to a sufficient elevation about sea level to control seawater intrusion, the basin water level trend did not indicate an average production significantly above 5,000 AFY could be sustained without creating adverse conditions.

Currently, two wells withdraw water from the Mound Groundwater Basin; Victoria Well No. 2, which was installed in 1995, and Mound Well No. 1, which began production in April 2003. Victoria Well No. 1, which was installed in 1982, is considered an inactive well at this time due to maintenance and water quality issues and is scheduled for destruction.

Historical agricultural and private well uses have typically extracted about 2,000 AFY while the City's average annual extraction for the last ten years has been approximately 4,000 AFY. Therefore the City's current reliable water supply from the Mound Basin is 4,000 AFY.

4. Oxnard Plain Groundwater Basin (Fox Canyon Aquifer)

Wells near the Buenaventura Golf Course have drawn from the Oxnard Plain Groundwater Basin since 1961. Currently, two wells, Golf Course Wells No. 5 and 6, produce potable water for the City's system and a third well (Golf Course Well No. 3) is out of service for major rehabilitation. This third well could be used as an emergency source and will only return to service during a drought, following the replacement of wellhead, pump, electrical and raw water connection. These wells pump from the Fox Canyon Aquifer of the Oxnard Plain Groundwater Basin.

The Fox Canyon Groundwater Management Agency (GMA) was created by state legislation in 1982 to manage local groundwater resources in a manner to reduce overdraft of the Oxnard Plain and stop seawater intrusion. A major goal of the GMA is to regulate and reduce future extractions of groundwater from the Oxnard Plain aquifers, in order to operate and restore the basin to a safe yield. In August 1990, the GMA passed Ordinance No. 5, which required existing groundwater users to reduce their extractions by five percent every five years until a 25 percent reduction was reached by the year 2010.

The City's historical allocation was set by the GMA at 5,472 AFY, which was the average extraction from the Golf Course Wells for the base period 1985 to 1989. Beginning in 1992, historical extractions set by the GMA were reduced by five percent (5%) to 5,198 AFY, in 1995 it was reduced to 4,925 AFY, in 2000 it was reduced to 4,651 AFY and further reduced in 2010 to the current allocation of 4,100 AFY. Therefore the City's current reliable water supply from the Oxnard Plain Basin is 4,100 AFY.

5. Santa Paula Groundwater Basin (Santa Paula Basin)

The Saticoy Water Company was acquired by the City in 1968, which included Saticoy Well No. 1 that produced water from the Santa Paula Basin. Due to casing failure, the well was destroyed and replaced in 1991 with a new well designated as Saticoy Well No. 2. Well No. 2 was placed in

the same general location as Well No. 1. In May 2003, Saticoy Well No. 2 was rehabilitated. After rehabilitation, the resulting sustainable well supply was 1,600 AFY.

In March 1996, the City ended a five-year stalemate over the use of the Santa Paula Basin. Under a court stipulated judgment, the United Water Conservation District (United), the Santa Paula Basin Pumpers Association (an association of ranchers and businesses) and the City all have an interest in the Santa Paula Basin. The City can pump on average 3,000 AFY from the Santa Paula Basin. The City is not limited to this allocation in any single year, but may produce seven times its average annual allocation (21,000 AF) over any running seven-year period. In addition, the City may pump an additional 3,000 AFY in case of an emergency resulting from a long-term drought situation.

If the court finds that the safe yield of the basin is less than the total pumping allocations, then the City may have reductions in pumping allocations. Stage 2 reduces the City's pumping to 1,141 AFY, Stage 3 reduces the City's pumping allocations to 641 AFY, Stage 4 reduces the City's pumping allocations to 481 AFY and Stage 5 reduces the City's allocations to zero.

However, due to the existence of only the one well, the City can only reliably count on the production of that well to provide supply at this time. Therefore the City's current reliable water supply from the Santa Paula Basin is 1,600 AFY.

6. Recycled Water

The City collects and treats wastewater at their Ventura Water Reclamation Facility (VWRF). The reclamation facility has a current capacity of 12 MGD. Average annual flows to the reclamation facility total approximately 9 MGD. A portion of the effluent is pumped to recycled water customers and the remaining effluent is discharged to the Santa Clara River Estuary (Estuary). The recycled water produced from the VWRF is used for general irrigation of the two golf courses, a City park and landscape irrigation areas located along the existing distribution alignment. The City's average annual recycled water demand is approximately 700 AFY.

The City's existing water supply portfolio is summarized in Table 4-1.

Table 4-1
Summary of Current Water Supply

Water Supply Source	Current Supply (AFY)
Casitas Municipal Water District	5,000 [1]
Ventura River / Foster Park	4,200
Mound Groundwater Basin	4,000
Oxnard Plain Groundwater Basin	4,100
Santa Paula Groundwater Basin	1,600
Recycled Water	700
Total	**19,600**

[1] Demand within Casitas service area is approximately 5,000 AFY at this time.

C. FUTURE WATER SUPPLY

1. Casitas Municipal Water District (Casitas)

While additional supply (up to 8,000 AFY) may be available to the City in future years, the present annual supply used within the Casitas district boundary of the City service system is approximately 5,000 AFY. However, as discussed in Section 3, and shown on Table 3-7, it is estimated that the added water supply required to meet the demand of the under construction and approved projects that are located within the Casitas boundary is 390 AFY. Therefore, the anticipated future water supply from Casitas will increase by an equivalent amount, to approximately 5,390 AFY, by Year 2019. Using the absorption rate discussed in Section 3, the estimated supply from Casitas is estimated to increase by 173 AFY in year 2015.

2. Ventura River Surface Water Intake and Upper Ventura River Groundwater Basin/Subsurface Intake and Wells (Foster Park)

In conjunction with the Matilija Dam Ecosystem Restoration Project, two additional wells were installed at Foster Park as part of the mitigation measures. The wells, identified as the Foster Park Wellfield Restoration Project (Wells no. 12 and 13), were constructed by and funded through a grant received by the Ventura County Watershed Protection District for the City in order to mitigate for water lost as a result of increases in turbidity due to the removal of Matilija Dam. To date these wells have not been activated and are not to be operated until the project related impacts after removal of Matilija Dam necessitate the activation of these new wells. These two wells will be operated in accordance with the National Marine Fisheries Biological Opinion for the project.

It is anticipated that future construction of the Foster Park Wellfield Production Restoration Project and the expansion of the Avenue Treatment Plant to its maximum capacity will increase the supply from this source in the future. These improvements are anticipated to restore historical production capabilities to produce up to 6,700 AFY.

3. Mound Groundwater Basin (Mound Basin)

The City anticipates conducting a study within the next few years to review the perennial yield of the Mound Basin and determine if the annual average yield of the basin is still believed to be

accurate. The anticipated future water supply from the Mound Basin will remain approximately 4,000 AFY.

4. Oxnard Plain Groundwater Basin (Fox Canyon Aquifer)

The anticipated future water supply from the Oxnard Plain Basin will remain as 4,100 AFY per the discussions in the previous section on the basin.

5. Santa Paula Groundwater Basin (Santa Paula Basin)

In March 1996, the City ended a five-year stalemate over the use of the Santa Paula Basin. Under an agreement with the United Water Conservation District (United) and the Santa Paula Basin Pumpers Association (an association of ranchers and businesses), the City can pump on average 3,000 AFY from the Santa Paula Basin. The City is not limited to this allocation in any single year, but may produce seven times its average annual allocation (21,000 AF) over any running seven-year period. In addition, the City may pump an additional 3,000 AFY in case of an emergency resulting from a long-term drought situation.

The City is currently constructing Saticoy Well No. 3, which will improve the water supply from the Santa Paula Basin. It is anticipated that Saticoy Well No. 3 will have an operational capacity of 2,000 gpm, thereby maximizing use of the City's 3,000 AFY allocation from the Santa Paula Basin in the near future.

However, as stated in the previous section on the Santa Paula Basin, there is potential for future reductions in the available supply. Therefore, the anticipated future water supply from the basin has a range from zero to 3,000 AFY.

6. Recycled Water

The City's existing Reclaimed Water Policy continues to encourage the use of recycled water. New development located near existing recycled water mains or within the defined recycled water focus area is required to use recycled water in lieu of potable water for irrigation and other uses as appropriate. In 2007, Kennedy Jenks Consultants completed a study on the potential recycled water market within the City. The total demand within the City limits that could potentially utilize recycled water was estimated at 1.3 MGD. Therefore, the anticipated future water supply from the VWRF at this time is 1,400 AFY.

The City's future water supply portfolio is summarized in Table 4-2.

Table 4-2
Summary of Future Water Supply
From Existing Sources

Water Supply Source [1]	2015 Supply (AFY)	2020 Supply (AFY)	2025 Supply (AFY)
Casitas Municipal Water District [2]	5,173	5,390	5,390
Ventura River / Foster Park	4,200	4,200 - 6,700	4,200 - 6,700
Mound Groundwater Basin	4,000	4,000	4,000
Oxnard Plain Groundwater Basin	4,100	4,100	4,100
Santa Paula Groundwater Basin [3]	0 - 3,000	0 - 3,000	0 - 3,000
Recycled Water	700	700	1,400
Total	**18,173 – 21,173**	**18,390 – 23,890**	**19,090 – 24,590**

[1] None of these numbers preclude the City's water rights.

[2] Supply will be adjusted as demand increases within the Casitas service area.

[3] The Santa Paula Basin Judgment allows the City to utilize on average 3,000 AF annually. There is potential for future reductions, therefore the supply range is shown from zero to 3,000 AFY.

D. POTENTIAL ADDITIONAL FUTURE SUPPLY SOURCES

This section will briefly describe any planned or proposed projects which may affect the water supply sources for the City.

1. State Water Project

The City has a 10,000 acre-foot per year allocation from the California State Water Project (SWP). The base contractual agreements concerning the City's annual entitlement to 10,000 acre-feet of SWP are: (1) the 1963 State Water Supply Contract of 20,000 acre-feet entitlement of SWP water between the Department of Water Resources (DWR) and Ventura County Watershed

Protection District (VCWPD) known formerly as Ventura County Flood Control District (VCFCD); (2) the 1970 agreement between VCFCD and Casitas known formerly as the Ventura Municipal Water District that assigned the 20,000 acre-feet entitlement to Casitas; and (3) the 1971 agreements between Casitas and the City providing the City with an annual entitlement of 10,000 acre-feet and Casitas and United providing United with an annual entitlement of 5,000 acre-feet. Ventura's 10,000 acre-foot entitlement offers the City the potential future advantage of using the SWP entitlement to augment the current water supply. At this time the City does not have the facilities required to deliver SWP water into the distribution system. The City's goal has been to protect and provide the additional water supply for our community, while minimizing the financial impact of keeping this entitlement. Recent information provided to the City estimates the wheeling costs that would be required to pay Metropolitan Water District in order for the City to wheel water through their facilities would be over $1,300/AF, not including the wheeling charges assessed by local agencies.

The City pays annual SWP Table A water fees to DWR, which cover construction costs for SWP facilities and administration to deliver allotments of water throughout the state. In addition, the citizens of Ventura voted November 3, 1993 in favor of desalinating seawater over importing water through the SWP, as the preferred supplemental water supply option. However, based on the City Attorney's review of the City's SWP Table A water, the City cannot unilaterally end its involvement in the SWP's financial obligations and SWP Table A water without great risk.

The Monterey Amendment to the State Water Contract in 1999 provided the City a formal mechanism to allow the City to place their SWP water into a "turn back" pool to be purchased by other SWP contractors. The City has taken part in the SWP "turn back" pool over the past several years which has provided a small annual revenue offset. The City has also worked recently with United who requested to receive the City's allocation at the "turn back" pool rate which provided water benefits to the County area as a whole.

Recent changes in the regulations and the current potential market for state water has provided a possible opportunity for the City to recover a more significant revenue offset. However, at the same time the annual costs associated with SWP water are anticipated to increase substantially while the available supply from the state has gone down resulting in a reduction of allocation to SWP Contractors in recent years to 40-50%. The higher costs and lower supplies are due to proposed projects in the Sacramento-San Joaquin Delta because of several years of drought and environmental concerns over protecting endangered species. The City is evaluating the existing

policy on SWP water and the City's options related to short term and long term leases of its SWP entitlement.

2. Saticoy County Yard Well

In 2004 the County of Ventura proposed relocating their maintenance yard from the existing location to a site within the Saticoy Community contiguous to the City's water system. In exchange for City water service, which required an extraterritorial water service agreement, the County provided the City with a new well and pipeline facilities. The new well was provided to offset the County's anticipated water demand, as well as, provide significant additional water supply. The pipeline facilities provided by the County included approximately 2,320 feet of 14" pipeline from the new well to a location where the City would eventually complete the remainder of the raw water pipeline to the City's existing Saticoy Conditioning Facility for treatment.

A domestic pipeline was also provided that tied into the City's existing pipeline system at two locations. The County's' facilities were completed in 2006. The City's Capital Improvement Program (CIP) Plan included the City's portion of the raw water pipeline that connected the County provided raw water pipeline to the City's Saticoy County Yard Well. The City's' portion was completed in 2009. In November 2009 the City Council was to certify the Final EIR for the Saticoy & Wells Community Plan and Development Code. During the certification process the Fox Canyon Groundwater Management Agency (FCGMA) and United voiced concerns regarding the water supply anticipated from the Saticoy Yard Well for the project area. Consequently, the City approved a *Limitation and Tolling Agreement* whereby the parties agreed to a cooperative Operations Testing Plan to provide testing of the impact of the water drawn from the Saticoy County Yard Well. As a result of the testing under the Operations Plan it was determined that the April 2004 County of Ventura Saticoy Operations Yard EIR was not sufficient for the anticipated operations of the Saticoy County Yard Well and therefore additional environmental clearance is warranted for operation of the well.

Therefore, the anticipated future water supply from the Saticoy County Yard Well is unknown at this time. It should be noted that the City's 2005 Urban Water Management Plan (UWMP) and 2008 Biennial Water Supply Report included the Saticoy County Yard Well as a water supply source of up to 2,400 acre-feet per year.

3. Recycled Water

a. Ventura Water Reclamation Facility (VWRF)

As mentioned previously, currently the City's Water Reclamation Facility (VWRF) discharges most of its tertiary treated effluent to the Santa Clara River Estuary (Estuary) with approximately 700 acre-feet per year (AFY) diverted as recycled water for landscape irrigation by several users.

The City's current and past recycled water planning efforts have centered on issues related to the beneficial uses of the Estuary. These issues have required the City to consider whether or not discharge from the VWRF provided enhancements to the beneficial uses of the Estuary, and consequently affects the amount of recycled water that can supplement domestic water supply. The following describes the history and issues related to recycled water planning within the City's service area.

Historically, the VWRF has been permitted to discharge the majority of its effluent to the Estuary. However, during the 2008 re-issuance process, controversy arose on whether or not the City should be permitted to continue its current volume of discharge into the Estuary. The Discharge Permit issued by the RWQCB allowed continuation of the discharge but required the City to perform three extensive studies.

The studies included the Estuary Subwatershed Study (completed March 2011), Phase 1 Recycled Water Market Study (completed March 2010), and Treatment Wetlands Study (completed March 2010). The Discharge permit also identified a Phase 2 of the Recycled Water Study.

A draft of the Phase 2 Recycled Water Study was recently completed and a Stakeholder Workshop was held at the City on February 21, 2013. The intent of the study was to answer the following question, "What is the best use of the treated water resources from the VWRF to protect the health of the Estuary?" The previous studies mentioned and previous workshops narrowed potential project alternatives down to the most feasible and most beneficial. Some of the alternatives being considered in the Draft Phase 2 Recycled Water Study have the potential of providing the City with some amount of additional water supply in the future. This could be additional recycled water to offset

current potable uses or an additional water supply utilizing indirect or direct potable reuse.

b. Ojai Valley Sanitary District (OVSD)

In 2007, the City in partnership with the Ojai Valley Sanitary District (OVSD), completed a preliminary feasibility analysis for the re-use of effluent currently discharged from OVSD into the Ventura River. The discharge averages approximately 2 million gallons per day, and enters the river approximately 5 miles upstream of the Pacific Ocean. The first part of the analysis focused on environmental issues primarily related to impacts of reduced discharge flow on the receiving environment, and possible impacts to water quality as a function of reduced flows. The second part of the analysis considered engineering and market issues related to different levels of effluent re-use. Ultimately, from an economic perspective, the cost and difficulty of providing the infrastructure necessary to supply recycled water to potential users has to be balanced against the demand for such water, and the willingness of potential users to pay for it.

The engineering and market analysis identified a cost-effective combination of localized users that minimized the additional infrastructure necessary to supply the recycled water. The primary users identified were Aera Energy and local growers, with Aera accounting for the bulk of the demand. These users, which are currently supplied water from the City with a combination of untreated and potable water, could utilize recycled water in the future. The primary users in the 2007 study have reduced their water demands and the combined FY 2011-2012 water consumption of these users is approximately 300 AFY. Collectively, the environment, engineering and market analysis suggested that the re-use of at least a portion of the effluent is sufficiently feasible to justify further consideration, although full CEQA documentation and review will be necessary prior to implementation. The City and OVSD continue to discuss and work together to investigate the potential reuse of OVSD effluent.

4. Ocean Desalination

As indicated in Section D.1 State Water Project, the citizens of Ventura voted November 3, 1993 in favor of desalinating seawater over importing water through the SWP, as the preferred supplemental water supply option. Current information on desalination of seawater presented by

The Pacific Institute recently completed a report entitled, “Desalination, With a Grain of Salt – A California Perspective”. The report indicates that the potential benefits of ocean desalination are great, but the economic, cultural and environmental costs of wide commercialization remain high. Alternatives such as treating low-quality local water sources, regional water transfers, improving conservation and efficiency and accelerating wastewater recycling and reuse can provide the same freshwater benefits of ocean desalination at far lower economic and environmental costs. The Pacific Institute analysis found that the cost to produce water from a desalination plant is high but subject to significant variability with recent estimates for plants proposed in the state ranging from $1,900 to more than $3,000 an acre-foot. City staff has been engaged in discussions with other local water agencies in regard to potential regional desalination projects and will continue to do so.

5. Water Conservation Measures/Water Efficiency Plan

Water conservation measures may help sustain existing water use and delay the need for new water supplies. In 2011, City Council adopted a five-year Water Efficiency Plan that focuses, amongst other efforts, on educating the youth and reducing outdoor landscape watering. Outdoor landscaping accounts for 40% to 60% of water use for residential units. The second year of the plan continues to focus efforts on reducing residential landscape watering. The efforts concentrate on appropriate watering for mature landscape as well as the planting of more sustainable gardens. Ocean Friendly Gardens provide potable water use savings as well as environmental sustainability capturing storm runoff. City efforts now focus on maintaining this savings threshold and possibly providing a buffer in a three year drought period. This will be a continuing challenge for the City.

6. Establish Water Rights Ordinance

In September 2012, Ventura Water took the concept of a water rights ordinance to Council. As new development is proposed, a consistent methodology is important for securing water rights and projecting water demands. To maintain the City’s supply levels and support long term sustainability, Ventura Water is drafting language for inclusion in a new water rights ordinance. The draft language includes providing rights, buying rights to offset new development demand, purchasing the City’s rights as well as the payment of in-lieu fees. Parcels that are within the Fox Canyon Groundwater Management Agency (FCGMA) boundary that use groundwater for current water use have an opportunity to bring water rights with any proposed development. According

to the FCGMA current policies, if a parcel has an “allocation” from a well within the boundary, the “allocation” may be transferred to the City so that the City’s current allocation will be increased by that amount. This would generally be the case where the “allocation” is currently a municipal and industrial use (M&I). In the case where the parcel is in agriculture use and is utilizing the FCGMA’s agriculture efficiency policy then the “allocation” that may be transferred to the City would be 1.5 acre-feet of groundwater “allocation” per acre of land. Parcels that are within the Santa Paula (SP) Basin boundary may have an allocation from an existing well that is serving that parcel or several parcels. Under the SP Basin Stipulated Judgment, the SP Basin Technical Advisory Committee has transfer procedures where a property owner may transfer water rights associated with the parcel to the City.

5. CONCLUSIONS & RECOMMENDATIONS

A. CONCLUSIONS

The City's total water demand for the most recent calendar year (2012) of data was 18,004 AFY. Over the past five years (2008-2012), the City experienced an average annual water demand of 17,601 AFY, and over the past ten years (2003-2012), the annual average water demand was 18,554 AFY. Although there have been extenuating circumstances that have occurred over the previous five year period, including an extended economic downturn, significant restrictions to the imported water supply to southern California, legal challenges to the Ventura River water supply and several years of drought conditions, it is recommended to include a larger data set to predict a "typical" average annual water demand. However, the City has identified a large industrial user that has significantly, and permanently, reduced their dependence on potable water in recent years. Therefore, the City is more comfortable that the 5-year average is more reflective of the current demand condition. Therefore the current baseline water demand is established to be 17,601 AFY.

The City has a total of 47 projects that are under construction or approved for development. These projects include an additional 864,000 SF of non-residential development and 2,372 residential dwelling units. By developing water usage factors based on recent consumption data, the City can more accurately predict the additional future water demand for the approved development projects. Using the City-specific water usage factors, the under construction and approved development projects will generate an additional annual average water demand of 1,042 AFY. Therefore, the estimated water demands that the City is committed to supply total 18,643 AFY. Assuming an average absorption rate of 350 dwelling units per (and the equivalent growth in non-residential development), it is anticipated that the currently under construction and approved projects will be completed by year 2019.

The City's available water supply is constantly changing, depending upon environmental and legal constraints. The City's current available water supply is 19,600 AFY, however at any time the available water supply could drop to an annual average of 18,000 AFY.

The near-term water supply picture to meet the needs of the development projects that are under construction and approved will remain relatively the same as the existing condition, however the

City can expect to increase the water supply from Casitas by 390 AFY to meet the additional water demand in the Casitas boundary.

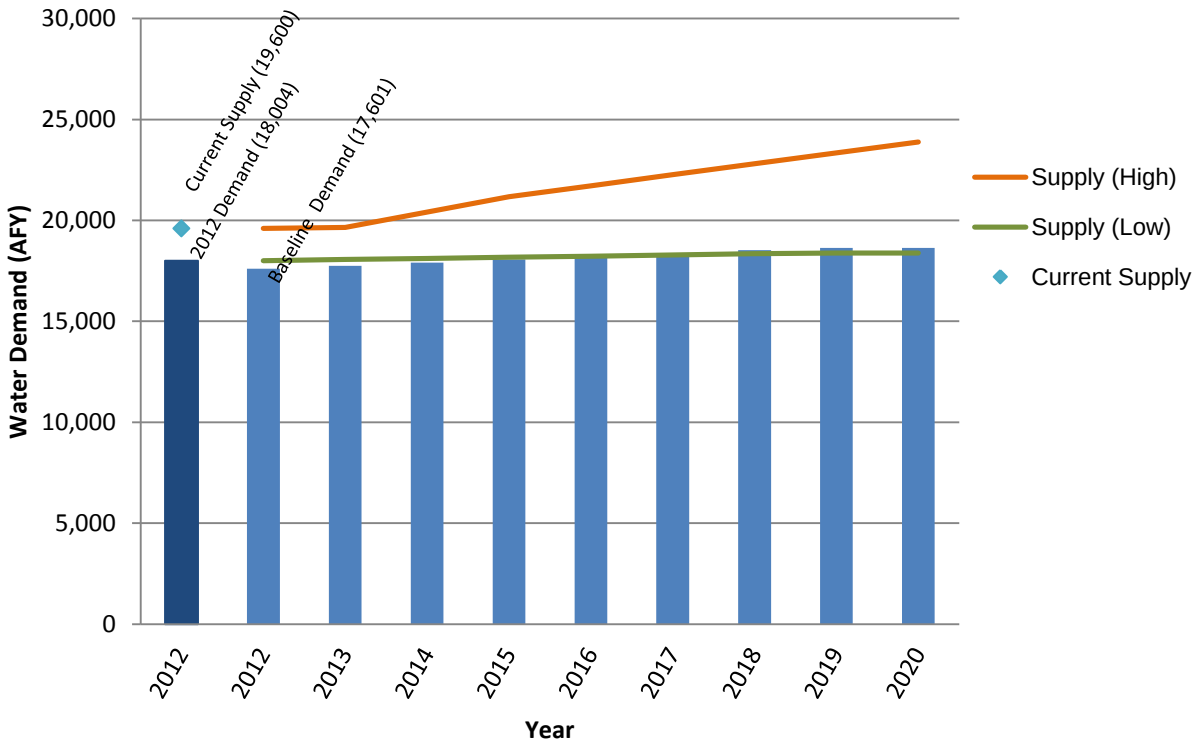
Table 5-1 provides a comparison of the existing water demand and supply, and the near-term water demand and supply. It should be noted that the low end of the water supply range is less than the anticipated demand beginning in year 2017.

Table 5-1
Demand vs. Supply Comparison

Year	Demand AFY	Supply Range			
		Low		High	
		AFY	% Diff.	AFY	% Diff.
2012	17,601	18,000	2.2%	19,600	10.2%
2013	17,755	18,058	1.7%	19,658	9.7%
2014	17,908	18,115	1.1%	20,416	12.3%
2015	18,062	18,173	0.6%	21,173	14.7%
2016	18,216	18,230	0.1%	21,716	16.1%
2017	18,370	18,288	-0.4%	22,260	17.5%
2018	18,523	18,346	-1.0%	22,803	18.8%
2019	18,643	18,390	-1.4%	23,347	20.1%
2020	18,643	18,390	-1.4%	23,890	22.0%

The water supply range and demand projections are also depicted graphically in Figure 5-1.

Figure 5-1
Demand vs. Supply Projection



B. RECOMMENDATIONS

The results of this Report indicate that the spread between the current water demand and the current water supply is very tight, and in some conditions the supply could be less than the demand. This presents challenges for the City moving forward in the ability to allocate water supply to development projects that will generate additional water demands. The recommendations for the City moving forward include:

1. Track the total water consumption on an annual basis.
2. Re-calculate the 3-year, 5-year and 10-year water consumption averages on an annual basis.
3. Update the water supply portfolio on an annual basis.
4. Update the existing land use data on an annual basis. This can be done through a system that tracks the development projects as the transition from “Under Construction” to “Existing,” and “Approved” to “Under Construction.”
5. All future development projects should be evaluated based on current supply and demand conditions.
6. Use the City-specific water usage factors to calculate the water demand of all development projects as the projects proceed through the City process prior to approval.
7. Continue to develop water supply through demand side management, securing water rights, establishing an in-lieu fee ordinance and continue to integrate the new water supply sources into the City’s water supply portfolio.

United States
Environmental Protection Agency
Region 9

Ventura River Reaches 3 and 4
Total Maximum Daily Loads For
Pumping & Water Diversion-Related
Water Quality Impairments



Draft December 2012

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List of Acronyms

ASSETS	Assessment of Estuarine Trophic Status
Basin Plan	Los Angeles Region Water Quality Control Plan
Caltrans	California Department of Transportation
CDFG	California Department of Fish and Game
CFR	Code of Federal Regulations
cfs	cubic feet per second
CMWD	Casitas Municipal Water District
CWA	Clean Water Act
CZARA	Coastal Zone Act Reauthorization Amendments
DO	Dissolved Oxygen
GIS	Geographic Information System
LARWQCB	Los Angeles RWQCB
LAs	Load Allocations
mg/L	milligrams per liter
mg/m^2	milligrams per square meter
MGD	million gallons per day
MS4	Municipal Separate Storm Sewer System
NEAA	National Estuarine Eutrophication Assessment
NMFS	National Marine Fisheries Service
NNE	Nutrient Numeric Endpoints
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NPS	nonpoint source
OVSD	Ojai Valley Sanitation District
Regional Boards	Regional Water Quality Control Boards
SBCK	Santa Barbara ChannelKeeper
SCAG	Southern California Association of Governments
SCCWRP	Southern California Coastal Water Research Project
SWAMP	Surface Water and Ambient Monitoring Program
SWRCB	State Water Resources Control Board
TMDLs	Total Maximum Daily Loads
TN	Total Nitrogen
TP	Total Phosphorous
USEPA	United States Environmental Protection Agency
VCWPD	Ventura County Watershed Protection District
WDRs	Waste Discharge Requirements
WLAs	waste load allocations
WQOs	water quality objectives
WWTP	Waste Water Treatment Plant
µg/L	micrograms per liter

1 Introduction

The Ventura River Estuary and the Ventura River (including its tributaries), located in Ventura County, are identified on the 1998, 2002, 2006, and 2010 Clean Water Act (CWA) Section 303(d) list of impaired waterbodies due to algae, eutrophic conditions, low dissolved oxygen, nitrogen, pumping and water diversions (Table 1-1). The CWA requires the development of Total Maximum Daily Loads (TMDLs) to restore impaired waterbodies to fully support their beneficial uses.

The *Algae, Eutrophic Conditions, and Nutrients Total Maximum Daily Loads for Ventura River and its Tributaries* (Ventura River Watershed Algae TMDL; LARWQCB, 2012) is concurrently being developed to address the algae, eutrophic conditions, low dissolved oxygen, and nitrogen impairments (LARWQCB, 2012). In conjunction with the Ventura River Watershed Algae TMDL, this TMDL provides background information used by the United States Environmental Protection Agency (USEPA) on the pumping and water diversion impairments associated with Ventura River Reach 3 (Reach 3) and Ventura River Reach 4 (Reach 4).

Table 1-1. 2010 CWA Section 303(d) list of impairments for Ventura River Watershed

Water Body Name	Pollutant(s)
Ventura River Reach 4 (Coyote Creek to Camino Cielo Road)	Pumping, water diversion
San Antonio Creek	Nitrogen, indicator bacteria, total dissolved solids
Ventura River Reach 3 (Weldon Canyon to confluence with Coyote Creek at Casitas Vista/Santa Ana Road)	Pumping, water diversion, indicator bacteria
Cañada Larga	Low dissolved oxygen, fecal coliform, total dissolved solids
Ventura River Reach 1 and 2 (Estuary to Weldon Canyon)	Algae
Ventura River Estuary	Algae, eutrophic, total coliform, trash

As documented in this TMDL, the pumping and water diversion impairments of Reach 3 and Reach 4 affect the same beneficial uses addressed in the Ventura River Watershed Algae TMDL (LARWQCB, 2012). This TMDL presents data evaluation and documentation of the impairments observed at Reaches 3 and 4. Our assessment confirms that impairments due to nutrient loading, including low DO conditions, are strongly related to the effects of pumping and water diversions. We find that addressing the nutrient-related water quality impairments will simultaneously benefit the waterbodies impacted from pumping and water diversions. This will result in significant improvement towards protection of the identified beneficial uses for Reaches 3 and 4 of Ventura River. Because the identified impairments are linked to complex sources, a full restoration of Reaches 3 and 4 would require addressing the nutrient-related water quality impairments, as proposed in this TMDL.

1.1 Regulatory Background

Section 303(d) of the CWA requires that "Each State shall identify those waters within its boundaries for which the effluent limitations are not stringent enough to implement any water quality standard applicable to such waters." The CWA also requires states to establish a priority ranking for waters on the 303(d) list of impaired waters and establish TMDLs for such waters.

The elements of a TMDL are described in 40 Code of Federal Regulations (CFR) sections 130.2 and 130.7 and Section 303(d) of the CWA, as well as in the U.S. Environmental Protection Agency guidance (USEPA, 2000). A TMDL defined as the "sum of the individual waste load allocations for point sources and load allocations for nonpoint sources and natural background" (40 CFR section 130.2) such that the capacity of the waterbody to assimilate pollutant loadings (the Loading Capacity) is not exceeded. TMDLs are also required to account for seasonal variations, and include a margin of safety to address uncertainty in the analysis.

The USEPA has oversight authority for the 303(d) program and is required to review and either approve or disapprove the TMDLs submitted by states. In California, the State Water Resources Control Board (SWRCB) and the nine Regional Water Quality Control Boards (Regional Boards) are responsible for preparing lists of impaired waterbodies under the 303(d) program and for preparing TMDLs, both subject to USEPA approval. If the USEPA disapproves a TMDL submitted by a state, USEPA is required to establish a TMDL for that waterbody. The Regional Boards hold regulatory authority for many of the regulatory instruments used to implement the TMDLs, such as National Pollutant Discharge Elimination System (NPDES) permits and state-specified Waste Discharge Requirements (WDRs). In California, the state must develop water quality management plans to implement the TMDL (40 CFR section 130.6).

As part of its 1996 and 1998 regional water quality assessments, the Los Angeles RWQCB (LARWQCB) identified over 700 waterbody-pollutant combinations in the Los Angeles Region where TMDLs would be required (LARWQCB, 1996, 1998). These are referred to as "listed" or "303(d) listed" waterbodies or waterbody segments. A 13-year schedule for development of TMDLs in the Los Angeles Region was established in a consent decree approved between USEPA and several environmental groups on March 22, 1999 (Heal the Bay Inc., et al. v. Browner, et al. C 98-4825 SBA). Following a modification to the consent decree (September 2, 2010), USEPA must establish these TMDLs by March 24, 2013. For the purpose of scheduling TMDL development, the consent decree combined the more than 700 waterbody-pollutant combinations into 92 TMDL analytical units. In accordance with the consent decree, this TMDL addresses the waterbodies in analytical unit 88. This document summarizes the analyses performed and presents the TMDLs for those water quality related impairments linked to pumping and water diversions in the Ventura River Watershed.

1.2 Elements of a TMDL

There are seven elements of a TMDL. Sections 2 through 7 of this document are organized such that each section describes one or two of the elements, with the analysis and findings of this TMDL for that element. The elements are:

- Section 2: Problem Identification. This section reviews the data used to add the waterbody to the 303(d) list, and summarizes existing conditions using that evidence along with any new information acquired since the listing. This element identifies those beneficial uses that are not supported by the waterbody; the water quality objectives (WQOs) designed to protect those beneficial uses; and summarizes the evidence supporting the decision to list each reach, such as the number and severity of exceedances observed.
- Section 3: Numeric Targets. The numeric targets for this TMDL are based upon the WQOs described in the Los Angeles Region Water Quality Control Plan (Basin Plan).
- Section 4: Source Assessment. Describes and identifies the potential point sources and nonpoint sources to the Ventura River and its tributaries.
- Section 5: Linkage Analysis. This analysis shows how the sources of pollutants discharged to the waterbody are linked to the observed conditions in the impaired waterbody.
- Section 6: TMDL and Pollutant Allocations. Each pollutant source is allocated a quantitative load that it can discharge to meet the numeric targets. Point sources are assigned waste load allocations (WLAs) and nonpoint sources are assigned load allocations (LAs). Allocations are designed such that the waterbody will not exceed numeric targets for any of the compounds or related effects. Allocations are based on critical conditions, so that the allocated pollutant loads may be expected to remove the impairments at all times.
- Section 7: Implementation and Monitoring. This section describes the plans, regulatory tools, or other mechanisms by which the WLAs and LAs may be achieved. The TMDL includes a monitoring program to assess TMDL effectiveness and attainment of water quality standards. It also describes special studies to address uncertainties in assumptions made in the development of this TMDL and the process by which new information may be used to refine the TMDL.

1.3 Environmental Setting

The Ventura River Watershed (Figure 1-1) is located in the northwestern portion of Ventura County with a small portion in the southeastern portion of Santa Barbara County. The watershed drains a fan-shaped area of about 220 square miles with an elevation from 6,000 feet to sea level. The Ventura River has several major tributaries, including Matilija Creek, North Fork Matilija Creek, San Antonio Creek, Coyote Creek and Cañada Larga. Matilija Creek (15 miles) drains the Santa Ynez Mountains as it flows to the Matilija Reservoir and the Matilija Dam. The creek continues below the dam for about one half mile before it joins North Fork Matilija Creek. North Fork Matilija Creek, which is about 12 miles long, generally follows Highway 33 in the Los Padres National Forest until it joins Matilija Creek.



Figure 1-1. Major surface waters in Ventura River Watershed

The Ventura River, which is comprised of five reaches, starts at the confluence of Matilija Creek and North Fork Matilija Creek. The Ventura River then flows for about 16 miles in a southerly direction to the estuary and the Pacific Ocean. The Ventura River has intermittent direct discharge to the ocean; longshore transport of sand can cause a sand bar to form at the mouth of the estuary in the late summer and early fall.

The Ventura River Estuary (Reach 1; Figure 1-1) extends from the ocean to approximately 150 meters upstream of the railroad bridge based on tidal influence. The Estuary includes an open water area that is separated from the ocean by a berm that forms during the dry season. The berm is breached during storm events and slowly rebuilds through the summer, sometimes not fully building until August or September. The Estuary is flushed by tides when the berm is open and is dominated by slightly brackish to freshwater when the berm is closed (Ventura River Watershed State of the Watershed Report).

The watershed topography is characterized by rugged mountains in the upper basins transitioning to less steep areas and valleys in the lower watershed. The gradient in the watershed ranges from about 150 feet per mile at the headwaters to about 40 feet per mile near mouth of the river. The U.S. Bureau of Reclamation classifies the watershed topography as fifteen percent valley, forty percent foothill, and forty-five percent mountain. The highest point in the watershed is at 6,025 feet in the Santa Ynez Mountains.

There are two reservoirs within the watershed: Lake Casitas and Matilija Reservoir. Lake Casitas serves as an important source of municipal supply water and is a popular recreation area. The Matilija Reservoir was originally constructed in 1947 to supply water for both agriculture and municipal uses and provide limited flood control. However, over the years large amounts of sediment has been trapped behind the dam and the storage capacity has been significantly reduced. Today the current dam capacity is estimated at less than 500 acre-feet (Tetra Tech, 2012). In 1998, studies were initiated to investigate the effect of removing the dam and the *Matilija Dam Ecosystem Restoration Project* was developed. This project aims to remove both Matilija Dam and the sediment accumulated behind the dam. Removal of the dam would eliminate a barrier to fish passage on Matilija Creek and facilitate the migration, spawning, and rearing of southern steelhead trout.

1.3.1 Land Use

Based on the Southern California Association of Governments (SCAG) Geographic Information System (GIS) database, eighty-five percent of the land use in the Ventura River Watershed (Figure 1-2) is classified as open space and approximately one half of the watershed lies within the Los Padres National Forest. The Matilija Wilderness area, which is managed by the Los Padres National Forest and Ojai Ranger District, is an open space area with access only allowed by foot on marked trails. The remainder of the forest area in the watershed is designated as semi-primitive and has roads leading to recreation areas.

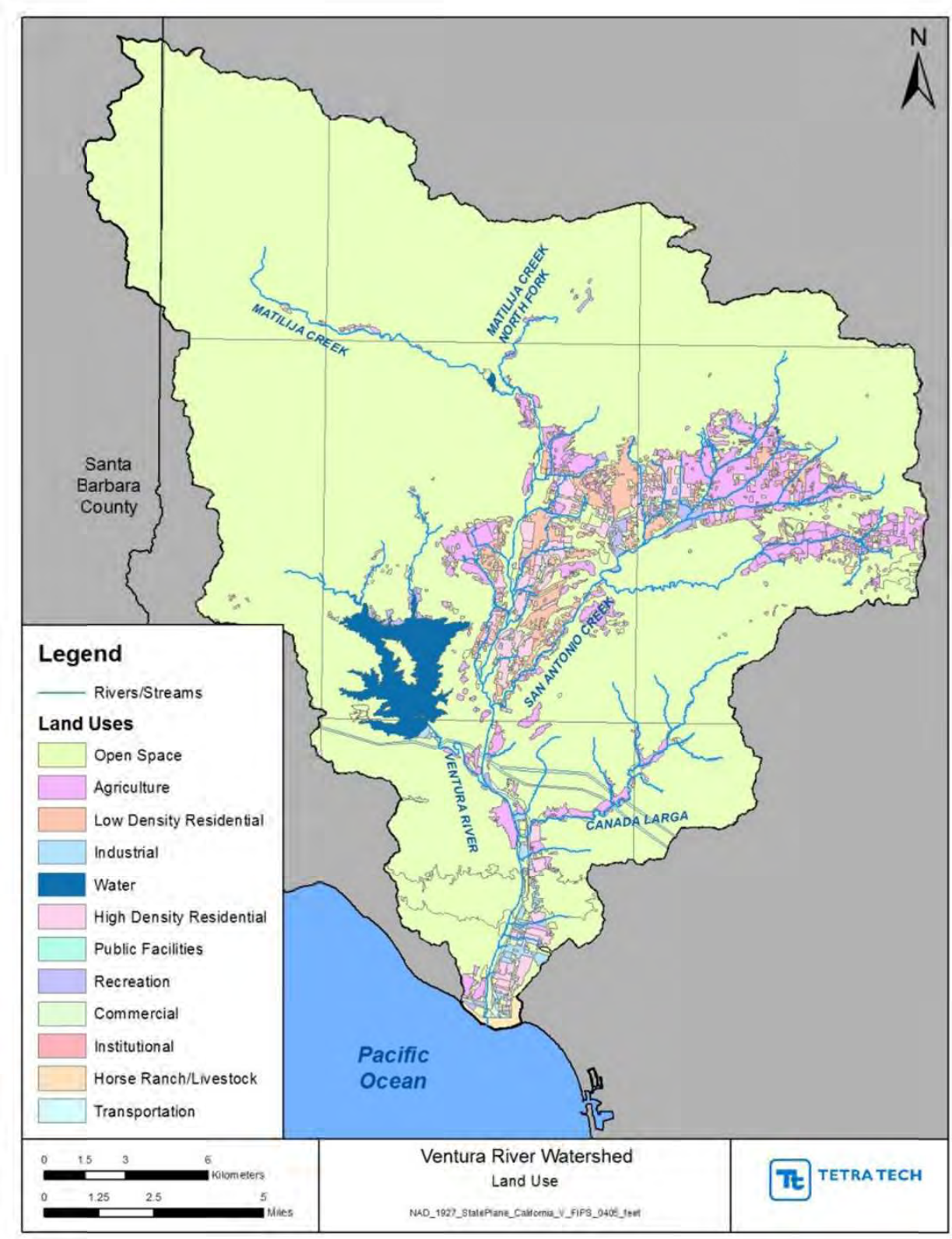


Figure 1-2. Land uses of the Ventura River Watershed

Agricultural land use is the second largest in the watershed at 4.5 percent of the watershed area. The developed area of the watershed is very limited compared to the open space areas, high density and low density residential land uses account for 1.9 and 2.9 percent, respectively. The cities of Ojai and Ventura are the largest urban areas in the watershed and the communities of Casitas Springs, Foster Park, Oak View, Valley Vista, Mira Monte, Meiners Oaks, Upper Ojai and Live Oak Acres are within the unincorporated Ventura County. Industrial areas in the watershed are generally used for oil production and mining and account for 2.1 percent of the watershed area. The remaining land uses (Public Facilities, Recreation, Commercial, Education Institutions, Horse Ranch/Livestock, Transportation, and Mixed Urban) each account for less than 1 percent of the land use within the watershed (Table 1-2).

Table 1-2. Land uses of Ventura River Watershed

Land Use	Area (Square miles)	Percentage (%)
Open Space	186	84.6
Agriculture	9.98	4.5
Low Density Residential	6.33	2.9
Industrial	4.65	2.1
Water	4.17	1.9
High Density Residential	4.08	1.9
Public Facilities	1.17	0.5
Recreation	1.15	0.5
Commercial	0.70	0.3
Education Institutions	0.59	0.3
Horse Ranch/Livestock	0.57	0.3
Transportation	0.39	0.2
Mixed Urban	0.02	<0.1
Total of all classes	**220**	**100**

1.3.2 Hydrology

Flow in the Ventura River varies seasonally due to the Mediterranean climate pattern of wet cool winters from November through March and dry warm summers from April through October. Annual rainfall can vary considerably from year to year. Figure 1-3 presents the annual rainfall from 2005 to 2010 as measured by Ventura County Watershed Protection District at Ojai County Fire Station.

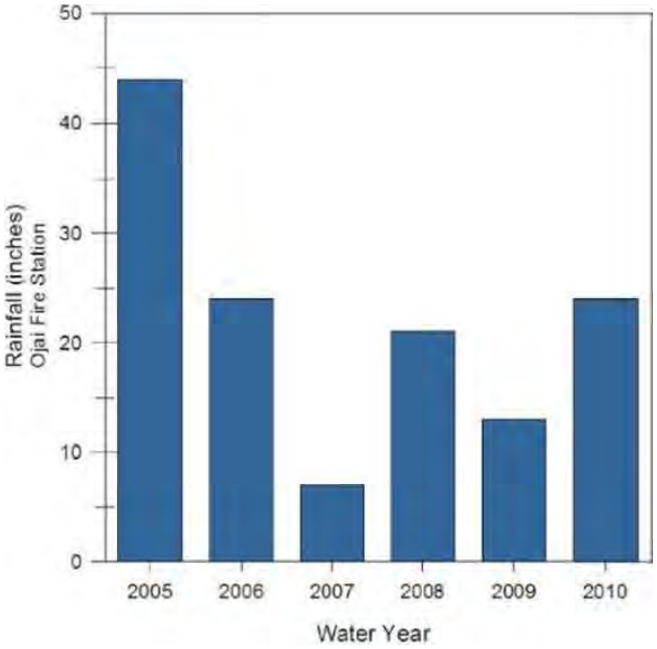


Figure 1-3. Annual rainfall at Ojai County Fire Station (from LACRWQCB, 2012)

High flows predominate during the rainy season, starting in winter through early spring. For example, Figure 1-4 presents flow in the Ventura River at Foster Park from October 2000 – 2008; peak flows occur after winter storm events and the flows decline to very low levels, less than 1 cubic foot per second (cfs), during the summer dry season. However, this pattern is mitigated in the lower Ventura River by effluent from the Ojai Valley Waste Water Treatment Plant (WWTP), which constitutes a majority or, at times, all of the flow in this section of the river during the summers and fall of dry years. The red hydrograph in Figure 1-4 is the flow from Ojai Valley WWTP.

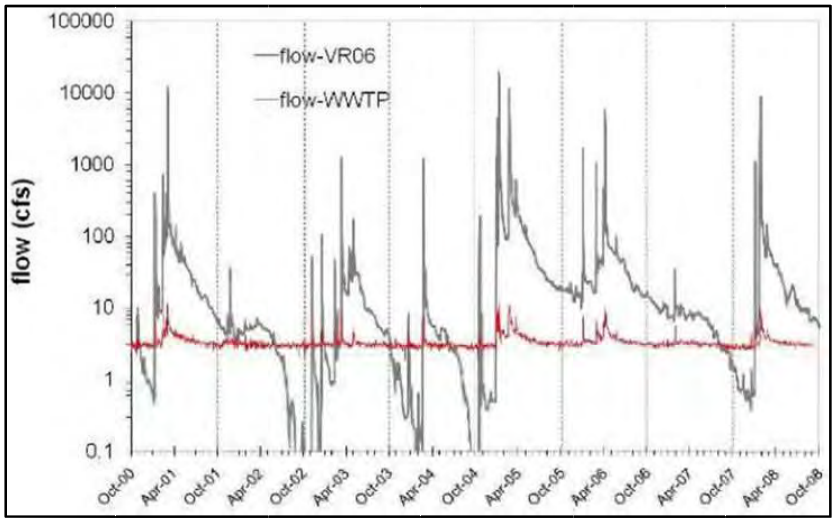


Figure 1-4. Stream flow in Ventura River at Foster Park and effluent discharge from Ojai Valley WWTP (Klose et al., 2009)

In addition to natural variations in flow, based on annual rainfall, flow regimes in the Ventura River have been altered to support water supply. Typically there is perennial flow from the headwaters to the Robles Diversion Dam, which is located about two miles downstream from the Matilija Dam. The Robles Diversion Dam was built in 1958 and is used to divert water from the Ventura River into Lake Casitas via the Robles-Casitas Canal.

Streamflow is highly climate-driven and variable; total precipitation over the course of a year, the frequency and intensity of storms, the proceeding years' rainfall regime (drought, normal, or wet), and other general weather characteristics (i.e., cooler than usual summers, warmer than usual winters) all contribute to any one year's streamflows, which generally follow a pattern of higher flows in the winter/spring and lower flows in summer/fall. Flow in any particular reach of the river is additionally affected by the status of the underlying groundwater basin (whether full, filling, or emptying), the occurrence of natural recharge areas where surface flows will disappear at times, flow between groundwater basins, and the amount of surface or groundwater withdrawals for municipal, domestic, or agricultural uses. Residents, businesses, water utilities, and wildlife in the watershed are reliant on local water ultimately derived from precipitation; there is no infrastructure in place to import water.

The flow downstream of the Robles Diversion Dam to the confluence with San Antonio Creek is intermittent, particularly during the dry summer months. In 2005, the Casitas Municipal Water District (CMWD) constructed a fish ladder at the Robles Diversion Dam to provide fish access to spawning areas that were not previously accessible for over fifty years[1]. Geologic features in the area of Casitas Springs (lower part of Reach 4) causes rising groundwater and provides perennial base flow in the river. The flow in the river is disrupted at Foster Park (which overlies the Upper Ventura River Groundwater Basin) due to subsurface diversions and groundwater extraction. However, the river flow below Foster Park to the estuary increases due to effluent discharges from the Ojai Valley WWTP, flow under and around the Foster Park subsurface diversion, and rising groundwater associated with the Lower Ventura River Groundwater Basin.

1.3.3 Southern Steelhead Trout Life History in the Watershed

Southern steelhead trout are acclimated to the highly variable conditions described above. During average to wet water-years, winter storms breach the lagoons often formed at the mouths of rivers. This provides both access and a signal for the anadromous fish to leave the ocean and start the journey upstream to spawn. In a watershed unrestricted by physical barriers to passage such as dams, the fish would normally transit through the mainstem of the river over several days and eventually spawn where habitat is generally most suitable, in tributaries such as Matilija Creek. Even in barrier-free watersheds, however, smaller than normal winter storms might fail to breach the lagoon leaving the fish to stay in the ocean for another year. Or a large initial storm might breach the lagoon, but not be followed by enough subsequent rainfall to maintain streamflows in order for the fish to transit through the whole system. The steelhead runs for years such as those might be very small to nonexistent. In the Ventura River Watershed, during normal to wet years before dams were constructed that created physical barriers (i.e., prior to 1948), the steelhead run was estimated at 4,000-5,000 individuals. However, following the

[1] http://www.casitaswater.org/lower.php?url=robles-fish-facility

construction of Matilija Dam (located upstream of Reach 3), which cut off access to about half of the prime spawning habitat, and coincident with a drought in the late 1940s, steelhead runs dropped to about 2,000-2,500 individuals. Once the Robles Diversion was constructed around 1959, access to good spawning habitat in the North Fork of Matilija Creek was also cut off and fewer fish were produced that would eventually return to spawn as adults. The steelhead run dropped to around 100 individuals; these individuals had to utilize remaining favorable areas within the mainstem for spawning and rearing. Considering the high flows that can occur in the mainstem with larger storms (relative to flows in the tributaries), access might be attained but spawning and rearing might prove to be impossible at times. Conversely, during dry years, fish unable to transit back downstream to the ocean due to low flows must survive in pools in the mainstem and be subjected to elevated temperatures at times, endure competition with other fish for a decreasing food supply, and survive exposure to predators. Spawning might not occur or be extremely limited due to lack of water at sites appropriate for spawning during wetter years.

2 Problem Identification

This section provides an overview of the pumping and water diversion impairments of Ventura River Reaches 3 and 4. Subsection 2.1 provides background information on the impairments and their relation to water quality. Subsection 2.2 presents the numeric and narrative water quality objectives and beneficial uses applicable to the Ventura River reaches. Subsection 2.3 provides a review of the information used by the Regional Board to list Ventura River Reach 3 and Ventura River Reach 4 for pumping and water diversions and Section 2.4 presents the problem statement.

2.1 Water Pumping and Diversion History in Ventura River Watershed

The Ventura River has gone through a series of hydromodifications since the early 1900s. In 1906, the Foster Park Diversion/subsurface dam was constructed. This dam is downstream of San Antonio Creek near the point at which Reach 4 ends and Reach 3 begins; it also overlies the downstream end of the Upper Ventura River Groundwater Basin. In 1948, the Matilija Dam was constructed in the headwaters of the Ventura River (upstream of Reach 4). In 1958-1959, the Robles Diversion Dam and Robles-Casitas Canal was constructed two miles downstream of the Matilija Dam. The Robles Diversion diverts water from the Ventura River to Lake Casitas via the Robles-Casitas Canal and is located in the most upstream portion of Reach 4. In 2005, the CMWD constructed a fish ladder at the Robles Diversion Dam. Also located within the vicinity of Reach 4 are City of San Buenaventura diversions and City of Ventura municipal wells which draw water from the Ventura River system. In the downstream waters of Reach 4, water supply is replenished by the San Antonio Creek and rising groundwater from Casitas Springs before the Foster Park Diversion. Reach 3 starts downstream of the Foster Park Diversion and receives rising groundwater (from the Lower Ventura River Groundwater Basin), flow under and around the Foster Park subsurface diversion, and water from the Ojai Valley WWTP discharges into the very bottom of the Reach 3.

The Ventura River system has historically experienced highly variable flows that are significantly driven by annual rainfall. This variable and, at times, intermittent flow is illustrated through historical flow records (summarized by Tetra Tech, 2012) and a recently completed historical ecology study (Beller et al., 2011).

Although low and intermittent flows may be natural in the Ventura River system, low flows due to pumping and diversion activities likely exacerbate the flow and water quality conditions in Reaches 3 and 4. The low flows in conjunction with other existing degraded water quality conditions may affect beneficial uses of the two waterbodies. Excess nutrients and eutrophic conditions are present in the Ventura River system. Low and intermittent flows exacerbate the nutrient-related problems (too much algae) and lead to low dissolved oxygen concentrations in the River. The cumulative impacts of these conditions result in the failure to attain several beneficial uses, as described throughout the remainder of this section.

2.2 Water Quality Standards

California water quality standards consist of the following three elements: 1) beneficial uses, 2) narrative and/or numeric water quality objectives, and 3) an antidegradation policy. In California, beneficial uses are defined by the regional boards in their Water Quality Control Plans (Basin Plans). Narrative and numeric objectives are designed to be protective of the beneficial uses specified in the Los Angeles Region Basin Plan.

2.2.1 Beneficial Uses

The Basin Plan for the Los Angeles Regional Board (LARWQCB, 1994) defines twenty (20) beneficial uses for Ventura River and Ventura River Estuary (Table 2-1). These beneficial uses are recognized as existing (E), potential (P) or intermittent (I) uses. The most sensitive beneficial use in the Ventura River Watershed is the cold water aquatic habitat (COLD) use and the associated migratory (MIGR) and spawning and early development (SPWN) uses.

Table 2-1. Beneficial uses of the Ventura River Watershed

Watershed	MUN	IND	PROC	AGR	GWR	FRSH	NAV	REC1	REC2	COMM	WARM	COLD	EST	MAR	WILD	RARE	MIGR	SPWN	SHELL	WET
Ventura River Estuary							E	E	E	E	E		E	E	E	Ee	Ef	Ef	E	E
Ventura River R 1	P*	E		E	E	E		E	E		E	E			E	E	E	E		E
Ventura River R 2	P*	E		E	E	E		E	E		E	E			E	E	E	E		E
Ventura River R 3	P*	E		E	E	E		E	E		E	E			E	E	E	E		E
Ventura River R 4	E	E	E	E	E	E		E	E		E	E			E	Eg	E	E		E
Ventura River R 5	E	E	E	E	E	E		E	E		E	E			E	Eg	E	E		E
Cañada Larga	P*		I	I	I	I		I	I		I	I			E		I	I		
San Antonio Creek	E	E	E	E	E			E	E		E	E			E		E	E		E
San Antonio Creek (above Lion Creek)	E	E	E	E	E	E		E	E		E	E			E		E	E		E
Matilija Creek	P*				E			E	E			E			E		E	E		E
North Fork Matilija Creek	E*	E	E	E	E			E	E		E	E			E	E	E	E		E

Notes:
E = existing uses
P = potential uses
I = intermittent uses
* = Indicates a conditional use as defined in the Basin Plan
e = One or more rare species utilize all ocean, bays, estuaries, lagoons and coastal wetlands for foraging and/or nesting.
f = Aquatic organisms utilize all bays, estuaries, lagoons and coastal wetlands, to a certain extent, for spawning and early development. This may include migration into areas which are heavily influenced by freshwater
g = Condor refuge.

The Ventura River and its tributaries are home to Southern California Steelhead, which was first recognized as endangered by the National Oceanic and Atmospheric Administration (NOAA) National Marine Fisheries Service (NMFS) in 1997. Its status as endangered was reaffirmed in 2006. According to NMFS, the total population of the Southern California Steelhead has dropped from 32,000-46,000 spawning adults to less than 500 (NOAA, 2012). The Ventura River (including Reaches 3 and 4), Ventura River Estuary, San Antonio Creek, Cañada Larga, Matilija Creek and North Fork Matilija Creek, among other tributaries, have been designated by NMFS as critical habitat for the remaining population of the Southern California Steelhead.

The municipal and domestic supply (MUN) use designation applies to Ventura River Reaches 1, 2 and 3, Cañada Larga, and Matilija Creek as a potential (P) beneficial use. This beneficial use, for Ventura River and its tributaries, is indicated with an asterisk in the Basin Plan as a conditional use. Conditional designations are not recognized under federal law and are not water quality standards requiring TMDL development at this time. (See Letter from Alexis Strauss [USEPA] to Celeste Cantú [State Board], Feb. 15, 2002).

The recreation (REC1 and REC2), aquatic life (WARM, COLD, EST, WILD, RARE, MIGR, SPWN, and WET), and water supply (MUN) beneficial uses are likely affected by pumping and water diversion activities in Reaches 3 and 4. The COLD, MIGR, and SPWN beneficial uses are the most sensitive for protection. Low dissolved oxygen concentrations associated with nutrient loading and low flow result, at least in part, in impairments of these beneficial uses.

2.2.2 Water Quality Objectives

The Basin Plan specifies narrative and numeric water quality objectives, both of which apply to Ventura River Reaches 3 and 4 and the Ventura River Estuary. Although the listed impairment is pumping and water diversion, USEPA evaluated the linkages between the water quality related impairments and the water pumping and diversion activities. The related water quality parameters that are directly affected by pumping and water diversion activities are associated with nutrients. Excessive nutrients are linked to low flow conditions through data and trend analyses (see Section 5).

The following narrative objectives apply to this TMDL.

> **Biostimulatory Substances:** *Waters shall not contain biostimulatory substances in concentrations that promote aquatic growth to the extent that such growth causes nuisance or adversely affects beneficial uses.*

The numeric water quality objects applicable to this TMDL are listed below.

> **Dissolved Oxygen (DO):** *At a minimum the mean annual DO concentrations of all waters shall be greater than 7.0 mg/L, and no single determinations shall be less than 5.0 mg/L except when natural conditions cause lesser concentrations.*
>
> *The dissolved oxygen content of all surface waters designated as both COLD and SPWN shall not be depressed below 7 mg/L as a result of waste discharges.*

Ammonia: *In order to protect aquatic life, ammonia concentrations in inland freshwaters shall not exceed the values calculated for the appropriated in-stream conditions shown in tables 3-1 to 3-3 in the Basin Plan.*

For inland surface waters not characteristic of freshwater the four-day average concentration of un-ionized ammonia shall not exceed 0.035 mg/L and the one-hour average concentration shall not exceed 0.233 mg/L.

Determination of Freshwater, Brackish Water or Saltwater Conditions

For inland surface waters in which the salinity is equal to or less than 1 part per thousand 95% or more of the time, the applicable objectives are the freshwater objectives, based on the US EPA "1999 Update of Ambient Water Quality Criteria for Ammonia." (2) For waters in which the salinity is equal to or greater than 10 parts per thousand 95% or more of the time, the applicable objectives are a 4-day average concentration of 0.035 mg un-ionized NH_3/L and a one-hour average concentration of 0.233 mg un-ionized NH_3/L. (3) For waters in which the salinity is greater than 1 but less than 10 parts per thousand, the applicable objectives the more stringent of the freshwater or saltwater objectives.

Nitrogen: *Waters shall not exceed 10 mg/L nitrogen as nitrate-nitrogen plus nitrite-nitrogen (NO_3-N + NO_2 – N), 45 mg/L as nitrate (NO_3), 10 mg/L as nitrate-nitrogen (NO_3-N) or 1 mg/L as nitrite-nitrogen (NO_2-N) or as otherwise designated in Table 3-8.*

Basin Plan Table 3-8 presents the nitrogen objective for Ventura River Reaches 5, 4, 3, and 2 as 5 milligrams per liter (mg/L). This limit also applies to Cañada Larga and San Antonio Creek as tributaries to Reaches 2 and 4, respectively.

This nitrogen objective is established for the protection of the MUN beneficial use and objectives in Table 3-8 of the Basin Plan are waterbody-specific (LARWQCB, 1994). As presented in the next section, the numeric objective of 10 mg/L and the waterbody-specific objective of 5 mg/L is not sufficiently protective to control excessive algal growth and eutrophic conditions in the river and estuary and thus protect the most sensitive beneficial use in the watershed, which is aquatic life (LARWQCB, 2012). Because low flow conditions exacerbate excessive nutrient conditions, this TMDL will focus on attaining nutrient related WQOs to restore beneficial uses. USEPA concludes that a critical step in improving the impaired condition of Reaches 3 and 4 must involve, in a large part, the focus on reducing the excessive nutrient conditions. Although we understand that future actions may involve the removal of Matilija Dam, which may improve the water quality conditions and improve steelhead trout stream habitat access , this TMDL is currently addressing the relevant water quality parameters that are linked to the impairments and impacts to applicable beneficial uses in these Ventura River Reaches. .

2.2.3 Antidegradation

State Board Resolution 68-16, "Statement of Policy with Respect to Maintaining High Quality Water" in California, known as the "Antidegradation Policy," protects surface and ground waters from degradation. Any actions that can adversely affect water quality in all surface and ground

waters must be consistent with the maximum benefit to the people of the state, must not unreasonably affect present and anticipated beneficial use of such water, and must not result in water quality less than that prescribed in water quality plans and policies. Furthermore, any actions that can adversely affect surface waters are also subject to the federal Antidegradation Policy (40 CFR 131.12). The proposed TMDL will not degrade water quality, and will in fact improve water quality as it is designed to achieve compliance with existing water quality standards in order to ensure that beneficial uses of the Ventura River system are fully supported.

2.3 Basis for Listing

The impairment listing for Reach 3 and Reach 4 is for pumping and water diversions. These impairments originally appeared in the 1996 water quality assessment as not supporting aquatic life uses. A specific beneficial use, such as cold freshwater habitat or warm freshwater habitat was not cited although later listing cycles associated the impairments with cold freshwater habitat. The Steelhead Restoration and Management Plan for California (CDFG, 1995, finalized in 1996) was cited as the data source for the Reach 4 pumping and water diversion impairments. This plan made specific references to the Robles Diversion bypass flows and lack of fish passage as contributing factors not supporting beneficial uses such as cold freshwater habitat and migration. The impairment of cold freshwater habitat is a concern for Steelhead Trout which utilize cold waters, for spawning and growth. The Foster Park subsurface diversion located at the downstream end of Reach 4 is not mentioned in the California Department of Fish and Game (CDFG) Report nor is there reference to any specific pumping activities. As for the impairments in Reach 3, no specific information was cited to support the listing for pumping and water diversions. Although the Steelhead Restoration and Management Plan for California was used to support the same impairments in Reach 4 (directly upstream of Reach 3), there is no reference to any portion of Reach 3.

2.4 Problem Statement

A detailed data and trend analysis is presented in Section 5, documenting the linkage between the sources, WQOs, and impairments. The data analysis demonstrates the water quality problems related to eutrophication (note: additional analyses are presented in the Ventura River Watershed Algae TMDL [LARWQCB, 2012]), which are compounded by low flow. It also documents exceedances of the dissolved oxygen and biostimulatory substances WQOs during the growing season (dry, summer season). Decreased summer flows and elevated nutrient concentrations in the Ventura River contribute to the excessive algal biomass growth, which in turn contributes to low DO conditions. Reducing nutrient loading, concurrent with maintaining or increasing existing river flow, are the most effective way to address eutrophication, which is the underlying cause of the impaired aquatic life beneficial uses in the Ventura River system.

Favorable conditions for algal growth depend on the availability of nutrients, the form of nutrients, light, and other factors or “cofactors” including pH, temperature, oxygen, canopy cover, and flow. Favorable algal growth conditions may be enhanced by degraded or reduced riparian habitat where limited canopy cover allows more sunlight and increases water

temperatures. Low flows also contribute to favorable algal growth conditions, which yield more extreme DO conditions. In the Ventura River Watershed, these favorable conditions have been identified as critical conditions that occur during the summer dry season (May 1 to September 30). Under favorable conditions, excess algal biomass increases biological activities such as respiration and photosynthesis which drive significant changes in diurnal dissolved oxygen (DO) concentrations. Nighttime respiration naturally decreases oxygen levels. Increased nighttime respiration caused by eutrophication reduces DO to severely low levels which cause physiological stress on fish as their metabolic demands are being strained. This can severely affect fish specifically with greater oxygen demand requirements, such as Steelhead Trout, by impacting growth, development, swimming, feeding, and reproductive ability of juvenile and adult fish (Carter, 2005; Bjornn and Reiser, 1991).

The extreme diurnal effects of eutrophication and low flows both affect aquatic life as they contribute to low DO concentrations. Unlike high flows, low flows are often marked by low DO due to the lack of turbulence and water depth, which do not replenish oxygen levels in the water. In addition, low flows may contribute to increased temperatures which add to the favorable conditions conducive to eutrophication. Therefore, reduced flows in a eutrophic system exacerbate DO depletion. The DO trends presented in Section 5 document the extent of poor DO conditions during the summer dry season. Low DO contributes to multiple impacts on cold water fish, including decreased growth, increased stress, decreased reproductive success and increased juvenile and adult fish mortality. The changes in the river and estuary ecosystem degrades cold water habitat leading to impaired aquatic life and recreation beneficial uses. This TMDL will address the critical impairments causing the summer dry season exceedance of the biostimulatory substances WQO; by addressing these water quality parameters, this would effectively restore beneficial uses also impaired by pumping and water diversions in Reach 3 and Reach 4 (Table 2-2) because low flow conditions compound the concurrent nutrient impairments.

Table 2-2. Water quality impairments addressed by this TMDL

Waterbody	Impairment
Ventura River Reach 3	Pumping, water diversions
Ventura River Reach 4	Pumping, water diversions

Together these water quality conditions provide a stress on the aquatic environment leading to impaired beneficial uses as demonstrated in a conceptual model for rivers (Figure 2-1 [from LARWQCB, 2012]). In Figure 2-1, decreased flows serve as “Risk Cofactors,” which promote favorable conditions for eutrophication. The conceptual model demonstrates that increased nutrient loading in conjunction with decreased river flows may lead to impairments of several beneficial uses including WARM, COLD, RARE, SPWN, MIGR, REC 1, and REC 2. These beneficial uses, with the exception of WARM, are existing beneficial uses recognized in Ventura River Reach 3 and Reach 4. To protect beneficial uses, limiting nutrient input and maintaining river flow would increase minimum DO concentrations, restore a natural nutrient balance in the system, and overall improve aquatic life habitat; therefore, the pumping and water diversion

impairments addressed in this TMDL should be considered concurrently with the impairments documented in the Ventura River Watershed Algae TMDL (LARWQCB, 2012).

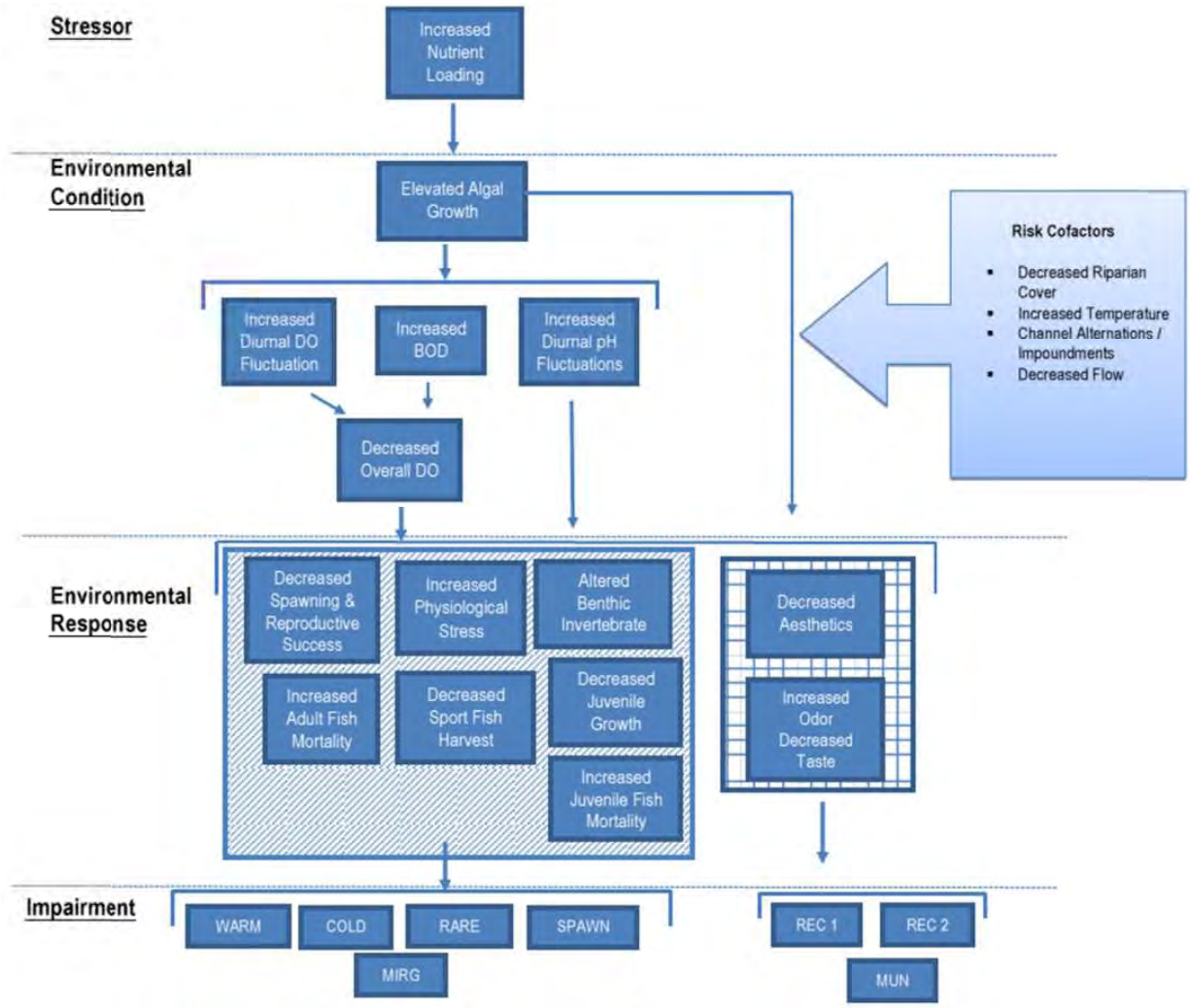


Figure 2-1. Conceptual model for rivers

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3 Numeric Targets

This section identifies numeric targets that will be used to assess attainment of water quality objectives and the protection of beneficial uses. Multiple numeric targets may be used when a single target is not sufficient to fully evaluate attainment of water quality standards and protect beneficial uses. This is especially critical for pumping and water diversion impairments. These TMDLs address those water quality related parameters that are linked to the listed impairments, but, most critically, that will lead to the goal of protection of the identified beneficial aquatic life uses. As noted previously, pumping and water diversion impairments are closely linked to nutrient impairments; therefore, the WQOs in this TMDL are associated with nutrient-related parameters.

Specifically, the numeric targets are expressed as algal biomass, macroalgal percent cover, phytoplankton biomass, dissolved oxygen, and pH (Table 3-1). The DO and pH numeric targets are set equal to the numeric water quality objectives contained in Chapter 3 of the Basin Plan and the numeric targets for algal and phytoplankton biomass and cover are established as a numeric interpretation the water quality condition that will demonstrate attainment of the narrative WQO for biostimulatory substances presented in Chapter 3 of the Basin Plan.

Table 3-1. TMDL numeric targets

Indicator	Numeric Target	Waterbody
Total Algal Biomass	150 mg/m^2 chlorophyll *a* as seasonal average	Ventura River and tributaries
Macroalgal Cover (attached & unattached)	< 30 percent (seasonal average)	Ventura River and tributaries
Phytoplankton Biomass	20 µg/L chlorophyll *a* as seasonal average	Estuary (shallow subtidal area)
Macroalgal Cover	< 15 percent (seasonal average)	Estuary (intertidal and shallow subtidal areas)
Dissolved Oxygen	> 7 mg/L daily minimum	River, Tributaries and Estuary
pH	6.5 – 8.5 (instantaneous value)	River, Tributaries and Estuary

Notes:

Biomass and percent cover indicator targets apply during the dry, summer season. The seasonal averaging period for algal biomass and percent cover is the summer season of May 1 to September 30th. River Indicators are averaged over a sampling reach as required by the SWAMP monitoring protocol Bioassessment SOP 0_2.

Estuary macroalgal cover is measured using 3 transects and evaluating percent cover at 10 random points along each transect. Results are reported as a transect average. See methods used in the Bight '08 Estuarine Eutrophication Assessment (McLaughlin K et. al. Southern California Bight 2008 Regional Monitoring Program: Estuarine Eutrophication Assessment. Southern California Coastal Water Research Project. Costa Mesa, CA.

These targets are consistent with those presented in the Ventura River Watershed Algae TMDL (LARWQCB, 2012). In addition, the Ventura River Watershed Algae TMDL provides detail on the various sources of the WQOs. These sources are summarized in the remainder of this section

and the Ventura River Watershed Algae TMDL should be referenced for specific, technical detail.

The California Nutrient Numeric Endpoints (NNE) framework (Tetra Tech, 2006) was used to set the total algal biomass numeric target. This is a science-based approach to translate the narrative water quality objective for *Biostimulatory Substances* to numeric endpoints that can be applied in a TMDL or other regulatory program. Other biological indicators (macroalgal cover and phytoplankton biomass) are based on the review of available data and scientific literature, while the estuary phytoplankton biomass target is based on the Assessment of Estuarine Trophic Status (ASSETS), developed by the NOAA National Estuarine Eutrophication Assessment (NEAA) (Bricker, 2003). Chlorophyll *a* is used a primary indicator for eutrophic condition.

For the macroalgal percent cover numeric target in the estuary, staff relied upon the classification framework presented in Scanlan (2007). The numeric target for percent cover algal biomass is set at < 15 percent; this target equates to good water quality at moderate amounts of biomass. Both of these estuarine water quality assessment frameworks (ASSETS and Scanlan) were also used by the Southern California Bight 2008 Regional Monitoring Program coordinated by the Southern California Coastal Water Research Project (SCCWRP) to evaluate estuarine eutrophication. The numeric target for dissolved oxygen of 7 mg/L is set equal to the Basin Plan objective for all waters in the Ventura River Watershed designated COLD and SPWN. This target is also applied to the estuary, which is designated SPWN and MIGR because this watershed supports a Southern California steelhead trout cold water fishery.

4 Source Assessment

This section identifies the potential sources of pumping and water diversion and nutrients in the Ventura River Watershed, in particular, those associated with Reaches 3 and 4. In the context of TMDLs, pollutant sources are classified as either point sources or nonpoint sources. Nonpoint sources originate from land runoff, precipitation, atmospheric deposition, drainage, seepage, or hydrologic modification. The term "nonpoint source" is defined to mean any source of water pollution that does not meet the legal definition of "point source" in section 502(14) of the Clean Water Act. A point source, as defined in the Clean Water Act, means any discernible, confined and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft, from which pollutants are or may be discharged. Point sources include discharges from wastewater treatment plants and industrial and municipal storm drain outfalls, but do not include agricultural storm water discharges and return flows from irrigated agriculture.

The major categories of pumping and water diversion and nutrient sources in the Ventura River Watershed are (note: these sources are present throughout the watershed; however, those directly connected to Reach 3 and/or Reach 4 are identified in parentheses below):

Point Sources

- Stormwater and dry weather runoff from storm drains (Reaches 3 and 4)
- Ojai Valley WWTP discharge (Reach 3)
- Other NPDES permits (Reach 4)

Nonpoint Sources

- Runoff from horse and cattle facilities (Reaches 3 and 4)
- Runoff from agricultural areas (Reaches 3 and 4)
- Runoff from undeveloped natural areas (Reaches 3 and 4)
- Onsite wastewater treatment systems (i.e., septic tanks) (Reaches 3 and 4)
- Groundwater discharge (Reaches 3 and 4)
- Atmospheric deposition (Reaches 3 and 4)

Additional Entities Related to Assimilative Capacity

- Robles-Casitas Canal (Reach 4) – operated by CMWD
- City of Ventura municipal wells (Reach 4)
- Foster Park Subsurface Diversion – operated by the City of San Buenaventura (Reach 4)

For the purposes of the source assessment, the Ventura River Watershed was divided into seven subwatersheds based on a GIS layer from Ventura County Watershed Protection District (VCWPD) (Figure 4-1). These subwatersheds are the Upper Watershed, Ventura River Reach 4,

Ventura River Reach 3, the Lower Watershed, San Antonio Creek, Cañada Larga, and Other (Coyote Creek above Casitas Dam).

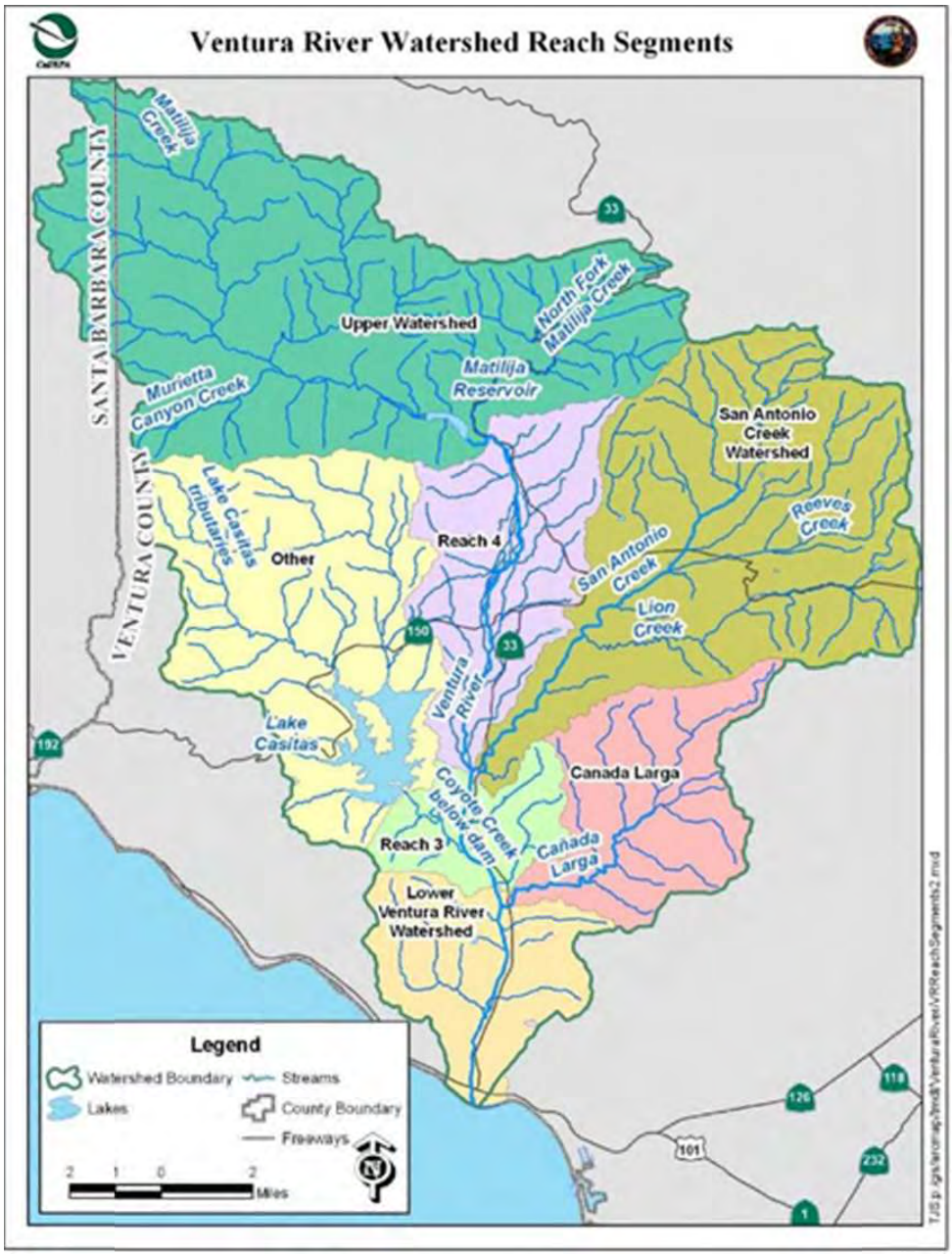


Figure 4-1. Ventura River subwatersheds (from LARWQCB, 2012)

Most water in Lake Casitas goes to consumptive uses or evaporation and is rarely released below the dam (Tetra Tech, 2012). According to CMWD staff, water is only released from the dam when it overflows. The last time water spilled over the Dam was in 1998 (an El Niño year). Thus, water is only released from the dam during very high flows and is released from the top of the reservoir. Therefore, the subwatershed draining to Lake Casitas (named "Other" in the figure

below) is not considered a potential source of nutrients to the Ventura River for the purposes of this source assessment. Land that drains to Coyote Creek downstream of the dam is considered a source and is included as part of the Reach 3 subwatershed.

The Upper Watershed, Reach 4, and San Antonio Creek subwatersheds all contribute loadings to Reach 4. Loads to Reach 3 are comprised of the total loadings to Reach 4 as well as those from the Reach 3 subwatershed.

Land use data (Table 1-2) were obtained from Southern California Association of Governments (SCAG, 2005). The 2005 dataset was used because the 2008 SCAG dataset is based on parcels and can leave out roads, which are considered in this source assessment. In addition, it should be noted that the total area for the 2005 SCAG land use data does not match the total area of the watershed based on the watershed delineation in the GIS maps provided by VCWPD. However, the discrepancy in area is due to differences in the area of open space, which has a negligible effect on the source assessment. The land uses in Table 1-2 were aggregated into 17 categories corresponding to high density residential, low density residential, commercial, industrial, public facilities, education, transportation, mixed urban, open, water, recreation, cropland/improved pasture, orchards/vineyards, nurseries, dairy/intensive livestock, other agriculture, and horse ranches land uses. The acreages of various land uses by subwatershed are presented in Table 4-1 and the subwatersheds draining to Reaches 3 and 4 are shaded.

Table 4-1. Drainage areas (acres) for various land uses in the Ventura River Watershed

Land Use	Upper Watershed	Reach 4	Reach 3	Lower Watershed	San Antonio Creek	Cañada Larga	Other	Total
High Density Residential	0	1,256	28.8	611	680	33.2	0	**2,610**
Low Density Residential	110	1,548	154	20.9	2,160	33.3	24.4	**4,051**
Commercial	0	83	0	207	153	1.69	0	**445**
Industrial	12.6	6.53	25.3	2,766	163	5.08	0	**2,978**
Public Facilities	0	97.1	275	53.6	80.7	127	112	**746**
Education	0	99.3	0.05	52.9	227	0.04	0	**379**
Transportation	0	7.58	44.3	185	6.38	8.40	0	**251**
Mixed Urban	0	0	0	6.30	7.62	0	0	**13.92**
Open	40,838	8,990	4,865	5,950	24,829	11,721	21,827	**119,018**
Water	30.1	10.99	0	6.56	25.52	0	2,596	**2,669**
Recreation	34.4	45.0	28.7	84.1	408	0	134	**735**
Cropland/ Improved Pasture	0	487	171	133	695	335	0	**1,821**
Orchards/ Vineyards	3.41	1,027	101	214	3,009	21.9	25.5	**4,401**
Nurseries	0	0	0	4.33	12.3	0	0	**16.7**

Land Use	Upper Watershed	Reach 4	Reach 3	Lower Watershed	San Antonio Creek	Cañada Larga	Other	Total
Dairy/Intensive Livestock	0	3.93	0	0	0	0	0	**3.93**
Other Agriculture	4.93	19.7	5.98	12.7	82.0	7.65	9.21	**142**
Horse Ranches	9.41	107	9.12	0	207	18.8	5.53	**357**
Total area	**41,043**	**13,787**	**5,709**	**10,307**	**32,745**	**12,312**	**24,734**	**140,638**

Note: Shading indicates subwatershed draining to Ventura River Reach 3 and 4.

The drainage to Ventura River Reaches 3 and 4 (Upper Watershed, Reach 4, San Antonio Creek, and Reach 3 subwatersheds) makes up two thirds of the Ventura River Watershed. Overall, the Reach 3 and 4 drainage area is 85 percent open. Residential (combination of high and low density) and agricultural (sum of cropland, orchards, nurseries, and other agriculture) areas each contribute about 6 percent of the total area.

4.1 Point Sources

The NPDES permits for stormwater and dry weather urban runoff discharges in the Ventura River Watershed are the Ventura County municipal separate storm sewer system (MS4) permit (R4-2010-0108), the statewide California Department of Transportation (Caltrans) MS4 permit (99-06-DWQ), the statewide general industrial stormwater permit (97-03-DWQ), and the statewide general construction stormwater permit (2009-0009- DWQ).

The NPDES permits for wastewater and industrial discharges in the Ventura River Watershed are for the Ojai Valley WWTP (R4-2008-0039) and four general NPDES permits for Foster Park Well Field (R4-2003-0108), Development and Startup Project Well #2 Aquifer Testing (R4-2003-0108), San Antonio Filter Plant (R4-2009-0047), and Golden State Water Company Ojai-Mutual Plant (R4-2003-0108) (Table 4-2).

This source assessment describes point source loadings of nutrients from stormwater and dry weather urban runoff sources and the Ojai Valley WWTP, both of which impact Reach 3 and/or 4. The loadings from the general NPDES permits are not quantified in this source assessment. General Permit No. R4-2003- 0108 is for discharges of groundwater from potable water supply wells to surface waters, including groundwater generated during well purging for data collection purposes, extracted from major well-rehabilitation and redevelopment activities, and generated from well drilling, construction, and development. General Permit No. R4-2009-0047 is issued to the San Antonio Filter Plant for the discharge of filter backwash water, redevelopment and start-up wastewater to San Antonio Creek. The discharges from the general NPDES permits are intermittent and considered negligible for the purposes of this source assessment.

Table 4-2. Summary of NPDES permits in the Ventura River Watershed

Type of NPDES Permit	Total Permits
Ventura County MS4	1
Caltrans MS4	1
General Industrial Stormwater	28
General Construction Stormwater	14
Ojai Valley WWTP (Major)	1
General NPDES Permits	4
Total	**50**

4.1.1 Nutrient Loading from Stormwater and Dry Weather Urban Runoff Sources

Runoff from residential, industrial, commercial, and transportation areas are a significant source of nutrients to the Ventura River. The potential sources of nutrients from urban areas include fertilizer used for lawns and landscaping; organic debris from gardens, landscaping, and parks; trash such as food wastes; and domestic waste. Potential sources of nutrients from highways and transportation land uses include fallen leaves and other vegetation, vehicle exhaust, and atmospheric deposition. Nutrients build up, particularly on impervious surfaces, and are discharged into the receiving waters through storm drains when it rains or by dry weather runoff (i.e., wet-weather and dry-weather loading). The Ventura River Watershed Algae TMDL provides wet- and dry- weather loadings for the subwatersheds (LARWQCB, 2012). These values were used to characterize existing conditions and calculate required reductions.

4.1.2 Nutrient Loading from Ojai Valley WWTP Discharge

The Ojai Valley WWTP has capacity of 3.0 million gallons per day (MGD) of tertiary-treated wastewater. The Ojai Valley Sanitary District serves 5,600 acres of watershed and the treatment plant provides wastewater collection services for an estimated population of 23,000 in the city of Ojai and in the communities of Meiners Oaks, Mira Monte, Oak View, Casitas Springs, and Foster Park.

Based on data collected from 2000 through 2012, Ojai Valley WWTP discharged tertiary-treated wastewater through an outfall at an average rate of 2.1 MGD into Ventura River. The discharge outfall is located approximately 3,000 feet upstream of the confluence of the Ventura River with Cañada Larga. The effluent concentrations of total nitrogen ranged from 2.6 mg/L to 21.1 mg/L, with an average of 5.86 mg/L. Nitrate-N was the dominant nitrogen compound, with concentrations ranging from 1.6 mg/L to 14.1 mg/L, and an average of 4.71 mg/L. Nitrite-N was generally below the detection limit of 0.1 mg/L. Ammonia-N was generally below the detection limit of 0.2 mg/L. Organic-N concentrations ranged from 0.2 mg/L to 12.7 mg/L, with an average of 1.1 mg/L. The total phosphorus concentration ranged from 0.062 mg/L to 5.7 mg/L, with an average of 1.38 mg/L. Phosphate-P was the dominant phosphorus compound, with

concentrations ranging from 0.07 mg/L to 3.8 mg/L, and an average of 1.2 mg/L. (OVSD, 2000-2012). The Ventura River Watershed Algae TMDL estimates nutrient loading to Ventura River from Ojai Valley WWTP by multiplying the average effluent flow with average total nutrient concentrations (LARWQCB, 2012).

4.2 Non Point Sources

Nonpoint sources of nutrients in the Ventura River Watershed include inputs from agricultural lands, horses and livestock, onsite wastewater treatment systems, groundwater, undeveloped open space, wildlife, and atmospheric deposition. An overview of each source and data used to characterize each source is presented in the Ventura River Watershed Algae TMDL (LARWQCB, 2012).

4.2.1 Additional Entities Related to Assimilative Capacity

In addition to these nutrient sources, several sources related to flow withdrawal or diversion contribute to the degraded water quality in Ventura River Reaches 3 and 4. These include the Robles-Casitas Canal (operated by CMWD; near the upstream end of Reach 4), the City of Ventura municipal wells in Reach 4, and the Foster Park Subsurface Diversion – operated by the City of San Buenaventura (near the downstream end of Reach 4). These facilities reduce water in the river and are also likely contributing to the nutrient impairments.

4.3 Summary of Sources

A summary of the source assessment by source/land use type for total nitrogen and total phosphorous is presented in Table 4-3 and Table 4-4, respectively (note: these are consistent with the existing loads for Reaches 3 and 4 presented in the Ventura River Watershed Algae TMDL [LARWQCB, 2012]). Based on available data and an estimation of nutrient loadings, stormwater and dry weather urban runoff via the MS4 contributes a large percentage of the total nitrogen loading to the Ventura River and its tributaries (18% in dry weather and 39% in wet weather). The Ojai Valley WWTP contributes a large portion of nitrogen loading to Reach 3 in dry-weather (50%) but a smaller portion in wet weather (2%). Horses/livestock and agricultural land uses contribute significant nitrogen loading in both dry and wet weather. Open space loading is a significant source of total nitrogen in wet weather (26%) and a smaller source of nutrients in dry weather (8%). Overall, these loads make up 73% of the land use-based and Ojai WWTP total nitrogen loads for the entire watershed. For total phosphorous (Table 4-4), the Ojai WWTP contributes 71% of loading during dry weather, while horses/livestock contribute 20%. Horses/livestock also contribute a significant amount during wet weather (35%), just below wet weather urban runoff at 47%. Collectively, the total phosphorous loads contributing to Reaches 3 and 4 are 71.4% of the watershed-wide land-use based and Ojai WWTP loads.

The Ventura River Watershed Algae TMDL also presents loads associated with groundwater discharge, septic systems, and atmospheric deposition, which cannot be readily separated to the Reach 3 and 4 drainage area (LARWQCB, 2012) and is therefore not included in the table

below. All sources of nutrients are assigned WLAs and LAs in the TMDL. In addition, parties responsible for pumping, water diversions, and withdrawals are assigned LAs.

Table 4-3. Summary of land use-based and WWTP TN loading to Ventura River Reaches 3 and 4

Source Type	TN (lb/year)	% total	% dry	% wet
Dry Weather				
Dry-weather Runoff from Urban Areas	12,111	5%	18%	n/a
Ojai Valley WWTP dry days	33,984	15%	50%	n/a
Dry-weather Runoff from Agriculture	7,132	3%	11%	n/a
Dry-weather Runoff from Horse/Livestock	8,694	4%	13%	n/a
Dry-weather Runoff from Open Space	5,628	3%	8%	n/a
Wet-weather				
Urban Wet-weather Runoff	58,895	27%	n/a	39%
Ojai Valley WWTP wet days	3,491	2%	n/a	2%
Agriculture Wet-weather Runoff	17,046	8%	n/a	11%
Horse/Livestock Wet-weather Runoff	33,987	15%	n/a	22%
Open Space Wet-weather Runoff	39,253	18%	n/a	26%
Total	**220,221**			

Table 4-4. Summary of land use-based and WWTP TP loading to Ventura River Reaches 3 and 4

Source Type	TP (lb/year)	% total	% dry	% wet
Dry Weather				
Dry-weather Runoff from Urban Areas	128	0%	1%	n/a
Ojai Valley WWTP dry days	8,030	30%	71%	n/a
Dry-weather Runoff from Agriculture	28	0%	0%	n/a
Dry-weather Runoff from Horse/Livestock	2,295	8%	20%	n/a
Dry-weather Runoff from Open Space	853	3%	8%	n/a
Wet-weather				
Urban Wet-weather Runoff	7,474	28%	n/a	47%
Ojai Valley WWTP wet days	825	3%	n/a	5%
Agriculture Wet-weather Runoff	1,342	5%	n/a	8%
Horse/Livestock Wet-weather Runoff	5,469	20%	n/a	35%
Open Space Wet-weather Runoff	726	3%	n/a	5%
Total	**27,169**			

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5 Linkage Analysis

To determine the effects of sources on water quality, it is necessary to describe the linkage between the sources, existing water quality, and numeric targets. This linkage defines the assimilative capacity of the receiving water under critical conditions to protect the aquatic life beneficial uses. The linkage analysis for this TMDL uses data analyses to make the connections between flow and nutrient impairments in the Ventura River watershed, particularly Ventura River Reaches 3 and 4. Subsequent TMDLs and allocations are built off of these analyses and utilize the linkage analysis for nutrients presented in the Ventura River Watershed Algae TMDL (LARWQCB, 2012).

USEPA evaluated the critical impacts to the identified beneficial use during the assessment of the listed impairment of pumping and water diversion for Reaches 3 and 4. In reviewing the ecological structure and function of the river reach, it is necessary to consider all the variables that have a direct impact on the impaired condition of the waterbody. In this case, USEPA reviewed all the available data for Ventura River Reaches 3 and 4, and determined that these waterbodies are impaired.

Although the listing is for pumping and water diversion, we investigated the applicable and relevant causes of the impairment. USEPA finds that multiple variables are at play in causing the impaired condition of the reaches; these variables, both nutrient-related and flow parameters, are interlinked. In rivers and streams with low flushing rates, eutrophication becomes a concern when excessive algal biomass develops in response to nutrient enrichment. For example, the Shasta River TMDL was developed to address impairments due to low DO and elevated temperatures, and low stream flow conditions were contributing to the problem in certain segments (NCRWQCB, 2006). In Oregon, the Rogue River TMDL, correlated high stream temperatures with "removal of water" amongst other causes (Oregon Department of Environmental Quality, 2008). The Bitterroot River TMDL described certain impaired segments were due to "low flow alterations" (Montana Department of Environmental Quality, 2011). Also, the Murray Darling River (Australia) is subject to excessive algal blooms during low flow periods (Maier, 2001).

When natural dilution exceeds the growth rate in a waterbody, it becomes challenging for phytoplankton populations to significantly flourish without additional or external sources of phytoplankton (e.g., upstream reservoir) (Dodd, 2007). As such, it is the availability of energy to the food web that defines the health of the community integrity and ecosystem function; and this availability of energy is directly influenced by light, external carbon source, nutrients, food web structure, and the hydrology (Dodd, 2007). It is difficult to determine, in this case, which factor is more critical; instead, it is important to recognize that these factors are intimately linked and the improvement of one factor will likely contribute to the overall benefit of the waterbody's condition, in this case the critical aquatic life habitat.

The following sections discuss and confirm the trends in flow, nutrients, and DO levels throughout the Ventura River watershed in Sections 5.1.1, Section 5.1.2, and Section 5.1.2.2, respectively. Collectively, these water quality conditions play an intertwined role in eutrophic conditions and non-attainment of beneficial uses in the system.

5.1 Data-driven and Geographic-based Analyses

Most current and available data were used to assess flow, nutrient, and dissolved oxygen conditions in the Ventura River watershed. Hydrologic and water quality datasets are identified and discussed below. Flow, nutrients, and dissolved oxygen all play a collective role in eutrophic conditions within the Ventura River system, which is a primary cause of the aquatic life impairment. To examine these parameters under critical conditions, flow and nutrients were evaluated seasonally and DO levels were assessed in pre-dawn samples. Flow and nutrients play a critical role in eutrophication during the dry, summer season and DO levels are lowest during pre-dawn hours while nighttime respiration is at its peak. Evaluating water quality under these critical conditions focuses the protection of beneficial uses during the most sensitive periods.

5.1.1 Flow Trends

For a conservative hydrologic evaluation of the Ventura River system, median winter flows and median summer flows were examined. The stream gages used in this hydrologic assessment are listed in Table 5-1 and illustrated in Figure 5-1. It is important to note that Gage 605 is situated on San Antonio Creek near its confluence with Ventura River. It is therefore representative of flow entering Ventura River, rather than the Ventura River itself. Only gages with daily flows in the Ventura River or at the confluence with a tributary were evaluated in this analysis. Flow in the Ventura River Estuary was estimated based on flow at other gages on the mainstem as well as major tributaries (Tetra Tech, 2012).

Table 5-1. Ventura River stream gages

ID	USGS ID	Name/Location
602B	11115500	Matilija Creek below Dam at Matilija Hot Springs
607	11116550	Ventura River at Robles Diversion (Reach 4)
605		San Antonio Creek
608	11118500	Ventura River near Ventura (Reach 3)
630		Cañada Larga

For a conservative hydrologic evaluation of the Ventura River system, median winter flows and median summer flows were examined, as illustrated in Figure 5-2 and Figure 5-3, respectively. Direct comparison of seasonal median flows is illustrated in Figure 5-4. As shown, flows are generally higher during winter season with the exception of a few sites. In both seasons, flow is reduced at Gage 607 when compared to Gage 602B, which is located a few miles upstream. This gage is downstream of the Casitas-Robles diversion and may reflect the effects of water diversions. There is then a long span on the mainstem without long-term flow data. The next gage downstream is Gage 608, which is downstream of both the Foster Park Diversion and Coyote Creek. Gage 608 demonstrates increased flows when compared to Gage 607, which can be attributed to input from Coyote Creek. Ultimately, the diversions near the end of Reach 4 have minimal impact on overall stream flow during the wet and dry seasons, when considering

groundwater and tributary inputs in that stretch of river. After the Foster Park Diversion, flows generally increase as the river reaches the Ventura Estuary and Pacific Ocean, in part due to the contribution of the Ojai WWTP effluent just upstream of the transition between Reaches 2 and 3; and the increase is also due to discharge from the Upper Ventura River Groundwater Basin into the Lower Groundwater Basin, which rises to the surface, and flow under and around one end of the Foster Park Subsurface Diversion (through a gap due to the diversion not extending completely across the river underground).



Figure 5-1. Flow gages in the Ventura River Watershed



Figure 5-2. Winter median flows within the Ventura River

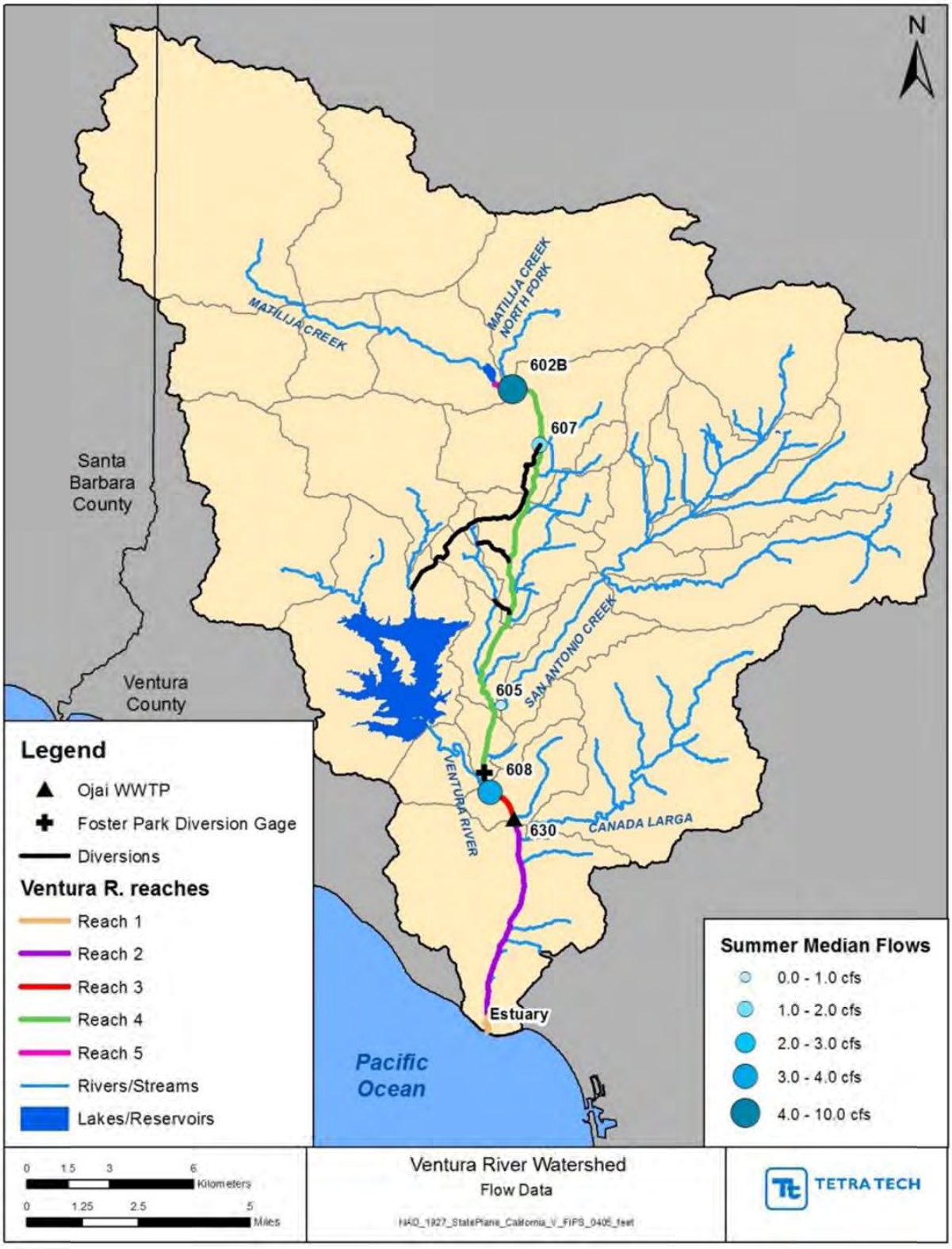


Figure 5-3. Summer median flows within the Ventura River

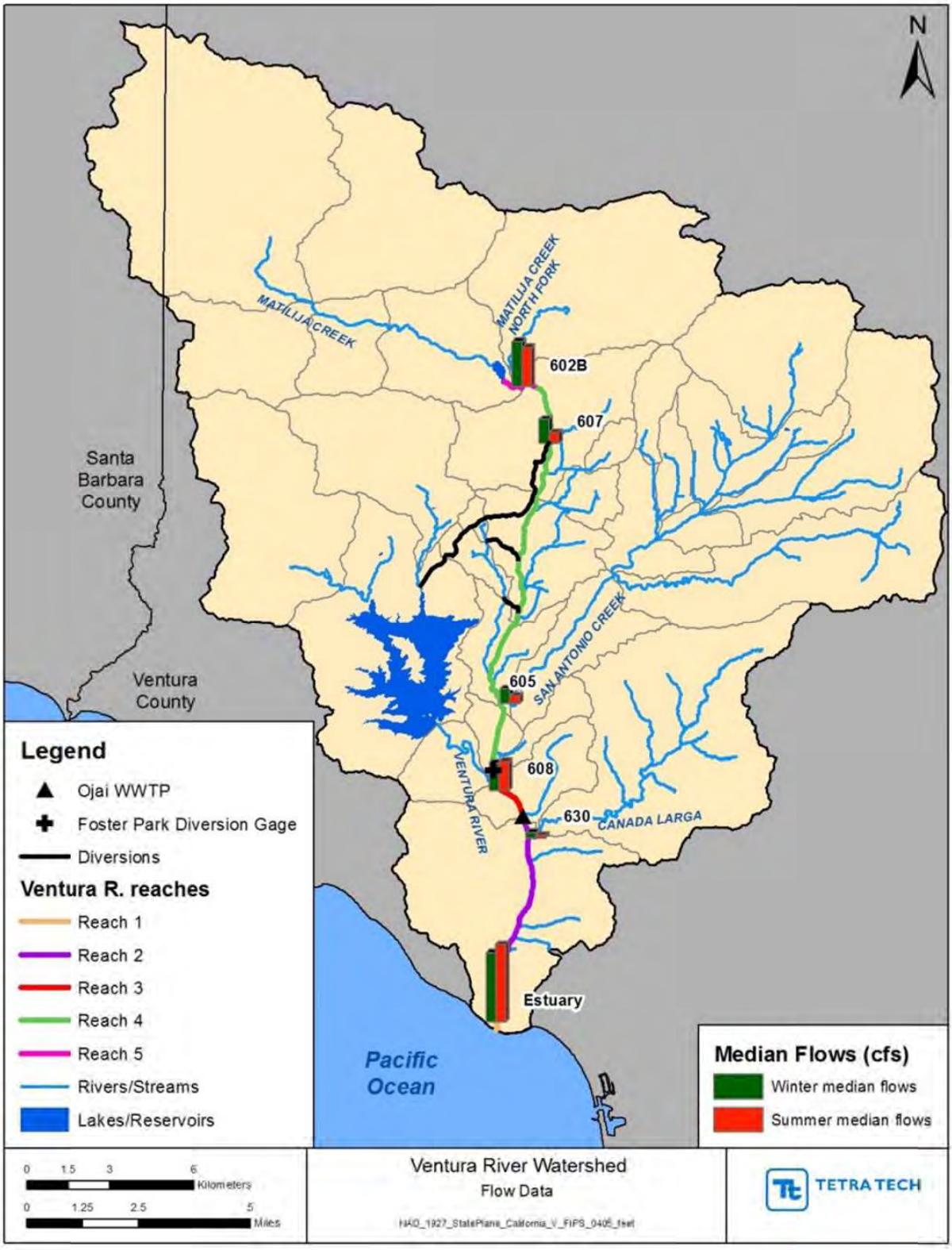


Figure 5-4. Median winter and summer flows

5.1.2 Water Quality Trends

Similar to the flow assessment above, nutrients (nitrate and phosphate) were compared seasonally to illustrate trends between critical and non-critical conditions. Nutrient data were obtained from Santa Barbara ChannelKeeper (SBCK). The period of record spans from 2001 through 2012. To study the low DO trends, pre-dawn DO sampling results were used in this assessment as they represent minimum DO concentrations or truly critical DO concentrations.

Through SBCK monitoring efforts, pre-dawn monitoring has been performed in 2005 and more consistently in 2008 through 2009. These efforts started at a few sites and then expanded to cover several sites as years progressed. Pre-dawn conditions occur naturally each day due to diurnal patterns in temperature and respiration, so while they may be truly critical conditions, they may not illustrate the remainder of the day, which may be more representative of cumulative longer-term impaired conditions. Therefore, additional DO data were evaluated to ensure the full suite of conditions in the watershed is presented.

A list of the monitoring locations and respective water quality data is presented in Table 5-2. Pre-dawn DO data were obtained at both the eastern and western ends of the Ventura Estuary. These values were averaged and presented as a single Ventura Estuary point in the data analysis. Locations of the nutrient and DO monitoring locations are presented in Figure 5-5.

Table 5-2. Water quality monitoring locations in the Ventura River Watershed

Site ID	Site Location	SBCK Data (Nutrients)	SBCK Data (pre-dawn DO)
VRW000	Ventura @ Estuary	x	x
VRW000E	Ventura Estuary, East		x
VRW00W	Ventura Estuary, West		x
VRW001	Ventura @ Main St. Bridge	x	x
VRW002	Ventura @ Stanley Ave	x	
VRW003	Ventura @ Shell Bridge	x	x
VRW03.5	Ventura @ above Cañada Larga confluence	x	x
VRW004	Cañada Larga @ confluence (@ Ventura Ave., @ bicycle Bridge, Lower Cañada Larga)	x	x
VRW005	Cañada Larga @ upper crossing (Upper Cañada Larga)	x	
VRW006	Ventura @ Foster Park	x	x
VRW06.1	Ventura @ above OVSD	x	x
VRW06.3	Ventura @ above S. Antonio confluence (@ San Antonio Creek Confluence)	x	x
VRW007	San Antonio @ Old Creek Rd. (Lower San Antonio Creek)	x	x
VRW007A	San Antonio @ confluence (bike path)	x	x
VRW008	Lion Canyon Creek (Close to VR017, 50m up from San Antonio Creek)	x	

Site ID	Site Location	SBCK Data (Nutrients)	SBCK data (pre-dawn do)
VRW009	Stewart/Fox (Pirie Cr.)	x	x
VRW010	Upper San Antonio Creek	x	x
VRW011	Ventura @ Santa Anna Blvd. (@ Santa Ana Rd Bridge)	x	x
VRW012	Ventura @ Hwy 150	x	x
VRW12.4	Ventura @ below Robles Diversion (VR12.4)	x	
VRW12.5	Ventura @ above Robles Diversion (VR12.5)	x	
VRW12.9	Ventura @ Camino Cielo, below Matilija Forks	x	x
VRW013	Matilija Creek below dam (250m up from confluence)	x	x
VRW014	N. Fork Matilija Creek	x	x
VRW015	Matilija Creek above dam (Upper Matilija)	x	x
VRW017	San Antonio @ Lion Canyon, above or below (Middle San Antonio Creek)	x	x
VRW021	Matilija @ Wilderness Boundary (Upper N. Fork Matilija)	x	
VRW022	N. Fork Matilija @ near FS Campground (At Wheeler Gorge)	x	



Figure 5-5. Water quality monitoring locations in the Ventura River Watershed

5.1.2.1 Trends in Nutrient Concentrations

Similar to the flow assessment, nutrients (represented by nitrate and phosphate) were compared seasonally to illustrate trends between critical and non-critical conditions. Table 5-3 presents the period of record for nutrient data at each monitoring station.

Table 5-3. Monitoring locations in the Ventura River Watershed

Site ID	Site Name	Start Date	End Date
VRW000	Ventura @ Estuary	11/29/2007	3/3/2012
VRW001	Ventura @ Main St. Bridge	11/18/2000	3/3/2012
VRW002	Ventura @ Stanley Ave	5/19/2001	10/4/2008
VRW003	Ventura @ Shell Bridge	5/19/2001	9/1/2008
VRW03.5	Ventura @ above Cañada Larga confluence	5/20/2008	3/3/2012
VRW004	Cañada Larga @ confluence (@ Ventura Ave., @ bicycle Bridge, Lower Cañada Larga)	4/22/2001	3/3/2012
VRW005	Cañada Larga @ upper crossing (Upper Cañada Larga)	5/19/2001	7/12/2008
VRW006	Ventura @ Foster Park	5/19/2001	3/3/2012
VRW06.1	Ventura @ above OVSD	4/2/2011	10/1/2011
VRW06.3	Ventura @ above S. Antonio confluence (@ San Antonio Creek Confluence)	5/18/2008	3/3/2012
VRW007	San Antonio @ Old Creek Rd. (Lower San Antonio Creek)	5/19/2001	9/6/2008
VRW007A	San Antonio @ confluence (bike path)	5/16/2008	3/3/2012
VRW008	Lion Canyon Creek (Close to VR017, 50m up from San Antonio Creek)	5/19/2001	7/11/2009
VRW009	Stewart/Fox (Pirie Cr.)	5/19/2001	3/3/2012
VRW010	Upper San Antonio Creek	5/19/2001	3/3/2012
VRW011	Ventura @ Santa Anna Blvd. (@ Santa Ana Rd Bridge)	4/22/2001	6/5/2010
VRW012	Ventura @ Hwy 150	4/22/2001	6/4/2011
VRW12.4	Ventura @ below Robles Diversion (VR12.4)	9/2/2008	9/2/2008
VRW12.5	Ventura @ above Robles Diversion (VR12.5)	9/2/2008	9/2/2008
VRW12.9	Ventura @ Camino Cielo, below Matilija Forks	6/4/2008	3/3/2012
VRW013	Matilija Creek below dam (250m up from confluence)	4/22/2001	1/10/2009
VRW014	N. Fork Matilija Creek	4/22/2001	3/3/2012
VRW015	Matilija Creek above dam (Upper Matilija)	7/14/2001	3/3/2012
VRW017	San Antonio @ Lion Canyon, above or below (Middle San Antonio Creek)	6/1/2002	3/3/2012
VRW021	Matilija @ Wilderness Boundary (Upper N. Fork Matilija)	3/8/2007	7/9/2008
VRW022	N. Fork Matilija @ near FS Campground (At Wheeler Gorge)	3/8/2007	7/9/2008

Average winter and summer nitrate concentrations are illustrated in Figure 5-6 and Figure 5-7, respectively. The assessment of nutrients in the Ventura River system illustrates that the Matilija Creek and the Matilija Creek North Fork headwaters do not significantly influence nutrient levels in the Ventura River. Comparatively, some of the highest nutrient levels in the system are observed in the headwaters of San Antonio Creek, which may be attributed to the agricultural and developed land uses in that subwatershed. Winter season nitrate concentrations begin to increase throughout Reach 4, upstream and downstream of the San Antonio Creek confluence, while during the dry season, the nitrate concentrations typically increase only below this confluence (Figure 5-6 and Figure 5-7).

Direct comparison between winter and summer season nitrate and phosphate concentrations are presented in Figure 5-8 and Figure 5-9, respectively. Nutrient concentrations are generally higher in the winter season than in the summer season; however, concentrations of nitrate during the summer season are typically similar to the winter season values. Nitrate levels are particularly high in San Antonio Creek, just downstream of the Cañada Larga confluence, and downstream of the Ojai WWTP along Reaches 1 and 2 of the Ventura River. Following the Cañada Larga confluence, summer nitrate levels appear to be higher at VRW003 (Ventura River at Shell Bridge) compared to nitrate levels upstream in the Ventura River and in Cañada Larga itself. Phosphate concentrations appear to be most significant in the downstream reaches of the Ventura River, south of the Cañada Larga confluence and the Ojai WWTP. This may indicate significant phosphate uptake sources throughout other portions of the watershed, but further assessment of sources would be needed to confirm.



Figure 5-6. Average nitrate concentrations during winter season

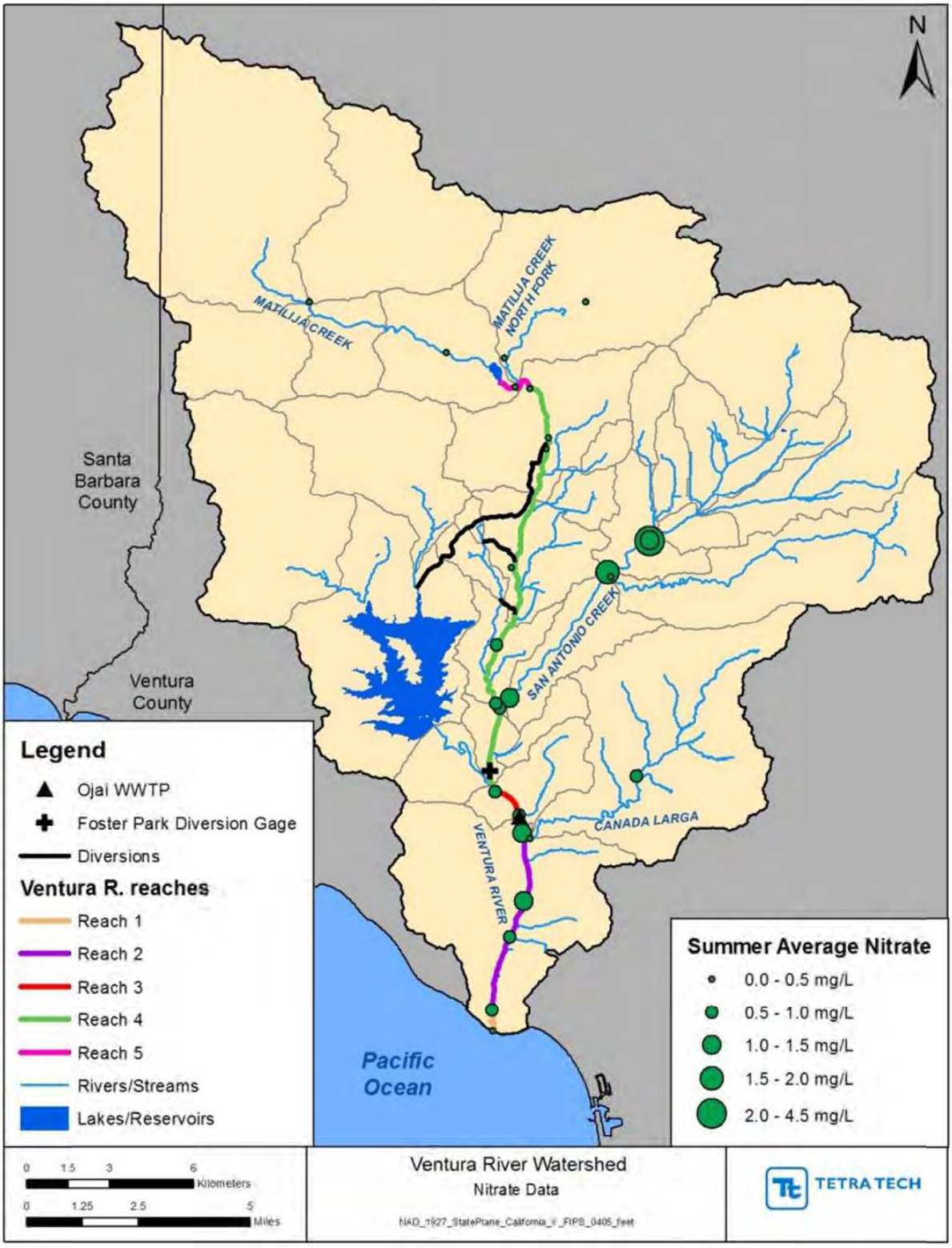


Figure 5-7. Average nitrate concentrations during summer season

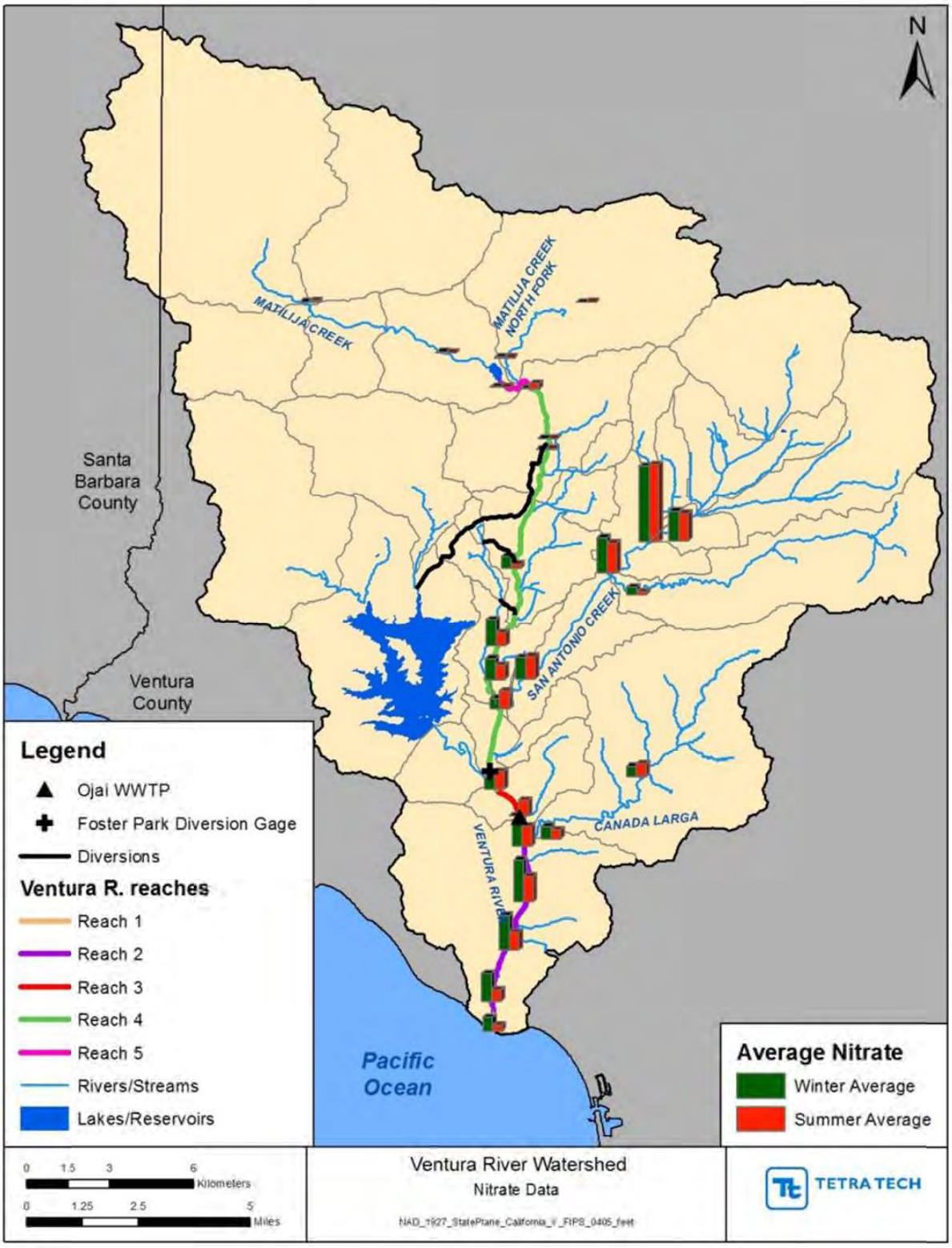


Figure 5-8. Comparison of average winter and summer nitrate concentrations in the Ventura River Watershed

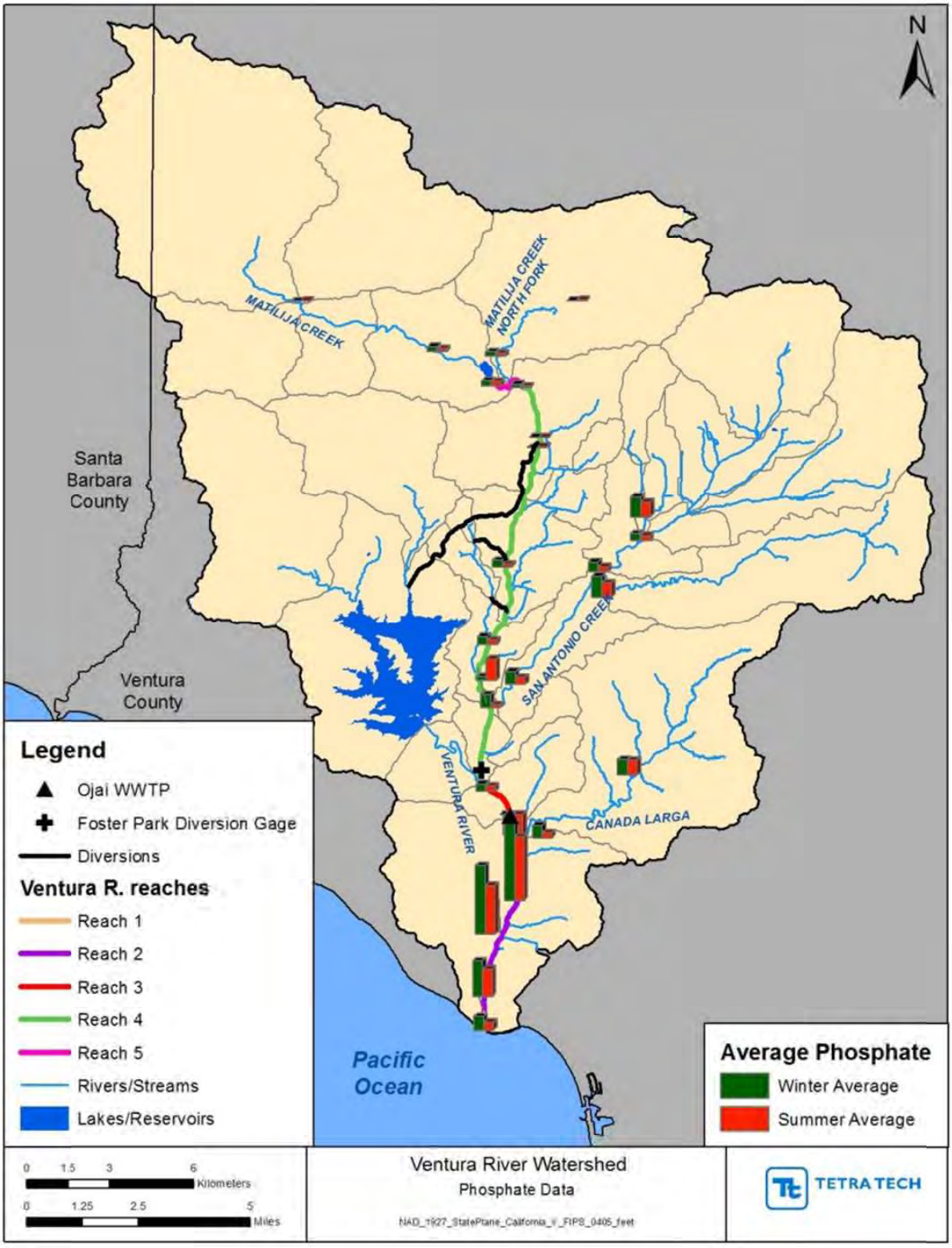


Figure 5-9. Comparison of average winter and summer phosphate concentrations in the Ventura River Watershed

5.1.2.2 Trends in Pre-dawn DO

To study the trends in dissolved oxygen concentration, pre-dawn DO sampling results were used as they represent minimum DO concentrations during the most critical conditions. Through SBCK monitoring efforts, pre-dawn monitoring has been performed starting in 2005 and more consistently in 2008 through 2009. These efforts started at a few sites and then expanded to cover several sites as years progressed. Table 5-4 presents a summary of the pre-dawn DO data, including the number of samples, summary statistics at each station (minimum, maximum, and mean concentration), and a comparison to the DO WQO (number and percentage of excursions).

Table 5-4. Pre-dawn DO monitoring data summary

Site ID	Site Location	Total number of samples	Number of samples below 7.0 mg/L	Percent of samples below 7.0 mg/L (%)	Min (mg/L)	Max (mg/L)	Mean (mg/L)
VRW000	Ventura Estuary (East/West average)	24	12	50.0	5.04	9.07	7.00
VRW000e	Estuary east side	15	5	33.3	5.19	10.27	7.43
VRW000w	Estuary west side	22	11	50.0	3.99	10.03	6.83
VRW001	Ventura River at Main Street	26	13	50.0	4.54	9.16	6.85
VRW003	Ventura River at Shell Road	4	2	50.0	4.93	8.32	6.98
VRW003.5	Ventura River above Cañada Larga confluence	22	5	22.7	5.92	9.09	7.46
VRW004	Lower Cañada Larga	10	0	0.0	7.3	11.08	8.90
VRW006	Ventura River at Foster Park	25	9	36.0	5.28	9.32	7.32
VRW006.1	Ventura River above OVSD	18	2	11.1	6.62	9.23	7.79
VRW006.3	Ventura River above S.A. Creek confluence	20	17	85.0	5.29	8.51	6.41
VRW007	Lower S.A. Creek	14	11	78.6	5.56	8.9	6.57
VRW007A	S.A. Creek at confluence	19	13	68.4	1.87	9.21	5.93
VRW009	Pirie Creek	19	9	47.4	4.91	9.44	7.33
VRW010	Upper S.A. Creek	13	10	76.9	5.7	8.74	6.64
VRW011	Ventura River at Santa Ana Blvd	3	1	33.3	6.73	9.31	7.72
VRW012	Ventura River at Highway 150	7	3	42.9	4.17	9.33	7.05
VRW012.9	Camino Cielo	22	0	0.0	7.49	10.09	8.64

Site ID	Site Location	Total number of samples	Number of samples below 7.0 mg/L	Percent of samples below 7.0 mg/L (%)	Min (mg/L)	Max (mg/L)	Mean (mg/L)
VRW013	Matilija Creek below dam	14	2	14.3	5.82	9.74	7.80
VRW014	N. Fork Matilija Creek	26	1	3.9	6.6	10.55	8.84
VRW015	Matilija Creek above dam	24	3	12.5	6.3	9.81	8.01
VRW017	Middle S.A. Creek	18	2	11.1	6.38	10.05	8.23

Some of the components of the data summary presented in the table above are illustrated in Figure 5-10 and Figure 5-11. As shown in Figure 5-10, pre-dawn DO concentrations fall below the 7.0 mg/L dissolved oxygen WQO at nearly all stations with pre-dawn data. The frequency of observations below WQO is demonstrated in Figure 5-11. In general and as expected, the monitoring stations with considerably low DO values also have elevated nutrient levels. As discussed previously, San Antonio Creek headwaters are responsible for significant nutrient input into the Ventura River. The highest percent exceedances of the DO WQO occur at and around the San Antonio Creek confluence.

5.1.2.3 Trends in Mid-Morning and Afternoon DO

DO data were also evaluated at times later in the day when natural overnight conditions represented in the pre-dawn data no longer impact the receiving waters. These data are illustrated in Figure 5-12 through Figure 5-14. These figures present the percent exceedance and minimum, average, and maximum concentrations at several stations moving upstream to downstream from just above Reach 4 through just below Reach 3 (blue symbols in graphs). In addition, one station is shown for San Antonio Creek (orange symbols in graphs) as this tributary is a significant source of loading to Reach 4. Figure 5-12 shows data at all of these stations, while Figure 5-13 and Figure 5-14 present wet and dry season data, respectively.

In all cases, the average DO concentration was above the 7 mg/L minimum WQO. The upstream station consistently had the most DO exceedances and the lowest minimum DO concentration on the main stem; however, San Antonio Creek had the lowest minimum DO concentration of all stations evaluated (Figure 5-12). Overall, these results show the similar trends to the pre-dawn data. Immediately upstream of San Antonio Creek at Station VRW006.3, no exceedances are observed during dry weather; however, some exceedances are observed during wet weather (which impact the overall results). Then San Antonio Creek enters along Reach 4, with the highest exceedances and lowest minimum DO concentrations. Downstream of San Antonio Creek, at Station VRW006, dry weather exceedances are observed, likely due to the influence of the creek. In summary, during the summer, dry season, which is the critical period represented in this TMDL, exceedances are observed at the station upstream of Reach 4 as well as at several stations along Reaches 4 and 3 (Figure 5-14).

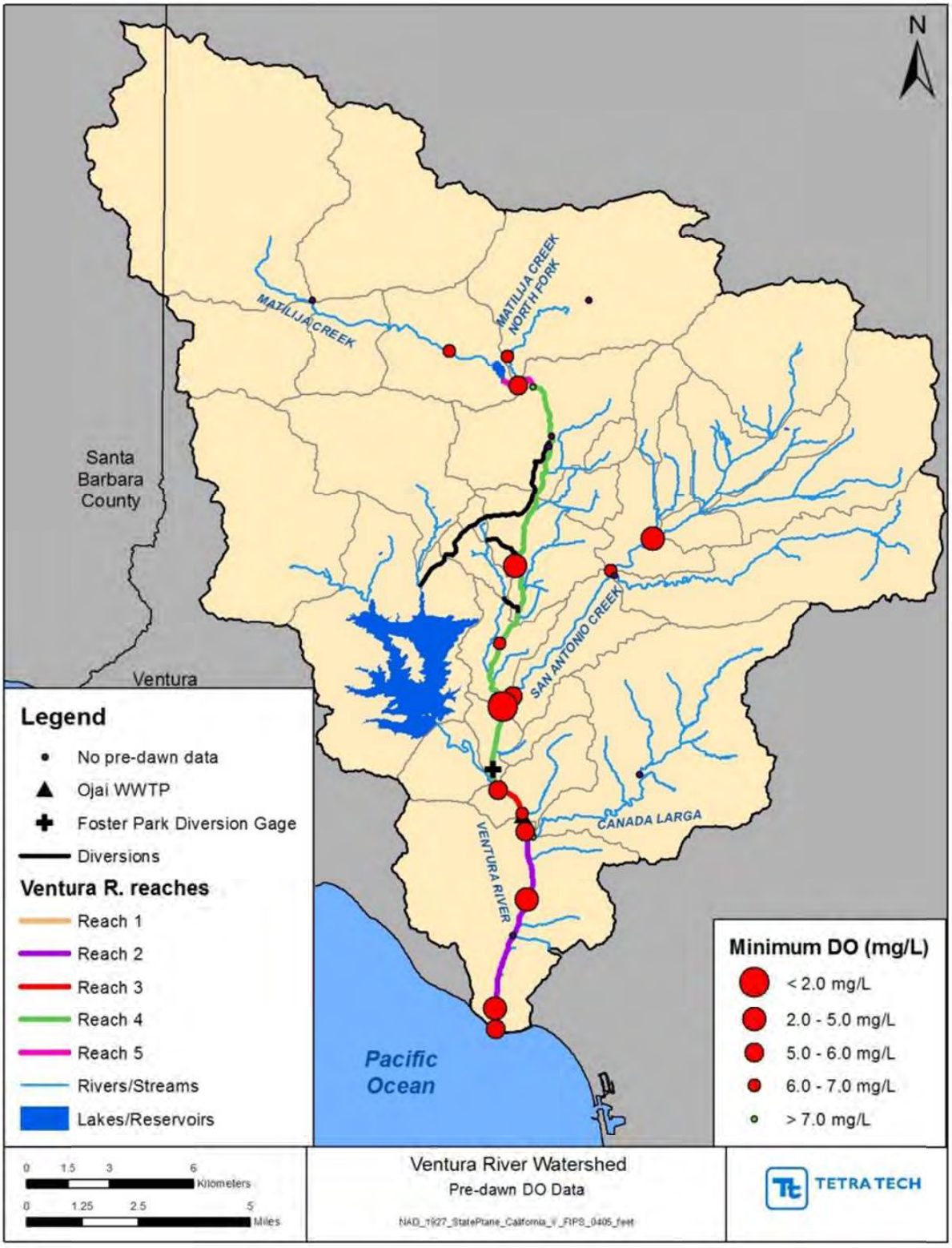


Figure 5-10. Minimum DO concentrations in Ventura River Watershed

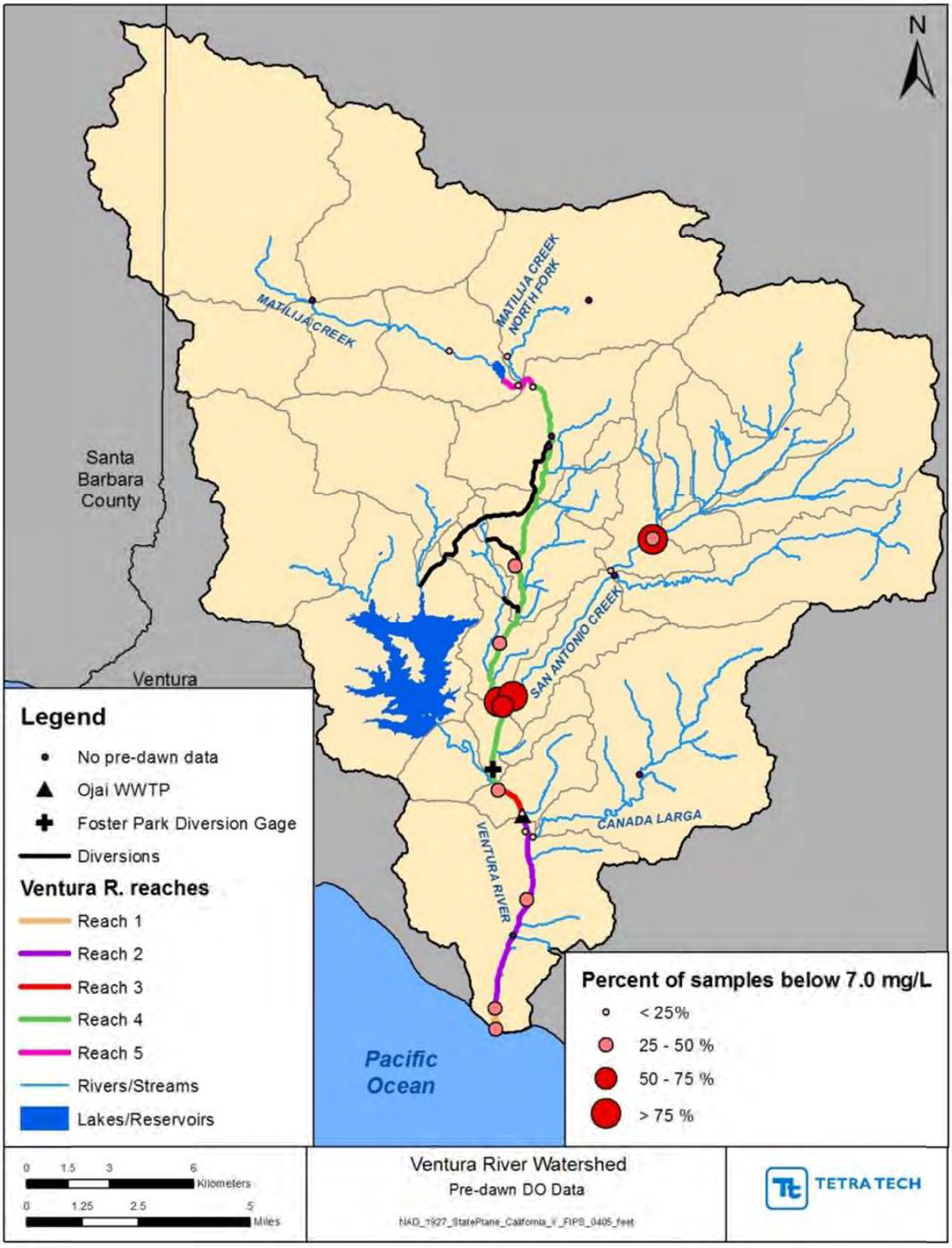


Figure 5-11. Percentage of DO samples below the water quality standard

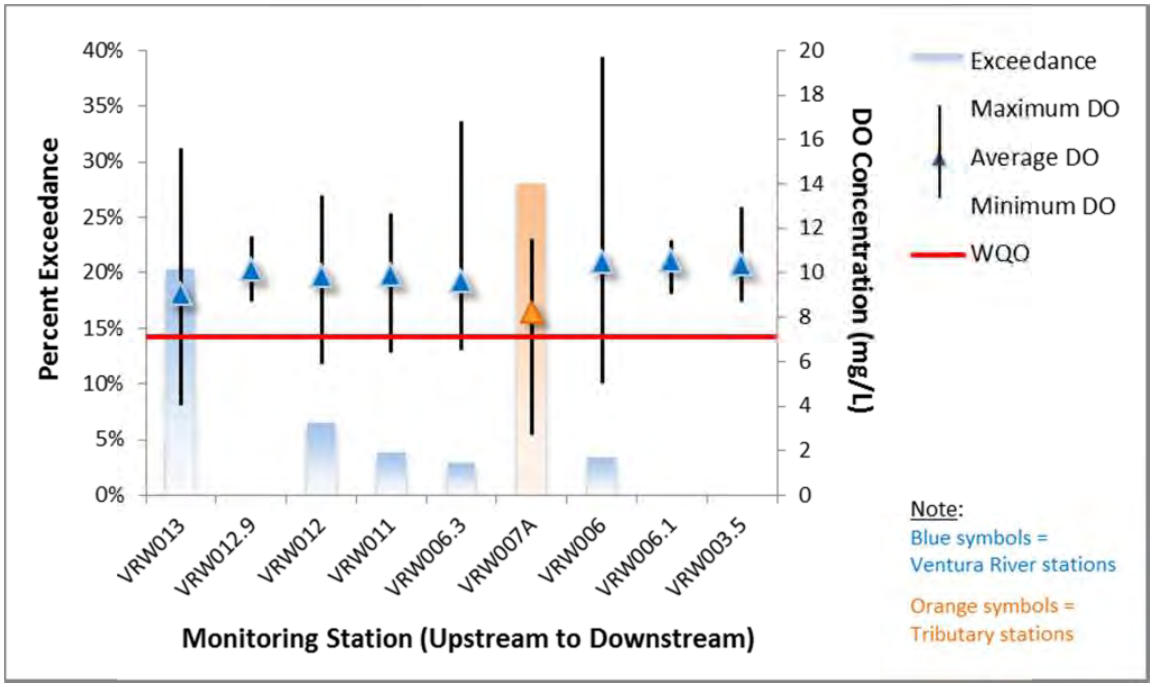


Figure 5-12. Mid-morning and afternoon DO data summary (all data)

Notes on Ventura River station identification numbers: VRW013 = Matilija Creek below Dam; VRW012.9 = Camino Cielo; VRW012 = Hwy 150; VRW011 = Santa Ana Blvd./Bridge; VRW06.3 = above San Antonio confluence; VRW007A = San Antonio Creek at confluence *(tributary to Ventura River)*; VRW006 = Foster Park; VRW006.1 = above OVSD (WWTP); VRW003.5 = above Cañada Larga confluence

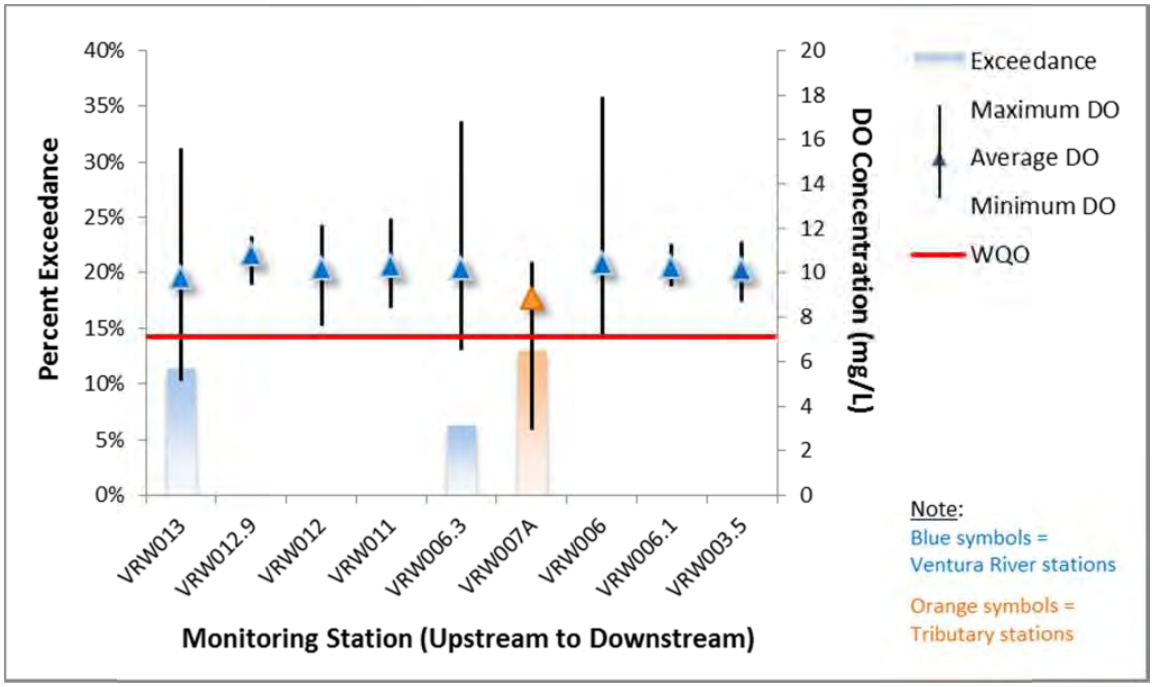


Figure 5-13. Mid-morning and afternoon DO data summary (wet season)

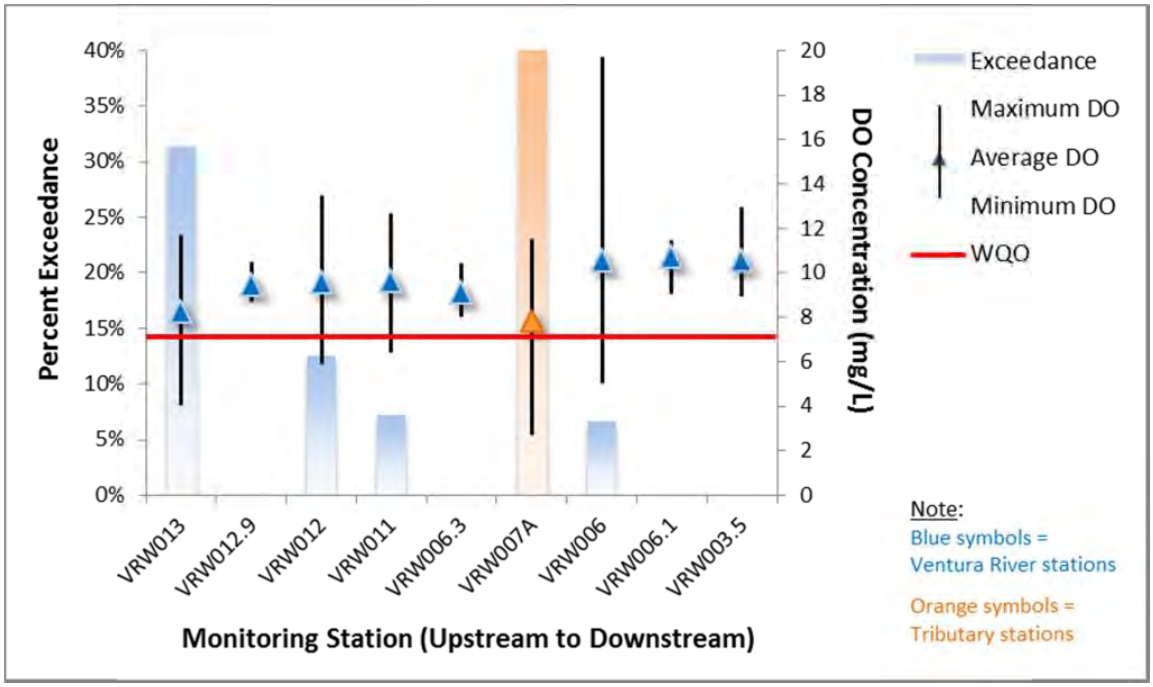


Figure 5-14. Mid-morning and afternoon DO data summary (dry season)

5.2 Summary

In general, we observe between a 25% to over 75% exceedance of the DO objective at Reaches 3 and 4 based on pre-dawn data and a 0 to 20% exceedance rate later in the day along the main stem (including stations immediately upstream and downstream of the impaired reaches). Furthermore, upon review of the pre-dawn and other DO data, it is evident that the critical location during the summer dry season for low dissolved oxygen is near and along Reach 4, immediately around the San Antonio Creek confluence. This area has the potential to significantly impair the aquatic life beneficial uses as survival is threatened in such degraded water quality. When comparing this area with the flow analyses, this stretch of Reach 4 appears to be gaining flow, despite the presence of diversions and well withdrawals; therefore, flow conditions are only a contributing factor to the overall impairments of the aquatic life beneficial uses. As discussed earlier, there are multiple factors that cause the observed impaired conditions of Reach 4, and these results support the conclusion that this TMDL examine all the relevant and applicable parameters responsible for the impaired condition.

The Ventura River Watershed Algae TMDL presents a detailed linkage between nutrient sources and their resulting in-stream concentrations for the Ventura River. This approach utilizes a one-dimensional QUAL2K steady state model that simulates stream transport and mixing processes. Conditions in the estuary were assessed using the NNE BATHTUB spreadsheet modeling tool as well as empirical relationships between nutrient loading and algal biomass (see LARWQCB, 2012 for additional detail). Given that the Ventura River Watershed Algae TMDL focuses on the same beneficial use impairments and the pollutants causing these impairments are related, the results of the Ventura River Watershed Algae TMDL inform this TMDL's calculations.

6 Pollutant Allocations and TMDLs

This section explains the development of the loading capacity and allocations for Ventura River Reaches 3 and 4. USEPA regulations require that a TMDL include waste load allocations (WLAs), which identify the portion of the loading capacity allocated to existing and future point sources (40 CFR §130.2(h)), and load allocations (LAs), which identify the portion of the loading capacity allocated to nonpoint sources (40 CFR §130.2 (g)). TMDLs also include a margin of safety to account for any uncertainty in the analyses. These components are described below.

6.1 Dry-weather Allocations

As established in the problem statement, linkage analysis, and Section 6.3 below, the critical condition for this TMDL is the summer dry season as it is loading in this season that results in water quality impairments to the aquatic life beneficial use. The allocations are thus primarily focused on dry-weather nutrient reductions. Basing the allocations on *dry-weather* loading is a conservative approach to addressing impairments in the *summer dry season* (because dry-weather days occur during both the wet and dry seasons). Dry-weather is defined as a day with no rain. Wet-weather is defined as any day with rain.

Based on the relationship between nutrient concentrations and algal biomass obtained from the freshwater model used in the Ventura River Watershed Algae TMDL, the allowable in-stream concentration of total nitrogen (TN) is equal to 1.15 mg/L (LARWQCB, 2012). To maintain a balance of nutrients for biomass growth and prevent limitation by one nutrient or another, a ratio of total nitrogen to total phosphorus of 10:1 is used to derive the allowable in-stream concentration of total phosphorus equal to 0.115 mg/L (Thomann, Mueller, 1987).

The Ventura River Watershed Algae TMDL provides load-based dry weather allocations based on a modeling scenario that resulted in in-stream nutrient concentrations that attained numeric targets for algal biomass with an explicit margin of safety (LARWQCB, 2012). In this TMDL, the dry weather allocations are consistent with nutrient concentrations in the Ventura River Watershed Algae TMDL; however, for this TMDL, these allocations are strictly concentration-based. This consistent concentration ensures that the allocations identified in the Ventura River Watershed Algae TMDL are met. It also ensures that flow rates cannot be reduced as the only means to achieve the Ventura River Watershed Algae TMDL since maintaining flow rates are important to the pumping and water diversion impairments (which are ultimately interpreted as low flows) and ensuring adequate water is maintained in the stream for fish passage and protection of critical aquatic life habitat.

The concentration-based allocations are presented for each source in Table 6-1 for total nitrogen and total phosphorous. These concentrations are based on the Ventura River Watershed Algae TMDL mass-based allocation scenarios . The mass-based allocations in the Ventura River Watershed Algae TMDL have been translated into concentration-based allocations for this TMDL using assumptions presented in the Ventura River Watershed Algae TMDL Source Assessment and Pollutant Allocations Sections (LARWQCB, 2012). For example, the allowable dry-weather concentration for the Ventura MS4, the Caltrans MS4, and Agriculture are based on

a 50% reduction of existing concentrations in effluent. When existing discharge concentrations are less than required in-stream concentrations (i.e., Ventura MS4 and Agriculture TP existing discharge concentrations), the allocations are set equal to existing discharge concentrations. The percent reductions required are consistent with those in the Ventura River Watershed Algae TMDL.

Table 6-1. Summer dry season WLAs and LAs for TN and TP

Source Type	TN Allowable Dry-Weather Concentration (mg/L)	Percent TN Reduction	TP Allowable Dry-Weather Concentration (mg/L)	Percent TP Reduction
Dry-weather WLAs for Ventura MS4[1]	1.5	50%	0.028	0%
Dry-weather WLAs for Caltrans MS4[1]	2.5	50%	0.25	50%
Dry-weather WLAs for Ojai Valley WWTP[1]	3.00	40%	1.00	28%
Dry-weather WLAs for General Industrial Stormwater Permittees[1]	1.15	---	0.115	---
Dry-weather WLAs for General Construction Stormwater Permittees[1]	1.15	---	0.115	---
Dry-weather WLAs for Other NPDES Permittees[1]	1.15	---	0.115	---
Dry-weather LAs for Agriculture[1]	7.6	50%	0.06	0%
Dry-weather LAs for Horses/Intensive Livestock[2]	1.15	*	0.115	*
Dry-weather LAs for Grazing Activities[2]	1.15	*	0.115	*
Dry-weather LAs for OWTS[2]	1.15	*	---	---

Notes:

"---" indicates that no percent reductions were presented in the Ventura River Watershed Algae TMDL.

1 – Applies at the discharge point.

2 – Applies in-stream.

* Percent reduction in Ventura River Watershed Algae TMDL not based on discharge concentration; thus, allocation here is presented as required in-stream concentration.

6.1.1 Additional Entities Related to Assimilative Capacity

In addition to the identified sources in Table 6-1, this TMDL also identifies those entities responsible for pumping or diverting the surface or subsurface flow from Reaches 3 and 4; these activities have influence on the water quality condition of the listed impaired reaches, as described above. Decreases in surface flow and volume are exacerbating nutrient levels,

contributing to excessive algae and low DO conditions during the summer dry season. In addition, such activities may indirectly lead to overland runoff flow into the stream reaches elsewhere (i.e., redirected flow results in runoff). Such activities decrease the assimilative capacity of the Reaches. At this point, it is imperative to understand the pumping-, diverting-, and/or discharge-related activities that likely have a direct impact on the waterbody's in-stream water quality condition.

USEPA is inviting comments from those entities impacting the assimilative capacity of Reaches 3 and 4 to provide additional information on the direct, indirect or a clear lack of impact from such activities on the water quality condition.

6.2 Wet-weather Allocations

Wet-weather loads do not have a significant impact on receiving water quality in the Ventura River and its tributaries or the Estuary (Section 6.3). Thus, wet-weather allocations are set to attain site-specific concentration-based WQOs from Table 3-8 of the Basin Plan (Table 6-2). There are no site-specific objectives for Reach 1 or the Estuary. For Reach 1 and the Estuary, wet-weather WLAs for stormwater sources are equal to existing water quality in stormwater discharges (maximum TN = 7.4 mg/L from LARWQCB, 2012) and LAs for agriculture and horse/livestock sources are equal to benchmarks of 10 mg/L nitrate-N + nitrite-N in the Agriculture Waiver.

Table 6-2. Wet- weather WLAs and LAs for TN and TP by segment

Reach	Nitrate-N + Nitrite-N (mg/L)
Ventura River Estuary	*
Ventura River Reach 1	*
Ventura River Reach 2	10
Cañada Larga	10
Ventura River Reach 3	5
San Antonio Creek	5
Ventura River Reach 4	5
Ventura River Reach 5	5

*WLAs for stormwater are equal to 7.4 mg/ L TN and LAs for agriculture and horse/livestock sources are equal to 10 mg/L nitrate-N + nitrite-N.

In wet-weather conditions, the biological performance of treatment operations at the Ojai Valley WWTP may be reduced due to lower temperatures and loading may increase due to increased inflows. For nitrogen (TN) discharges of Ojai Valley WWTP, the WLAs in Table 6-3 apply to wet and dry weather conditions in the winter season (October 1st to April 30th). The phosphorus (TP) discharges apply during wet-weather conditions only, which are defined as any day of rainfall.

Table 6-3. Ojai Valley WWTP Winter/Wet-weather WLAs

TN (mg/L)	TP (mg/L)
4.6	2.6

Note: TN WLA applies during winter season; TP WLA applies during wet-weather only.

6.3 Critical Conditions

The critical condition is the period in which the receiving waterbody is most sensitive to the impacts associated with the pollutants of concern. Critical conditions for nutrients and low flow in the Ventura River watershed are during the summer dry season (defined as May 1 to September 30, consistent with the Ventura River Watershed Algae TMDL), especially during consecutive dry-weather days (i.e., days with no rainfall) during the summer dry season. The summer dry season is when flows are the lowest and temperatures are the highest, creating favorable conditions for algae growth, which reduces dissolved oxygen (note: nutrients are loaded year round; however those in the summer dry season are responsible for the aquatic life impairments). The Ventura River Watershed Algae TMDL provides a detailed discussion justifying the selection of the critical condition (LARWQCB, 2012). These calculations are applicable to this TMDL because Reaches 3 and 4 are located with the Ventura River Watershed and it is important to maintain consistency for comparable water quality parameters.

6.4 Margin of Safety

This TMDL establishes a relationship with the analyses presented in the Ventura River Watershed Algae TMDL (LARWQCB, 2012). Therefore, the sources of uncertainty in this TMDL are consistent with that TMDL and are related to the selection of the algal biomass target, the relationship between nutrient concentrations and algal biomass in freshwater river systems and estuaries, the estimate of watershed-based nutrient loading, and the model-predicted water quality conditions in the receiving water. These areas of uncertainty are addressed with both an implicit and explicit margin of safety.

The implicit margin of safety includes conservative assumptions made when estimated watershed-based nutrient loading. For example, the nitrate and phosphate concentrations used to estimate dry-weather loading from agriculture is based upon measured data from an area more intensely farmed (and having tile drains, which concentrate nutrients) than in the Ventura River watershed. The flows for Cañada Larga and San Antonio Creek were higher than the median flows obtained from long-term flow records. This overestimates the loading into the main stem of the river and conservatively predicts main stem nutrient concentrations. Finally, basing the allocations on dry-weather loading is a conservative approach to addressing impairments in the summer dry season.

The explicit margin of safety is calculated as the difference between the model-predicted maximum concentration in-stream after implementation of reduction scenarios and the desired

in-stream concentrations of 1.15 mg/L TN and 0.115 mg/L TP. The resulting explicit margin of safety is 7%. This explicit margin of safety is applied to account for uncertainty in the algal biomass numeric target of 150 mg/m^2 and the relationship between the required in-stream nutrient concentrations necessary to attain this value. This explicit margin of safety also addresses the fact that the model-predicted nutrient concentrations are reflective of median measured concentrations, and do not capture not maximum concentrations.

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7 Implementation

This section describes the regulatory mechanisms that may be used to implement the TMDL and monitoring recommendations. The Ventura River Watershed Algae TMDL provided a detailed implementation plan, including specific regulatory mechanisms, how compliance with WLAs and LAs will be determined, implementation measures that could be used to attain WLAs and LAs and their associated costs, and an implementation schedule (LARWQCB, 2012). Implementation of this plan will attain both the Ventura River Watershed Algae TMDL as well as this TMDL for pumping and water diversions by restoring all applicable beneficial uses.

7.1 Implementation of WLAs

The regulatory mechanisms used to implement the WLAs include the Ojai Valley WWTP NPDES permit, the Ventura County MS4 NPDES permit, the Caltrans MS4 NPDES permit, the general industrial storm water permits, the general construction storm water permits, and other NPDES permits. WLAs shall be incorporated into each permit at the time of permit issuance, modification, or renewal of the permit.

7.2 Implementation of LAs

Two primary federal statutes establish a framework in California for addressing nonpoint source water pollution: Section 319 of the CWA of 1987 and Section 6217 of the Coastal Zone Act Reauthorization Amendments of 1990 (CZARA). In accordance with these statutes, the state assesses water quality associated with nonpoint sources of pollution and develops programs to address nonpoint sources. The *Plan for California's Nonpoint Source Pollution Control Program* (Nonpoint Source [NPS] Program Plan), which became effective in 2000, provides a coordinated statewide approach to dealing with nonpoint source pollution. Federal approval of the NPS Program Plan required the SWRCB to provide assurances that it has the legal authority to implement and enforce the NPS Program Plan. In 2004, the SWRCB adopted the Nonpoint Source Implementation and Enforcement Policy. This policy specified that the regional boards have the administrative permitting authorities to regulate nonpoint sources of pollution through Basin Plan prohibitions, WDRs, and waivers of WDRs. The regulatory mechanisms that will be used to implement LAs for each source category are described below.

7.3 Potential Implementation Strategies

The TMDL requires responsible parties to attain WLAs and LAs for nutrients to prevent excessive algal growth and maintain adequate dissolved oxygen concentrations and pH values in the Ventura River and its tributaries. There are many implementation alternatives available to reduce nutrient loading. Rather than a single treatment solution, a combination of implementation measures may be required to reduce nutrients and algae and improve DO to

acceptable levels. Several potential implementation strategies could be used to comply with the TMDL. Many of the structural and nonstructural BMPs to address nutrient loadings could also reduce the loading of other contaminants, which could assist in meeting the requirements of other existing or future Ventura River TMDLs. Additionally for this TMDL, care should be taken during BMP planning and implementation to monitor river flows (with the goal of maintaining existing flows, especially with higher quality water or increasing river flow rates) to ensure water levels are high enough to support fish populations, most notably the southern steelhead trout.

Additional potential implementation strategies are described below.

7.3.1 Compliance With and Enforcement of State Water Rights Laws

USEPA recognizes the State has additional options for implementation strategies through compliance and enforcement with water rights laws. The State Water Resources Control Board, Division of Water Rights, enforces water rights laws in the State. The Division may be involved at several levels of effort as resources allow.

Briefly, the State has authority over water rights appropriation. USEPA recommends that the State review the specific activities in Reaches 3 and 4 and ensure that the appropriate requirements are met in the waterbody (e.g., holders cannot store water during a wet time period; riparian right holders must file with the Division of Water Rights and describe their activity and any impacts resulting from their activity; failure to report can be subject to civil liabilities). As described earlier, the stream ecosystem is connected to water quality, habitat, hydrology, and physical structure conditions; all related activities, such as the general activity of pumping and diverting, are critical to ensuring that the water quality impairments can be achieved.

7.3.2 Maintenance of Bypass Flow Pattern at Robles Diversions

It is USEPA's current understanding that the Casitas Municipal Water District (Casitas MWD) currently operates a bypass flow pattern at the Robles Diversion (located in the upper part of Reach 4); this was established in the National Oceanic and Atmospheric Administration (NOAA) Fisheries Biological Opinion (BO) of 2003. The BO established bypass flows to closely duplicate the surge of water in the river coincident with large storms followed by the gradual reductions in flows during the days after rain ceases. The owner of the dam is the federal Bureau of Reclamation (BOR). If transfer of ownership from the BOR to Casitas MWD occurs at any point in the future, the terms of the BO would no longer apply. USEPA strongly recommends that voluntary maintenance of this bypass flow pattern be continued by Casitas MWD since this would continue support of steelhead trout in this reach.

7.3.3 Continued Implementation of the 2004 Ecosystem Restoration Feasibility Study

In reviewing the past implementation related activities relevant to Reaches 3 and 4, we are aware that multiple stakeholders in the watershed (led by the Ventura County Watershed Protection District and the U.S. Army Corps of Engineers) participated in the completion of the Ecosystem Restoration Feasibility Study in 2004, which recommended removal of Matilija Dam. Various

implementation activities described in the plan has been occurring, including the demolition of the dam; however, this is dependent on the availability of future federal funding. All entities, including the numerous local stakeholders, state and federal agencies involved view this latter action as the critical long-term action to restore access to steelhead trout to prime spawning and rearing habitat in the upper watershed.

7.3.4 Development of a Groundwater Management Plan

The Upper Ventura River Groundwater Basin supports about 160 active domestic, municipal, and agricultural wells. Water agencies in the Upper Basin have stated that a Groundwater Management Plan would be beneficial to the larger impairment condition for the region.

7.3.5 Identification and Completion of Studies to Evaluate the Effects of Pumping on Habitat

The identification and completion of studies to evaluate the effects of pumping on surface flows and water levels in pools would be useful to our overall understanding of the many variables that impact water quality condition in these Reaches. A regular monitoring program associated with documenting water quality, flows, depth of pools, and presence/absence of steelhead trout should be established to evaluate better the relationship between condition and flow.

7.3.6 Implementation of Actions from NOAA Fisheries' 2012 Southern California Steelhead Recovery Plan

Implementation of additional conservation actions to address threats to steelhead trout recovery described in NOAA Fisheries' 2012 Southern California Steelhead Recovery Plan should be evaluated.

7.4 Monitoring Program

Monitoring programs will be designed to measure improvement in water quality and pollutant load reductions. The monitoring program has several goals including:

- Determine attainment of numeric targets;
- Determine compliance with the waste load and load allocations;
- Monitor the effect of implementation actions on river and estuary water quality.

The TMDL monitoring program is intended to be consistent with the Ventura River Watershed Algae TMDL (more details are provided in LARWQCB, 2012) and consists of three components: 1) receiving water monitoring, 2) discharger monitoring, and 3) optional special studies. All monitoring requirements may be included in subsequent permits or other orders and are subject to LARWQCB Executive Officer approval.

7.4.1 Receiving Water Monitoring

Responsible parties (Ojai Valley Sanitation District [OVSD], VCWPD, Ventura County, the City of Ojai, the City of Ventura, Caltrans, and agricultural dischargers) are responsible for developing and implementing a comprehensive monitoring plan to assess numeric target attainment and measure in-stream nutrient concentrations. Responsible parties are encouraged to work together to submit a join watershed-wide plan. Once horse and livestock owners are enrolled in the regulatory mechanism to implement their LAs, they shall participate in the implementation of the watershed-wide monitoring plan or submit their own plan. The monitoring plan should outline a program to sample for algal biomass, algal percent cover, nutrients (total and dissolved), *in situ* water quality parameters (dissolved oxygen, pH, temperature, electrical conductivity), and flow for the river and estuary. The monitoring procedures/methods, analysis, and quality assurance shall be Surface Water and Ambient Monitoring Program (SWAMP) comparable, where appropriate. The sampling frequency and locations must be adequate to assess beneficial use condition and attainment of applicable water quality objectives. At a minimum, for algal biomass and percent algal cover, the monitoring frequency shall be once per month in the summer dry season (May 1st to September 30th). After two years, if a significant difference between monthly algal biomass measurement is not observed, algal biomass monitoring may be reduced to three times during the summer dry season, during the months of May, July and September. DO and pH shall be measured continuously for two week periods on a quarterly basis. Continuous monitoring of DO shall occur during the months of May and September in the 2nd and 3rd quarters. All other parameters, including algal percent cover, shall be monitored monthly.

Existing receiving water monitoring conducted under other programs can be leveraged to assist in meeting these monitoring requirements. Responsible parties may build upon existing monitoring programs in the Ventura River watershed when developing the receiving water quality monitoring plan for this TMDL. Receiving water monitoring requirements shall be incorporated into the regulatory mechanisms for each responsible party upon issuance, renewal, or modification. The responsible parties may continue to coordinate a watershed-wide monitoring program to meet this requirement in order to fulfill permit, WDR, or waiver requirements. Receiving water monitoring shall continue beyond the final implementation date of the TMDL unless the Executive Officer approves a reduction or elimination of such monitoring.

7.4.2 Discharge Monitoring

Discharge monitoring will assess attainment of the waste load and load allocations. Discharge monitoring shall be required through the regulatory mechanisms used to implement the waste load and load allocations. Discharge monitoring shall be conducted as specified by the LARWQCB (2012). The monitoring procedures/methods, analysis, and quality assurance shall be SWAMP comparable, where appropriate, and are subject to approval by the LARWQCB Executive Officer.

7.4.3 Special Studies

Responsible parties within the watershed may conduct optional special studies designed to refine waste load and load allocations and numeric targets. The results of special studies and monitoring may be used to revise numeric targets and allocations, if supported, when the TMDL is reconsidered. The following are potential special studies.

- Build upon the algal biomass and total nitrogen relationship established in the 2008 University of California at Santa Barbara (UCSB) Study (Klose et al., 2009) and collect data to support the establishment of reach-specific relationships.
- Confirm the conclusion that an algal biomass target of 150 mg/m^2 is fully protective of aquatic life and minimizes the risk of low DO events.
- Collect additional source assessment information and model input data to refine model predicted relationships between watershed loading and in-stream nutrient concentrations.
- Investigate the influence of OWTS on surface water quality.
- Collect data to support development of an estuary model, which takes into account tidal influence, the dynamics of macroalgae and phytoplankton growth, residence time, and breaching conditions.
- Collect continuous flow and DO data in Reach 4 to characterize these parameters within stream inputs and outputs, especially near and downstream of San Antonio Creek.
- Investigate potential sources of low DO exceedances with Reach 4, especially near and downstream of San Antonio Creek.

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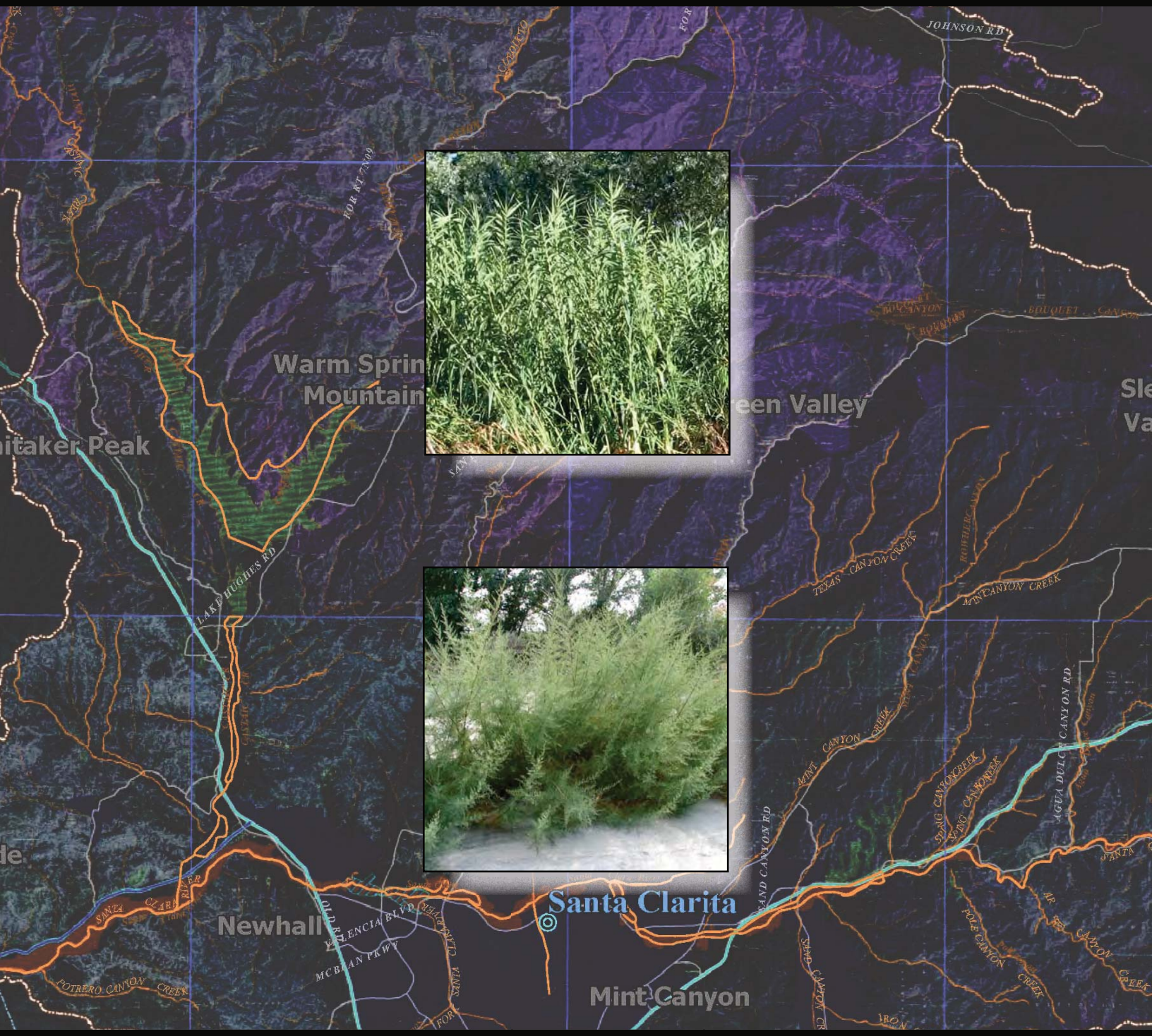
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Upper Santa Clara River Watershed
Arundo and Tamarisk Removal Program

Long-Term Implementation Plan



Ventura County Resource Conservation District

June 2006

Funding for this project has been provided in full through an Agreement with the State Water Resources Control Board (SWRCB) pursuant to the Costa-Machado Water Act of 2000 (Proposition 13) and any amendments hereto for the implementation of California's Nonpoint Source Pollution Control Program. The contents of this document do not necessarily reflect the views and policies of the SWRCB, nor does mention of trade names or commercial products constitute endorsement of recommendation of use.



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List of Acronyms

Acronym	Definition
°C	degrees Celsius
af	acre-feet
BMP	best management practices
Cal-IPC	California Invasive Plant Council
CDFA	California Department of Food and Agriculture
CDFG	California Department of Fish and Game
CA Parks/Rec	California Department of Parks and Recreation
CDPR	California Department of Pesticide Regulations
CESA	California Endangered Species Act
CLWA	Castaic Lake Water Agency
CNDDB	California Natural Diversity Database
CNPS	California Native Plant Society
CWA	Clean Water Act
DWR	California Department of Water Resources
FSCR	Friends of the Santa Clara River
FESA	Federal Endangered Species Act
I-5	Interstate 5
LADPW	Los Angeles County Department of Public Works
LBV	least Bell's vireo
MBTA	Migratory Bird Treaty Act
MOA	Memorandum of Agreement
MOU	Memorandum of Understanding
msl	mean sea level
NGO	Non-governmental organization
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
QAPP	Quality Assurance Project Plan
RGP	Regional General Permit
RWQCB	Regional Water Quality Control Board
SARMB	Santa Ana River Mitigation Bank
SCARP	Santa Clara River Arundo and Tamarisk Removal Program
SCREMP	Santa Clara River Enhancement Management Plan
SMSLRWMA	Santa Margarita and San Luis Rey Watershed Weed Management Area
SWFC	Southwestern willow fly-catcher
TADN	Team Arundo del Norte
TDS	total dissolved solids
TMDL	Total Maximum Daily Load
TNC	The Nature Conservancy
USACE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
USEPA	U.S. Environmental Protection Agency
USFS	U.S. Forest Service
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
UWCD	United Water Conservation District
VCRCD	Ventura County Resource Conservation District
VCWPD	Ventura County Watershed Protection District

1.0 Introduction

The Santa Clara River, its tributaries and the associated riparian or streamside habitats comprise one of the largest natural river systems remaining in Southern California. From its headwaters in the San Gabriel Mountains southeast of the town of Acton, the Santa Clara River flows for 84 miles through Los Angeles and Ventura Counties terminating at the Pacific Ocean. The 45-mile-long portion of the Santa Clara River and its associated tributaries within Los Angeles County are referred to as the upper Santa Clara River. Along this 45-mile course, the Santa Clara River crosses national forest land, large areas of moderately developed private rural lands, the growing City of Santa Clarita, and then large tracts of rural farmland extending west to the county line. The Santa Clara River and this wide range of adjacent land uses comprise the upper Santa Clara River watershed, which consists of approximately 680 square miles (409,703 acres). This area is the focus of this plan (Fig. 1).

The Santa Clara River system and its associated riparian habitats provide major benefits to the surrounding communities including groundwater recharge, urban and agricultural water supplies, flood conveyance, visual relief, and recreational opportunities. In addition, the types of habitat found in the Santa Clara River's riparian areas are some of the most valuable wildlife habitat in the state, in terms of both species diversity and abundance, and provide habitat for some of the state's most threatened and endangered wildlife. This is especially important since as much as 90 percent of California's streamside riparian plant communities have been eliminated by urban and agricultural development within the last 150 years.

Many threats to the values provided by the Santa Clara River and its tributaries exist, including encroaching development, increased urban runoff, and the spread of invasive, non-native plant species. According to the National Invasive Species Council, an "invasive species" is one that is a) non-native (or alien) to the ecosystem under consideration and b) whose introduction causes or is likely to cause economic or environmental harm or harm to human health.

In particular, the widespread establishment of two invasive plant species, arundo or giant reed (*Arundo donax*) and tamarisk or salt cedar (*Tamarix* spp.), severely threaten many of the benefits described above. Arundo and tamarisk have spread throughout the Santa Clara River and most of its tributaries such that their presence has become an important issue for the surrounding communities. Major stands of arundo dominate large sections of the Santa Clara River in northeast Los Angeles County and are even more prevalent throughout its reaches in Ventura County. Although less prevalent than arundo, tamarisk is also a major problem in some portions of the central and upper watershed.

1.1 Project Goals and Scope

The Upper Santa Clara River Watershed Arundo/Tamarisk Removal Plan (SCARP) provides guidance to stakeholders for implementing procedures to remove invasive, non native plants. The primary objective of the plan is to guide and facilitate the implementation of arundo and/or tamarisk removal projects within the upper Santa Clara River watershed of Los Angeles County. The SCARP is a living document and will be updated periodically as new technologies become available, regulations change, or new resources/issues are identified. The project focus is on approximately 16,300 acres of land within the 500 year floodplain of the Santa Clara River and its primary, secondary, and tertiary tributaries. These floodplain lands, particularly within the banks and channel of the Santa Clara River and tributaries, are where arundo and tamarisk infestations are primarily contained and where the bulk of removal activities would occur. However, additional activities such as access, equipment staging and storage, transport, and disposal may occur outside of the 500-year floodplain.

The SCARP has been prepared to provide local landowners, municipalities, environmental groups, and other stakeholders with a broad menu of available techniques for removal of arundo and tamarisk and guidance in obtaining proper permits and approval for removal. The SCARP also provides best management practices (BMP) needed to minimize impacts during removal projects. The following factors have been researched and considered in the development of this SCARP:

- Potential eradication methods
- Degree of infestation
- Existing habitats
- Presence of threatened and/or endangered species
- Access
- Land use
- Current work being conducted or planned
- Pre-existing environmental agency restrictions and permits
- Funding mechanisms in place and strategies for future funding

Taken together, these factors provide a framework for a long term eradication program and associated monitoring to facilitate removal of arundo and tamarisk from the upper Santa Clara River watershed and the restoration and maintenance of natural, economic and community values provided by these riparian corridors.

1.2 Project Partnerships

The lead agency directing this effort is the Ventura County Resource Conservation District (VCRCD). The VCRCD is one of 104 resource conservation districts in California and is a special district of the state, which receives funding primarily through grants. The VCRCD manages a diversity of programs including soil and water conservation projects, wildlife habitat enhancement and restoration, control of invasive plants species, and environmental education. The VCRCD has developed a Memorandum of Understanding (MOU) to show support for the SCARP project. The agencies and organizations, which have completed MOUs, are listed below and copies of these memoranda are included in Appendix 1:

- Antelope Valley Resource Conservation District (AVRCD)
- U.S. Forest Service (USFS)
- U.S. Fish and Wildlife Service (USFWS)
- Los Angeles County Department of Public Works (LADPW)
- Los Angeles Agricultural Commissioner's Office
- Los Angeles County Weed Management Area (LAWMA)
- City of Santa Clarita
- Friends of the Santa Clara River (FSCR)
- UC Cooperative Extension

A SCARP Working Group was also created to collaborate with the various organizations and agencies within the upper Santa Clara River watershed. There are many other local agencies and organizations assisting in various ways with the SCARP development such as the U.S. Army Corps of Engineers (USACE), the California Department of Fish and Game (CDFG), the U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS), the Los Angeles Regional Water Quality Control Board (RWQCB), the Ventura County Arundo Task Force, and the Ventura County Watershed Protection District (VCWPD).



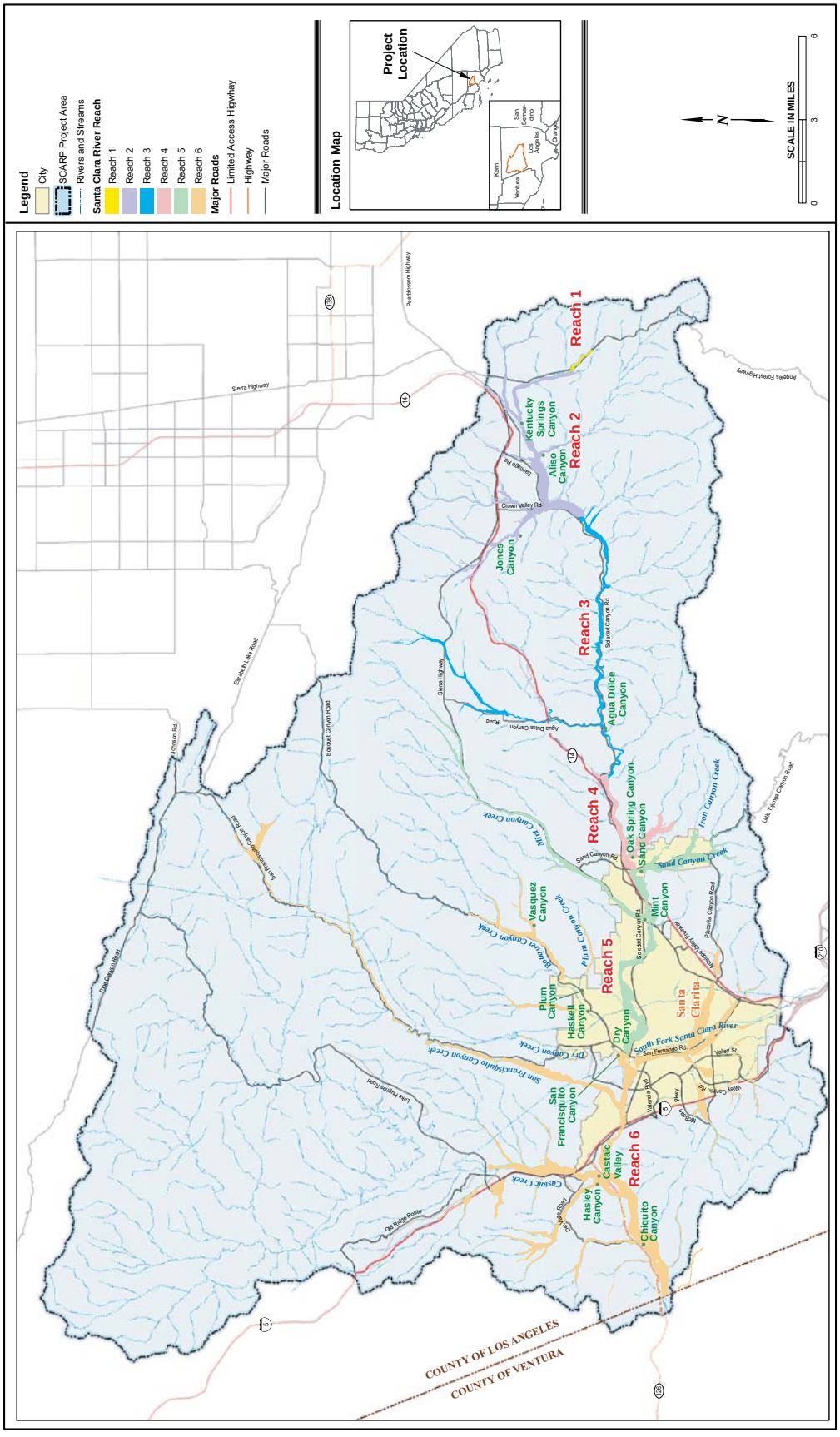


Figure 1: SCARP Project Location and Associated River Reaches



2.0 Invasive Plant Species in the Santa Clara River

The primary focus of this program is the eradication of arundo and tamarisk from the upper Santa Clara River watershed. These species and the issues involving them are described in detail in this section. However, the SCARP recognizes that arundo and tamarisk are not the only non-native invasive plant species present in the upper Santa Clara River watershed. Other species that have been identified within the project area are listed at the end of this chapter. While the removal methods described in Chapter 10 are primarily listed for their use in eradicating arundo and tamarisk, they may also be used to remove other non-native invasive species that are encountered during an individual eradication project.

2.1 Background on Arundo

Arundo is native to the Mediterranean region. It was introduced to the western United States by Spanish settlers in the early 1800s and became abundant in the Los Angeles River by the 1820s. It was historically used as a windbreak, soil stabilizer, fodder, and for making reeds for woodwind instruments. Material from this plant was also commonly woven into mats and used as building material. It is no longer widely used or harvested for these traditional products, but is still used in landscaping.

Arundo is a tall, perennial grass that can reach up to 30 feet in height. It is light to dark green in color and has long, broad blades, with large plume-like flowers. Arundo is one of the fastest growing plants in the world and grows quickly in response to elevated nitrogen levels. This plant is tolerant of both drought and flooding, and can survive extended periods of salinity exposure. Arundo reproduces vegetatively from rhizomes (underground stems) and stem segments. Stem segments usually need two nodes or points for both roots and shoots to grow, but shoots have been observed on stem segments with a single node. Once introduced, arundo has the capability to spread rapidly, forming extensive rhizome systems that out-compete native riparian vegetation and require human intervention to remove. A single clump typically has hundreds of stems that grow very closely together and very rapidly, up to several inches per day during the spring and summer months. Arundo does not usually spread from seed.

Arundo thrives in warm, tropical environments and is most often invasive in coastal riparian areas, where it forms dense monocultures. The invasiveness of arundo substantially affects water quality, water conservation, native biological resources, flooding, erosion hazards, and wildfire risks. Arundo uses at least twice the amount of water as native riparian plants, and can use as much as 17.3 liters/m^2 per day, which is nearly 20 times the amount used by native vegetation (Hendrickson and McGaugh 2005). Arundo is extremely flammable throughout most of the year and is highly adapted to fire. The height of arundo growth spreads fires to tree canopies and the dense growth in the river channels spread fires up and down the river system. The rhizomes also respond quickly after fires, sending up new shoots, and quickly outgrow native species that may have otherwise taken root or sprouted in a burned site (Bell 1997).

2.2 Background on Tamarisk

Similar to arundo, tamarisk is a native of south Eurasia and may have been introduced by Spanish settlers. It was present in California by the early 1900s. Tamarisk was historically, and is currently, used for windbreaks, firewood, shade, and in landscaping. There are currently five known species of tamarisk in California including *Tamarix ramosissima*, *T. parviflora*, *T. gallica*, *T. aphylla*, and *T. chinensis*. Tamarisk is found in rivers, streams, wetlands, desert alkali sinks, playas, and springs throughout Southern and Central California and the western United States.

Although currently less of a problem than arundo in this watershed, tamarisk may be spreading and has potential to cause substantial long-term effects on the water quality, water conservation, native biological resources, flood control, and fire hazards. Tamarisk is a hardy, perennial shrub or small to medium-sized tree, which under favorable circumstances can reach 30 to 40 feet in height. Tamarisk foliage is light to dark green, with small, alternate scale-like leaves. The bark varies from smooth to rough and is reddish-brown. The plants are able to flower after one year of growth.

Tamarisk spreads by seed dispersal and vegetative reproduction. Full-grown mature trees can produce




500,000 seeds per year. These seeds remain viable up to five weeks after being produced and some may survive to the next spring (DiTomaso 2003). These seeds are extremely small with a terminal tuft of exposed fibers that allows them to travel greater distances via wind or water. Unlike arundo, seed dispersal is tamarisk's primary form of reproduction and spreading. However, under favorable moist conditions, tamarisk can also become easily established from stem and root segments.

Tamarisk is an aggressive invasive plant that has a long taproot capable of extending down to the water table. Because of this long taproot, tamarisk is capable of obtaining water in inhospitable and fluctuating groundwater environments, which allows it to out-compete native vegetation. In particular, tamarisk displaces native woody species, such as cottonwood, willow, and mesquite, especially in disturbed areas. Tamarisk consumes at least twice the amount of water that native vegetation uses, or about 3.3 liters/m^2 per day (Hendrickson and McGaugh 2005). Tamarisk further impacts the environment by its ability to concentrate soil salts. Tamarisk leaves collect salt brought up from the soil by the roots. As leaf litter accumulates under the plant, the surface soil can become highly saline, thereby impeding future colonization by many native understory plant species (Carpenter 1998). In addition, dense stands of tamarisk can be highly flammable and tamarisk is likely to persist following fire and expand its dominance with repeated burning of low-elevation riparian plant communities (Busch 1995).

2.3 Long-term Effects of Arundo and Tamarisk Invasion

Both arundo and tamarisk are officially recognized as undesirable invasive plants. Both plants are listed as 'A-1' invaders (the most invasive and widespread wildland pest plants) by the California Invasive Plant Council (Cal-IPC) [formerly known as California Exotic Pest Plant Council] and as noxious weeds by the California Department of Food and Agriculture (CDFA). While the degree and specifics of problems associated with these species vary, general negative effects associated with the establishment of arundo and tamarisk within the watershed.

2.3.1 Water Quality and Supply

Both arundo and tamarisk consume large amounts of water, which negatively affects both instream and groundwater availability. Reduced water availability also adversely affects water-dependent plants and wildlife, and reduces the water available for beneficial urban and agricultural uses. Although native riparian plants have similar transpiration rates per unit of surface area to arundo and tamarisk, arundo and tamarisk have approximately two or more times greater leaf surface area. Therefore, they transpire more water than native plants (Kelly 2003). Water consumption by these species is so high that dense infestations can desiccate riparian areas (seeps, springs, rivers) in arid habitats (Egan and Walker 2000; Dudley 2000). Major arundo infestations can cause an overall increase in water temperature by reducing shade in riparian areas. Increased water temperature can ultimately lead to a reduction of dissolved oxygen, making the water unsuitable for aquatic organisms (Bell 1997). In addition, increased light exposure and temperature may encourage algal blooms, and consequently increase pH levels and severely reduce available habitat for aquatic organisms (Adamus et al. 1997). Increased pH also facilitates the conversion of usable ammonia to a toxic byproduct, which degrades water quality. All of these changes can adversely affect wildlife, including rare and sensitive species.

2.3.2 Flooding and Erosion

Both arundo and tamarisk are known to increase flood hazards and the potential for erosion of adjacent lands, particularly for farmland along the Santa Clara River. Both plants can alter stream geomorphology by trapping and stabilizing sediment, which narrows stream channels, widens floodplains, and causes increased flooding (Carpenter 1998; Lovich 2000; Zouhar 2003). Large stands of arundo and tamarisk may also obstruct flows and shunt floodwaters into areas that historically have not experienced water flow. This can exacerbate bank erosion problems and lead to an unnatural increase in the loss of adjacent public and private property that is often valuable farmland. Arundo provides less protection for steam banks from erosion, because its dense but shallow root masses are more easily undercut than

deep-rooted native riparian vegetation. In addition to increasing flood magnitudes, arundo and tamarisk debris may accumulate downstream of the infestations, trapping sediments, and impeding natural water flow. Arundo debris can create new establishments downstream and on the beach. In many cases, costly clean up efforts or repairs are required.

2.3.3 Fire Hazards

Both arundo and tamarisk contribute to increased fire hazards. Under natural conditions, riparian areas act as firebreaks, but as they are overcome by invasive species, they not only enable wildfires to spread more rapidly, but they can also become sites where fires may originate. Arundo, in particular, is highly flammable and burns more intensely than native riparian vegetation even when green (Bell 1997; Dudley 2000). Because arundo is able to grow to substantial heights, it can act as a ladder fuel, effectively carrying, fire into tree canopies, thereby causing "crown fires" that increase tree mortality. Further, fire disturbance encourages regrowth of arundo. Burned areas also favor tamarisk regrowth, generating a positive feedback loop which is ultimately destructive to native habitat and dangerous to human developments (Bell 1997). Tamarisk leaf litter is also highly flammable, and because both plants are more flammable than native riparian vegetation, fires may occur more frequently and contribute to the eventual exclusion of native plant species (Bell 1997; Carpenter 1998; Lovich 2000).

2.3.4 Native Habitats and Wildlife

Arundo and tamarisk threaten native riparian habitats and the wildlife that depends upon these habitats by excluding native plants from water resources, growing space, and sunlight. Arundo often forms dense monocultures that exclude native vegetation by monopolizing water resources, shading, and altering flood regimes critical to the establishment of native riparian vegetation (Bell 1997; Dudley 2000). The salt-laden leaf litter of tamarisk also precludes such native understory from establishing. Both plants do not offer the same amount of shade as native vegetation (Carpenter 1998). Both arundo and tamarisk reduce habitat quality and food supply for native wildlife, including insects and bird species (Bell 1997; Dudley 2000; Herrera 2003). Insects and other grazers are not able to use arundo as a food source due to the noxious chemicals it contains and its defensive cellular structure (Bell 1997). This is particularly important for federal and state listed species, such as least Bell's vireo, southwestern willow flycatcher, and yellow-billed cuckoo, which utilizes insects as a food source. Documented decreases in wildlife usage of riparian areas have occurred due to massive stands of arundo (Dudley 2000).

2.4 Other Invasive Species

In addition to arundo and tamarisk, perennial pepperweed is a third significant threat to the watershed. Once established, it is very difficult to remove, and the monocultures it creates effectively displace native flora and fauna. Similar to tamarisk, perennial pepperweed also has the ability to concentrate salts near the ground surface (Renz 2000). The following list contains additional noxious and invasive plant species, which may be treated when encountered. The Cal IPC and CDFA also have lists of noxious and invasive plant species. The removal project manager, in coordination with the resource agencies, will make a determination regarding the level of effort that should be exerted in removing each species. For example, mustard may only require treatment if it occurs in stands greater than 0.25 acre at greater than 50-percent cover. Table 1 below lists additional invasive plant species.





Table 1: Invasive Plant Species

Scientific Name	Common Name
Ageratina adenophora	eupatory
Ailanthus altissima	tree of heaven
Aptenia spp.	iceplant
Atriplex semibaccata	Australian saltbush
Avena spp.	non-native grasses
Bassia hyssopifolia	five hook bassia
Brassica spp.	mustard species
Bromus spp.	non-native grasses
Cardaria chalepensis or *C. draba*	hoary cress, white top
Carduus pycnocephalus	Italian thistle
Carpobrotus spp.	iceplant
Centaurea melitensis	tocalote
Centaurea solstitialis	yellow starthistle
Cirsium arvense	Canada thistle
Cirsium vulgare	bull thistle
Conium maculatum	poison hemlock
Cortaderia jubata or *C. selloana*	pampas grass
Cynara cardunculus	artichoke thistle
Cynodon spp.	non-native grasses
Cytisus scoparius	scotch broom
Erodium cicutarium	red stem filaree
Eucalyptus spp.	eucalyptus
Foeniculum vulgare	fennel
Genista monosperma	bridal veil broom
Hedera helix	English ivy
Lepidium latifolium	pepper weed
Linaria dalmatica	dalmation toadflax
Mesembryanthemum spp.	iceplant
Nerium oleander	oleander
Nicotiana glauca	tree tobacco
Phoenix canariensis	canary island palm
Ricinus communis	castor bean
Robinia pseudoacacia	black locust
Salsola spp.	Russian thistle
Schinus spp.	pepper trees
Silybum marianum	milk thistle
Washingtonia spp.	fan palm

3.0 Description of Project Area Reaches

This section provides specific details on the physical and environmental characteristics for each of the upper Santa Clara River's six designated reaches and discussion of future removal program issues and recommendations. The same general analysis is also provided for each of the upper Santa Clara River's ten major tributary systems. In some reaches, removal work may have been conducted prior to the development of the SCARP. The goal of this background information and analysis is to facilitate an understanding among and between future removal project applicants and concerned state and federal resource agencies about the issues surrounding arundo and tamarisk removal proposals. An additional goal is to set the stage for resource agencies such as CDFG, USFWS, and USACE to issue programmatic permits, which will facilitate future removal projects while still protecting critical resources. Reach discussions are generally organized from east to west; with Reach 1 beginning upstream at the eastern project boundary, and Reach 6 ending downstream at the western project boundary.

The upper Santa Clara River's ten main tributaries are grouped based on their hydrological connections to one another and their point of intersection with the mainstem. Eight of these tributaries are located on the north side of the watershed and extend into USFS land. Two tributaries are located on the south side of the watershed. Tables 2 and 2a list the reaches and tributaries within the upper Santa Clara River watershed. The location of the project area is shown in Figure 1. Mainstem and tributary surveys performed by AMEC are described in the text, however detailed tributary surveys conducted by Condor Environmental are included as a separate document in the Appendices. Additional information for each reach and its respective tributaries such as summary tables for reach characteristics, channel cover, and sensitive species can be found in Appendix 6.

Table 2: Reach Descriptions

Reach	Location (east to west)	Length of Reach (miles)	Arundo Coverage (acres)	Tamarisk Coverage (acres)
Reach 1	Eastern Project Boundary to the Angeles Forest Highway	3.6	0	0
Reach 2	Angeles Forest Highway to Acton	8.0	0	2.5
Reach 3	Acton to Spring Canyon	11.4	111	30
Reach 4	Spring Canyon to Sand Canyon	3.9	70.7	21.3
Reach 5	Sand Canyon to Bouquet Canyon	7.9	98.7	202.5
Reach 6	Bouquet Canyon to the Los Angeles County Line	11.0	464.3	190.3

Table 2a: Tributary Descriptions

Reach	Tributary Name	Length of Reach (miles)	Arundo Coverage Greater than 50% (acres)	Tamarisk Coverage Greater than 50% (acres)
Reach 1	No tributaries	n/a	0	0
Reach 2	Jones Canyon Tributaries	9.0	0	0
	Soledad	6.87	0	0
	Aliso Canyon	3.02	0	0
	Escondido Canyon	6.41	0	0
	Santiago Road	n/a	0	0
Reach 3	Aqua Dulce Canyon Tributary	4.7	0	0.15
Reach 4	Oak Spring	5.13	0	0
Reach 5	Sand Canyon Creek	8.5	0	0
	Mint Canyon Creek	13.6	3	0
Reach 6	Bouquet Canyon Creek	25.0	0	0
	South Fork Tributaries	7.5	0	0
	San Francisquito Canyon Creek	21.7	5	0
	Castaic Creek	23.5	3	2
	Hasley Canyon	5.4	0	0
	Chiquito Canyon Tributary	4.9	0	0
	Potrero	3.61	0	0
	Salt	7.24	0	0
	San Martinez Grande	3.22	0	0

3.1 Reach 1: Eastern Project Boundary to Angeles Forest Highway

Characteristics

Extending 3.6 miles, Reach 1 comprises the headwaters of the Santa Clara River which are located in Soledad and Kentucky Springs Canyons; and the river flows through Soledad Canyon for many of the following reaches. Kentucky Springs Canyon is fed by several small streams originating in the San Gabriel Mountains. Reach 1 lies entirely within the Angeles National Forest, although there are several private in-holdings. Reach 1 is an ephemeral stream, where surface water is present only after major storm events. The stream channel within this reach is narrow and steep due to surrounding topography. The 500-year floodplain of Reach 1 ranges between 250 and 500 feet in width and has primarily natural streambanks.

The vegetation in Reach 1 is dominated by big sagebrush and chamise. The remainder of the floodplain is dominated by juniper and walnut woodlands. Sensitive species including the coast horned lizard (state candidate for listing) and the short-joint beavertail cactus (state species of concern) have been reported in Reach 1 (CDFG 2004). This reach's high quality habitat may support other sensitive species; however, this area has only been partially surveyed.

Target Species

No known infestations of arundo, tamarisk, or other invasive plant species have been observed in Reach 1 and therefore no eradication projects are currently anticipated. Although this reach is not threatened or highly suitable for arundo or tamarisk, this reach should be monitored for development of arundo and tamarisk colonies, as presence of these species can lead to infestations downstream.

3.2 Reach 2: Angeles Forest Highway to Acton

Characteristics

Reach 2 begins where Angeles Forest Highway crosses the Santa Clara River at its intersection with BP & L Road and extends eight miles towards the town of Acton. Tributaries draining into the reach include Jones, Acton, and Aliso Canyons. Reach 2 contains substantial acreage of low-level development associated with the town of Acton. Low-density development is present throughout the reach, although it is primarily concentrated around the town of Acton and toward the western end of the reach. This development includes residential housing, ranches, campgrounds, recreation fields, and recreational vehicle parks. The channel within Reach 2 is an open, often shallow, low-gradient wash. The 500-year floodplain is relatively wide near the reach's western boundary, varying between 350 feet in width near its eastern extent and 2,250 feet near Acton.

Vegetation in this reach gradually shifts from dense brush to sparse scrub, with pinyon-juniper woodland in the east transitioning into high desert scrub in the west. Sensitive species in Reach 2 include the coast horned lizard and Mason's neststraw (CNPS List 1B), both known to occur within the 500-year floodplain of the reach (CDFG 2004). As with Reach 1, the lack of reported sensitive species may be due the lack of area surveys.

Target Species

No arundo infestation has been reported within the 500-year floodplain of Reach 2. However, tamarisk occurs in a few small stands at low densities within one mile of the western boundary of the reach.

3.2.1 Acton, Jones, and Kashmere Canyon Tributaries

Characteristics

The Jones Canyon tributaries are located north of the mainstem and connect with the Santa Clara River in Acton. These tributaries include Acton, Jones, and Kashmere Canyons. These canyons consist primarily of private land and scattered rural residences are located in the upper sections of these canyons. These tributaries tend to be arid washes with little or no surface flow of water except under high rain conditions. All three are dominated by desert vegetation and scrub. Sightings of coast horned

lizard have been recorded in these tributaries.

Target Species

Neither tamarisk nor arundo have been recorded in these tributaries. However, the tributaries are susceptible to infestation from ornamental landscaping by proximate private landowners. Therefore, residents in the area should be educated about arundo and tamarisk and the area should be monitored for possible future infestations.

3.2.2 Aliso Canyon Tributary

Characteristics

Aliso Canyon is located south of the mainstem in Reach 2. Aliso Canyon is also an arid wash, except in high rain conditions. Scattered rural residences and areas of agricultural production exist along portions of the canyon. Similar to the Jones Canyon tributaries, Aliso Canyon is characterized by desert vegetation and scrub and coast horned lizards have been sighted.

Target Species

Neither tamarisk nor arundo have been recorded in these tributaries. However, they are also susceptible to infestation from ornamental landscaping by proximate private landowners. Therefore, residents in the area should be educated about arundo and tamarisk and the area should be monitored for possible future infestations.

3.3 Reach 3: Acton to Spring Canyon

Characteristics

Reach 3 is the longest reach in the project area and extends for 11.4 miles from Acton to Spring Canyon. The only major tributary draining into Reach 3 is Agua Dulce Canyon, entering the mainstem from the north about two miles east of Spring Canyon. Development within the floodplain totals approximately 141 acres, including rural-residential housing, recreational vehicle parks, and campgrounds. Reach 3 traverses deep, narrow Soledad Canyon for nearly its entire length. The river channel is correspondingly narrow, with the 500-year floodplain generally limited to 200 and 500 feet in width. The stream channel is broad and often dry at its eastern border, transitioning into a steep narrow canyon for virtually its entire 11-mile extent. The majority of Reach 3 is bounded by natural banks that rise sharply from the channel, with minor areas of concrete hard bank protection.

This reach provides large areas of relatively high quality native riparian habitat Cottonwood woodland dominates this reach, occupying 329 acres of the floodplain, with 119 acres of open unvegetated channel breaking up these expanses of woodlands. These woodlands and associated habitats, such as the mixed willow and big sage, provide several uninterrupted one to two mile stretches of high value native habitat, particularly in the central portions of this reach. This area supports known resident populations of the federal and state endangered arroyo toad, unarmored threespine stickleback, and slender-horned spineflower. Potential suitable breeding habitat for the federal and state endangered least Bells' vireo and southwestern willow flycatcher also exist.

Target Species

There are only a few minor stands of arundo or tamarisk in the eastern five miles of Reach 3. Dense arundo stands occupy a total of 111 acres along this reach. With dense stands occurring approximately one mile both upstream and downstream of the confluence with Agua Dulce Creek. Tamarisk infestation occurs at low-to-moderate densities with approximately 30 acres of the reach's total area. Tamarisk is located in the same general areas of dense arundo stands, including upstream from Indian Springs Road, one mile upstream and downstream of the Agua Dulce tributary intersection, and near Capra Road.

3.3.1 Agua Dulce Canyon

Characteristics

Agua Dulce Canyon is a narrow canyon on the north side of the mainstem with headwaters near Vasquez Rocks County Park. It passes through steep rock walls and intersects with the mainstem in Reach 3 approximately four miles downstream from the headwaters. Near the headwaters, the stream channel is wash-like and has only seasonal surface flow. This section of the

canyon is used for rural residences and small ranches. As the canyon approaches the mainstem, it narrows and becomes steeper, especially downstream near the canyon's intersection with the mainstem. The only development in the base of the canyon is Agua Dulce Road.

The vegetation in Agua Dulce Canyon is dominated by mixed riparian vegetation and some desert species. There is no single dominant plant assemblage within Agua Dulce Canyon. Small cottonwood stands occur throughout the creek, as well as other riparian tree species. Sparse mule fat and other riparian scrub species occur within the creek, as well as scattered desert species such as juniper. Sensitive wildlife species that may be present in the canyon include the arroyo toad, coast horned lizard, and unarmored threespine stickleback.

Target Species

Arundo occurs in scattered, but dense stands along the streambed and on the banks of Agua Dulce Canyon. Due to the narrow nature of this tributary, many of the stands are smaller in size (approximately 5 meters in diameter), except for elbows in the tributary where some larger stands exist. Tamarisk occurs primarily in one stand mid-way to the headwaters off Agua Dulce Road, but additional stands may exist. Surrounding ranches provide sources of arundo and tamarisk.

3.4 Reach 4: Spring Canyon to Sand Canyon

Characteristics

Reach 4 extends 3.9 miles from Spring Canyon to Sand Canyon through the eastern extent of the City of Santa Clarita. The communities of PineTree and Canyon Country lie north of the Santa Clara River in this reach, while the communities of Lang and Sulfur Springs extend south from the Santa Clara River. Reach 4 is composed mainly of residential and mining development (91 acres) among sparsely scattered great basin and riparian vegetation. The 500-year floodplain through Reach 4 varies in width from 1,500 feet at its eastern border to 350 feet near Shadow Pines Boulevard and widening to 1,800 feet near Sand Canyon Road. Sand mining in the area near Spring Canyon has lowered the channel approximately 40 feet from its historic elevation.

Reach 4 is dominated by open channel, particularly in its central sections. Great basin and coastal scrub communities total 131 acres of the floodplain along this reach. At the reach's east end, stands of cottonwood woodland are intermixed with the scrub habitats. Sensitive species reported from Reach 4 are limited to coast horned lizard (state species of concern) from the northern margin of the east end of the reach. The two-striped garter snake (state species of concern) has been observed to the south and may occur when water is present in the floodplain area (CDFG 2004). The endangered slender-horned spineflower may also grow along the stream bank in the upstream portions of Reach 4, but its presence has not been confirmed (AMEC 2004).

Target Species

Arundo infestations range from low-to-high density throughout the 500-year floodplain, occupying approximately 71 acres. There are two extensive arundo stands located at the reach's east end, near the private River's End Campground (located in Reach 3). A one-mile section starts at the vicinity of Lang Station Road. Tamarisk is present on 21 acres of the floodplain in generally medium-to-low densities. With the exception of a small patch at the western end of Reach 4, tamarisk concentration within the 500-year floodplain is limited to the area between Lang Station Road and Poppy Meadows Street.

3.4.1 Oak Spring Tributary

Characteristics

Oak Spring Canyon feeds into the western extent of Reach 4. The golf course at the mouth of Oak Spring Canyon has contoured the channel throughout the golf course. Sensitive species reported in these tributaries include the two-striped garter snake.

Target Species

Neither tamarisk nor arundo have been recorded in these tributaries. However, they are also susceptible to infestation from ornamental landscaping by proximate private landowners. Therefore, residents in the area should be educated about arundo and tamarisk and the area should be monitored for possible future infesta-

tions.

3.5 Reach 5: Sand Canyon to Bouquet Canyon

Characteristics

Reach 5 extends 7.9 miles from Sand Canyon Road downstream to Bouquet Canyon Road. The majority of this reach falls within the City of Santa Clarita. Major tributaries to Reach 5 include those from Sand Canyon joining the mainstem from the south at the junction between Reaches 4 and 5, and Mint Canyon flowing into the Santa Clara River from the north approximately two miles downstream from this junction. Approximately 360 acres of the 500-year floodplain is developed along Reach 5, which is mostly within the City of Santa Clarita. The 500-year floodplain in Reach 5 varies in width from 500 feet by the Sierra Highway bridge to nearly 2,500 feet in the developed area off Oak Avenue.

Open channel dominates this reach, occupying 404 acres of the floodplain, with great basin plant communities concentrated along the east and west ends of the reach. The channel is heavily braided. Native vegetation communities are dominated by scalebroom and big sagebrush. Although there are scattered groves of cottonwoods and willows along the channel margins in the western portion of this reach, the riparian vegetation consists primarily of mule fat. This reach has limited native vegetation and only sparse data on sensitive species are available. However, the western spadefoot toad (state species of concern), arroyo chub (state species of concern), and the endangered unarmored threespine stickleback, federal threatened California red-legged frog have reported observations in Reach 5. Others that may be present are the coast horned lizard (state species of concern) and western whiptail (state candidate). Similarly, sensitive plant species have not been observed, but the floodplain in Reach 5 has the potential to support the endangered slender-horned spineflower and federally threatened spreading navarretia.

Target Species

Arundo and tamarisk occupy 302 acres together in low-to-moderate densities throughout this reach. Arundo is established on approximately 203 acres. Large stands of low-density arundo extend downstream for approximately 3.5 miles from the eastern boundary of Reach 4. Within the mainstem, one source of arundo is one mile west of the conservation camp near the stream channel. The Angeles National Forest cleared one-mile of the channel in 1995 downstream of the conservation camp. A large, high-density stand of arundo is also located downstream from where the Los Angeles aqueduct crosses the river. Additional large areas of low- and medium-density infestations are heavily intermixed with high-quality habitat at the western boundary. Tamarisk occupies approximately 99 acres. Dense stands occur one mile east of Bouquet Canyon Road, and are scattered throughout the eastern portion of the reach. Other invasive plant species identified in Reach 5 included tree tobacco, black locust, and pepper tree.

3.5.1 Sand Canyon Tributaries

Characteristics

The Sand Canyon tributaries are located on the south side of the mainstem and include Sand Canyon and Iron Canyon. Sand Canyon joins the mainstem at the intersection between Reaches 4 and 5. Iron Canyon joins Sand Canyon approximately two miles upstream from the mainstem. Channels of Sand Canyon tributaries tend to be narrow with seasonal surface water flows. Rural residences surround the majority of the Sand Canyon tributaries, many of which are sited in the 500-year floodplain. The headwaters of these tributaries are generally surrounded by protected open space. The Sand Canyon tributaries support scattered mule fat within the channel and live oaks near the stream banks. This stream channel supports only seasonal surface flow. Sensitive species reported in these tributaries include the western spadefoot toad reported in Sand Canyon.

Target Species

Arundo and tamarisk have not yet been identified in any of these tributaries; however, introductions may occur due to landscaping of rural residences.

3.5.2 Mint Canyon Tributaries

Characteristics

The Mint Canyon tributaries are located on the north

side of the Santa Clara River and join the mainstem about two miles downstream from the Reach 4 boundary. These tributaries include Mint and Rowher Canyons. The 500-year floodplain in Mint Canyon varies between 300 and 1,000 feet wide at its mouth. The streambed is narrow and channelized for 3.5 miles upstream from the mainstem. Surface water is seasonal within Mint Canyon.

Scattered mule fat and great basin scrub communities dominate the stream channel. In some areas, robust cottonwood-willow groves are also present. Southern sycamore-alder riparian forest is also found in a minor tributary near the headwaters of Mint Canyon. Slender-horned spineflower and slender mariposa lily have been reported within Mint Canyon. These occurrences were in the 3.5-mile stretch extending downstream from the intersection of Sand Canyon Road to the mainstem, and species may have since been extirpated by recent development.

Target Species

Tamarisk is present in moderate levels and arundo is present at low to moderate levels within and adjacent to the stream channel throughout Mint Canyon. Much of these infestations are associated with residences using arundo and tamarisk as landscaping plants, which now grow wild in stands. Pepper trees are also present within the stream corridor and are beginning to establish within Mint Canyon.

3.6 Reach 6: Bouquet Canyon to Ventura County Line

Characteristics

Reach 6 begins in Santa Clarita where Bouquet Canyon drains into the mainstem and stretches west 11 miles to the Ventura County line. Six main tributaries drain into Reach 6: Bouquet Canyon, South Fork, San Francisquito Canyon, Castaic Creek, Hasley Canyon, and Chiquito Canyon. Interstate 5 (I-5) divides Reach 6 into two characteristically distinct sections at the western border of Santa Clarita. The land surrounding this reach east of I-5 within Santa Clarita is heavily developed with residential, commercial, and industrial land uses. A public recreational path borders Reach 6 for its entire length between Bouquet Canyon Road and the South River Village Apartment Complex. The width of the 500-year floodplain on this part of the reach ranges between 700 to 1,000 feet. West of I-5, with the exception of the Six Flags Magic Mountain Theme Park (located adjacent to the Santa Clara River just west of I-5), the Santa Clara River is bordered by agricultural and other undeveloped open land. The majority of the land here is under the ownership of the Lennar-LNR. From I-5 to the Ventura County line, Reach 6 traverses a broad open valley, with a 500-year floodplain of ranging between 1,800 and 3,000 feet in width.

Water flow within Reach 6 is braided and subsidized year-round by effluent from two wastewater treatment plants: the Saugus Wastewater Treatment Plant and the Valencia Water Reclamation Plant. Over 600 acres of Reach 6 is currently open un-vegetated channel. The perennial water flows, cottonwood woodlands, and associated habitats such as mixed willow, mule fat, and big sage provide high quality habitat for several sensitive species. In particular, this reach includes the only known occurrences along the mainstem of the Santa Clara River for breeding of endangered least Bells' vireo. Further, these riparian habitats provide extensive suitable breeding habitat for the endangered southwestern willow flycatcher. This reach also supports known populations of the endangered arroyo toad and unarmored threespine stickleback. Declining sensitive aquatic species such as the western pond turtle (state species of concern) and the two-striped garter snake (state species of concern) are also present.

Target Species

The environmentally sensitive habitats along Reach 6 are also the section of the upper Santa Clara River watershed most heavily infested with arundo. Tamarisk is present to a lesser extent. Large areas of arundo and tamarisk occur at a low density infestation range of about 355 acres. An additional 176 acres of arundo occurs at densities of high density infestation range.

3.6.1 Bouquet Canyon Tributaries

Characteristics

The Bouquet Canyon tributaries are located on the north side of the mainstem and include Bouquet

Canyon, Dry Canyon, Haskell Canyon, Texas Canyon, Vasquez Canyon, and Plum Canyon. Land use surrounding Bouquet Canyon transitions from a highly urbanized area near the confluence to residential and rural residential upstream, before Bouquet Canyon enters Angeles National Forest. Land currently developed is used for campgrounds or rural residences. The length of the tributary that flows from the intersection of Plum Canyon and Bouquet Canyon through Santa Clarita to the mainstem is channelized. Above Plum Canyon, Bouquet Creek is often confined to a narrow natural channel. Scattered groves of cottonwood, oaks, and willows intermixed with mule fat are located throughout this section of the reach. Upstream, past the USFS boundary, cottonwood woodland transitions to dense live oak woodland. Portions of several of Bouquet Canyon's tributaries, notably the lower portions of Plum, Haskell, Vasquez, and Texas Canyons, contain 500-year floodplains that fall within the project boundary. These canyons vary from broad floodplain supporting scrub habitats with scattered cottonwoods to areas with higher quality riparian habitats. Some areas have been subject to extensive development and the streams are largely channelized.

Target Species

Bouquet Canyon exhibits heavy arundo infestation throughout the lower reaches of the canyon, and lacks public access to the tributary in some of the most heavily infested areas. Once beyond the channelized portion of the tributary, Bouquet Canyon is heavily infested with arundo. Arundo is also present north of the Angeles National Forest boundary. These infestations are smaller and are closely associated with private properties. No tamarisk was observed within Bouquet Canyon. Scattered stands of eucalyptus, pine trees, and pampas grass are located throughout Bouquet Canyon.

3.6.2 South Fork Tributaries

Characteristics

The South Fork of the Santa Clara River is a system of major tributaries, passing through the City of Santa Clarita. Tributaries include South Fork, Pico Canyon, Newhall Creek, and Placerita Creek. These tributaries are mostly contained within the limits of urban development. With the exception of Placerita Creek, the streams are channelized throughout much of South Fork system. The waterways therefore tend to be fairly degraded, with little or no vegetation growing within most of the channels. However, the four mile section of the South Fork tributary just prior to where it enters the mainstem is wider and contains more native vegetation, including scattered great basin scrub and mule fat. The channel has seasonal flow, which may be supplemented by urban runoff.

Target Species

Arundo is present in Placerita Creek, near its intersection with South Fork. Due to the channelization of the remaining waterways, there is little potential for invasive species to establish.

3.6.3 San Francisquito Canyon

Characteristics

San Francisquito Canyon is a large tributary of the Santa Clara River, stretching nearly 22 miles from headwaters on the northeastern boundary of the watershed to the mainstem. It enters the mainstem from the north in Santa Clarita near McBean Parkway. Much of the northern portion of the canyon is located within Angeles National Forest. As with Bouquet Canyon, land use surrounding San Francisquito Creek transitions from highly urban at the confluence to rural residential in the middle reaches and protected open space in the upstream half of the canyon. The 500-year floodplain of the San Francisquito Canyon ranges between 700 and 1,200 feet in the lower portion of the canyon. Most of San Francisquito Canyon has a wide, shallow stream channel with low velocity water flow, although some upstream sections are narrow and undeveloped, particularly near the headwaters in Angeles National Forest. San Francisquito Canyon provides large areas of relatively high value natural habitat, including sage scrub, cottonwood forest, mixed willow forest, sycamore and alder forest, coast live oak woodland.

Target Species

Arundo occurs at moderate to high densities throughout San Francisquito Canyon and presents a

threat to both resources in this tributary and the Santa Clara River's mainstem. Moderate density arundo infestations exist at and downstream of the Los Angeles County Fire Station. Small infestations were observed as high in the watershed as Bee Canyon. No infestations were observed beyond Bee Canyon. No tamarisk was identified within San Francisquito Canyon.

San Francisquito Canyon has had continuing efforts for arundo removal since 1995, which were initiated by the Angeles National Forest Service. The program was expanded in 1999 to include the LADWP property. During 2000 and 2001, the lowest 2.5 miles of San Francisquito were treated for mitigation as a result of a bridge construction and bank stabilization project. Other areas on San Francisquito have been treated by commercial property companies as mitigation for development impacts.

3.6.4 Castaic Creek Tributaries

Characteristics

The Castaic Creek tributaries are located on the northern side of the mainstem. Castaic Creek tends to be low velocity. Water flow may be subsurface throughout much of the year. The streambed is wide at the mouth of the creek, and is constrained by a barrier fence and agricultural lands on either side. Most of the adjacent land in this area is agricultural with a small amount of recreational open space. Water availability in the downstream section of the Castaic Creek is regulated by dam releases from Castaic Lake. Castaic Lake creates an artificial disjunct in the streambed geomorphology, which is broad with low velocity flow downstream and narrow and deeply incised upstream. Most of the land upstream of Castaic Lake is protected USFS land and is outside of the project area.

Target Species

Tamarisk and arundo are present in the area of Castaic Creek near where Commerce Center Drive meets Highway 126 and upstream of Castaic Lake on USFS property.

3.6.5 Hasley Canyon Tributary

Characteristics

Hasley Canyon is a small tributary that drains north from Castaic Creek. In general, the channel tends to have little vegetation, but contains some intermittent coastal scrub and live oaks. The channel has been contoured and directed by residents within much of the canyon. A large construction effort has widened the stream channel near the intersection of Hasley Canyon Road and Commerce Center Drive. Rural residential land surrounds most of Hasley Canyon, although the mouth of the tributary does pass through an unincorporated urbanized area.

Target Species

No arundo or tamarisk was identified within Hasley Canyon. The majority of other invasive species in the canyon persist as an artifact of private landscaping. Eucalyptus and pepper trees have sprouted outside private yard areas and are colonizing the canyon in areas. Sensitive species, which have been reported in Hasley Canyon, include the San Fernando Valley spineflower, the Los Angeles sunflower, and the Santa Ana sucker.

3.6.6 Chiquito Canyon Tributaries

Characteristics

The Chiquito Canyon tributaries consist of Chiquito Canyon and San Martinez Grande Canyon. In general, these tributaries are heavily affected by surrounding rural residences, with many landscaping plants encroaching on the stream channel. The stream channels tend to be narrow, and are sometimes paved-over at road crossings and other areas to avoid erosion. In general, there is little water, except for that introduced via runoff and over watering. However, higher amounts of water are present after heavy rain events. Rural residential areas and open space surround the Chiquito Canyon tributaries.

Great basin sagebrush and limited cottonwoods are present within the stream channel although in most areas the stream channel has no vegetation. Disturbed oak savanna, which appears to have been grazed historically, is present along downstream portions of the tributaries. The headwaters are dominated by high-quality coastal sage scrub. The San Fernando Valley spineflower is the only sensitive species known to be present in these

tributaries.

Target Species

There is little to no arundo within the Chiquito Canyon tributaries. Tamarisk is present at moderate densities within the Chiquito Canyon tributaries as individual plants have escaped residential cultivation and have become established along the stream bank. San Martinez Grande Canyon tends to have more tamarisk than Chiquito Canyon. Landscaping plants and non-native grass are the primary invasive species within the Chiquito Canyon tributaries. Liquid amber trees and pepper trees are also present within and along the stream channel.



4.0 Biological Resources

The upper Santa Clara River drains an area that extends from the mountainous areas along the western edge of the Mojave Desert in the east and north of the watershed, west to the inland extent of areas that are typically dominated by coastal habitat associations. The habitats present along the Santa Clara River itself and in the surrounding areas reflect the Santa Clara River's transit of habitats ranging from high desert and montane associations in the inland areas to coastal valley associations near the project area's western boundary. A similar transition from high desert or montane also occurs along many of the Santa Clara River's larger tributaries. Mapping has been completed for the mainstem and tributaries of the upper Santa Clara River watershed (Appendices 6 and 7). A plant and wildlife species list was compiled during these surveys and is included in Appendix 5.

Special status plant and wildlife species are recognized by the California Native Plant Society, CDFG, or USFWS because these species have limited populations. It is important to recognize these species and avoid impacts to them because of various regulatory restrictions as discussed in Chapter 9.

4.1 Special Status Plant Species

A total of 19 special status plant species with the potential to occur within the project area were identified (Table 3). The potential for these species to occur in the study area is based on a review of historical sensitive plant species locations identified in the CNDDB (CDFG 2002).

4.2 Special Status Wildlife Species

A total of 21 special status wildlife species with the potential to occur within the project area were identified (Table 4). The potential for these species to occur in the study area is also based on a review of historical wildlife species locations identified in the CNDDB), and a review of pertinent literature. Of these 21 species, eight are federally listed under the Federal Endangered

Table 3: Special Status Plant Species

Scientific Name	Common Name	Status[1]	Habitat	Potential to Occur in Each Reach/Tributary	Potential to Occur (High, Medium, Low, and Why)
Allium howellii var. *clokeyi*	Mt. Pinos onion	List 1B	Pinyon and juniper woodlands and Great Basin scrub; 4,265-6,000 feet above msl.	Potential to occur in Reaches 1 and 2 and all tributaries. Known to occur in Castaic Creek tributaries.	Low: The project area elevation is 4,265 feet at its highest point. This plant does not grow in the riparian flood channel where weed removal will occur.
Arenaria macradenia var. *kuschei*	Kusche's sandwort	List 1B	Granitic openings in chaparral; 4,000- 5,700 feet above msl.	Potential to occur in Reaches 1, 2, and 3 and all tributaries.	Low: The elevation for this plant is close to the highest elevation for the project (4,265 feet). This plant does not grow in the riparian flood channel where weed removal will occur.
Berberis nevinii	Nevin's barberry	SE, FE, List 1B	Chaparral, cismontane woodland, coastal scrub, riparian scrub/sandy or gravelly soils; 1,000-2,700 feet above msl.	Potential to occur in Reaches 2 though 6 and all tributaries. Known to occur in San Francisquito Canyon.	High: This plant grows in habitats (e.g., riparian scrubs) that could be impacted during weed removal and in habitats where access roads may need to be built.
Calochortus clavatus var. *gracilis*	Slender mariposa lily	List 1B	Chaparral and coastal sage scrub; 1,100-3,200 feet above msl.	Potential to occur in Reaches 3 though 6 and all tributaries. Known to occur in Mint Canyon Tributaries and in San Francisquito Canyon.	Low: This plant does not grow in the riparian flood channel where weed removal will occur.
Calochortus plummerae	Plummer's mariposa lily	List 1B	Chaparral, cismontane woodland, coastal scrub, lower montane coniferous forest, valley and foothill grassland in rocky habitats; 330-5,600 feet above msl.	Potential to occur in all reaches and tributaries. Known to occur in Agua Dulce Canyon and in the South Fork Tributaries.	Low: This plant does not grow in the riparian flood channel where weed removal will occur.
Castilleja gleasonii	Mt. Gleason Indian paintbrush	SR, List 1B	Lower montane coniferous forests and pinyon and juniper woodlands; 3,800-7,100 feet above msl.	Potential to occur in Reaches 1, 2, and 3 and all tributaries.	Low: The elevation for this plant is close to the highest elevation for the project (4,265 feet). This plant does not grow in the riparian flood channel where weed removal will occur.
Centromadia parryi var. *australis*	Southern tarplant	List 1B	The margins of marshes and swamps, valley and foothill grasslands, and vernal pools; 0-1,400 feet above msl.	Potential to occur in Reaches 5 and 6 and all tributaries.	High: This plant grows in habitats (e.g., margins of marshes and swamps) that could be impacted during weed removal and where access roads may need to be built.
Chorizanthe parryi var. *fernandina*	San Fernando Valley spineflower	SC, FC, List 1B	Sandy soils in coastal scrub; 500-4,000 feet above msl.	Potential to occur in Reaches 3 though 6 and all tributaries. Known to occur in Reach 6 and in Castaic Creek and Chiquito Canyon Tributaries	Medium: This plant grows in coastal sage and alluvial scrub habitats.

Scientific Name	Common Name	Status[1]	Habitat	Potential to Occur in Each Reach/Tributary	Potential to Occur (High, Medium, Low, and Why)
Dodecahema leptoceras	Slender-horned spineflower	SE, FE, List 1B	Sandy soils in chaparral, cismontane woodland, and coastal scrub (alluvial fans); 650-2,500 feet above msl.	Potential to occur in Reaches 2 though 6 and all tributaries. Known to occur in Reaches 3 and 5 and in Mint Canyon, South Fork, and Halsey Canyon Tributaries.	High: This plant grows in habitats (e.g., alluvial fans) that could be impacted during weed removal and in habitats where access roads may need to be built.
Erodium macrophyllum	Round-leaved filaree	List 2	Clay soils in cismontane woodland, valley and foothill grassland; 50-4,000 feet above msl.	Potential to occur in all reaches and tributaries.	Low: This plant does not grow in the riparian flood channel where weed removal will occur.
Galium grande	San Gabriel bedstraw	List 1B	Broadleaved upland forest, chaparral, cismontane woodland, lower montane coniferous forest; 1,400-5,000 feet above msl.	Potential to occur in all reaches and tributaries. Known to occur in Castaic Creek Tributaries.	Low: This plant does not grow in the riparian flood channel where weed removal will occur.
Helianthus nuttallii ssp. *parishii*	Los Angeles sunflower	List 1A	Coastal salt and freshwater marshes and swamps; 30-1,600 feet above msl.	Potential to occur in Reaches 3 through 6 and all tributaries. Known to occur in Reach 6.	High: This plant grows in habitats (e.g., marshes and swamps) that could be impacted during weed removal.
Lilium parryi	Lemon lily	List 1B	Mesic areas in lower montane coniferous forest, meadows and seeps, riparian scrub, upper montane coniferous forest; 4,300-8,600 feet above msl.	Potential to occur in Reaches 1 and 2 and all tributaries.	Low: The project area elevation is 4,265 feet at its highest point. This plant does not grow in the riparian flood channel where weed removal will occur.
Malacothamnus davidsonii	Davidson's bush mallow	List 1B	Chaparral, cismontane woodland, coastal scrub, riparian woodland; 600-2,800 feet above msl.	Potential to occur in Reaches 2 though 6 and all tributaries.	High: This plant grows in habitats (e.g., riparian woodland) that could be impacted during weed removal and in habitats where access roads may need to be built.
Navarretia fossalis	Spreading navarretia	FT, List 1B	Chenopod scrub, marshes and swamps (assorted shallow freshwater), playas, vernal pools; 100-4,300 feet above msl.	Potential to occur in all reaches. Known historically in Reach 5 and the Plum Canyon Tributary.	High: This plant grows in habitats (e.g., marshes and swamps) that could be impacted during weed removal and in habitats where access roads may need to be built.
Opuntia basilaris var. *brachyclada*	Short-joint beavertail	List 1B	Chaparral, Joshua tree woodland, Mojavean desert scrub, pinyon and juniper woodlands; 1,400-5,900 feet above msl.	Potential to occur in all reaches and tributaries. Known to occur in Reach 1 and in Bouquet Canyon and South Fork Tributaries.	Low: This plant does not grow in the riparian flood channel where weed removal will occur.

Scientific Name	Common Name	Status[1]	Habitat	Potential to Occur in Each Reach/Tributary	Potential to Occur (High, Medium, Low, and Why)
Orcuttia californica	California Orcutt grass	List 1B	Vernal pools; 50-2,200 feet above msl.	Potential to occur in Reaches 3 though 6 and all tributaries. Known to occur in Bouquet Canyon and in South Fork Tributaries.	Low: This plant does not grow in the riparian flood channel where weed removal will occur.
Senecio aphanactis	Rayless ragwort	List 2	Alkaline areas in chaparral, cismontane woodland, coastal scrub; 50-2,600 feet above msl.	Potential to occur in Reaches 2 though 6 and all tributaries. Known to occur in the South Fork Tributaries.	Low: This plant does not grow in the riparian flood channel where weed removal will occur.
Stylocline masonii	Mason's neststraw	List 1B	Sandy soils in chenopod scrub, pinyon, and juniper woodlands; 330-4,000 feet above msl.	Potential to occur in all reaches and tributaries. Known to occur in Reach 2.	Low: This plant does not grow in the riparian flood channel where weed removal will occur.

[1]FC: federal candidate
FE: federally listed as endangered
FT: federally listed as threatened
SC: state candidate
SR: state listed as rare
ST: state listed as threatened
CNPS List 1A: plant species are presumed extinct in California
CNPS List 1B: plant species are rare, threatened, or endangered in California and elsewhere
CNPS List 2: plants species are rare, threatened, or endangered in California, but more common elsewhere

Table 4: Special Status Wildlife Species

Scientific Name	Common Name	Status	Habitat	Potential to Occur in Each Reach/Tributary	Potential to Occur (High, Medium, Low) and Why
Mammals					
Neotoma lepida intermedia	San Diego desert woodrat	SC, SSC	Pinyon-Juniper in association with rocky outcrops, including burrows of ground squirrels and woodrats.	Upstream and middle reaches of project area.	Medium potential to occur since it is not a riparian species. Uplands surrounding riparian zone have greater potential for this species.
Perognathus alticola inexpectatus	Tehachapi pocket mouse	SSC	Prefers open, sandy upland habitats, with friable soils.	Potentially found in adjacent upland habitats in all reaches and tributaries.	Low potential since this species is primarily associated with upland habitats.
Taxidea taxus	American badger	SSC	Prefers open, sandy upland habitats.	Potentially found in adjacent upland habitats in all reaches and tributaries.	Medium potential to occur, but seldom seen due to its fossorial ecology. Not usually associated with riparian habitats, but found in adjacent upland habitats.
Birds					
Accipiter cooperii	Cooper's Hawk	SSC	Found in a variety of habitats, including riparian and uplands, as well as urban areas.	Found in all reaches and tributaries.	High potential to occur, for breeding, roosting, and foraging.
Athene cunicularia	Burrowing owl	SC, SSC	Typically found in open scrub habitats in uplands.	Potentially found in high-quality upland habitats in all reaches and tributaries.	Low potential, since this species does not typically inhabit riparian zones.
Coccyzus americanus occidentalis	Western yellow-billed cuckoo	SE	Prefers dense riparian habitats, including willow-cottonwood.	Potentially found in all reaches, although the species is very rare.	Low potential given the scarcity of this species, but it could be found in any reach with an overstory of riparian hardwoods.
Dendroica petechia brewsteri	Yellow warbler	SSC	Prefers willow riparian and associated habitats.	Potentially found throughout all reaches and tributaries.	Medium potential since this species will occur disjunctly throughout appropriate habitats.
Empidonax traillii extimus	Southwestern willow flycatcher	FE, SE	Riparian scrub, willow and mule fat, including arundo stands.	Known in Reaches 3 and 6.	High potential to occur in downstream reaches, below Soledad Canyon where high quality riparian habitat is prevalent.
Pilioptila californica californica	Coastal California gnatcatcher	FT, SSC	Coastal sage scrub	Known in Plum and Placerita Canyons.	Low potential, since this species does not typically inhabit riparian zones.

Scientific Name	Common Name	Status	Habitat	Potential to Occur in Each Reach/Tributary	Potential to Occur (High, Medium, Low) and Why
Gymnogyps californianus	California condor	FE, SE	Montane and cliff habitats, primarily limited to Sespe Wilderness area and adjacent lands.	Potentially found in all reaches, although the species is very rare.	Low potential to occur since no breeding sites are located within the project area, although this species has large home ranges and could potentially forage within the project area.
Icteria virens	Yellow-breasted chat	SSC	Riparian scrub, willow and mule fat, including arundo stands.	Likely to be found in all reaches with willow riparian habitat	High potential to occur in downstream reaches, below Soledad Canyon where high quality riparian habitat is present.
Toxostoma lecontei	Le Conte's thrasher	SSC	Open desert scrub, primarily found in habitats dominated by common saltbush.	Potentially found in Real 1 and 2.	Medium potential to occur in scrub habitats areas.
Vireo bellii pusillus	Least Bell's vireo	FE, SE	Riparian scrub, willow and mule fat, including arundo stands.	Most likely to be encountered in the downstream reaches, but possibly occurs throughout the Santa Clara River.	High potential to occur in downstream reaches, below Soledad Canyon.
Reptiles					
Aspidoscelis tigris stejnegeri	Coastal western whiptail lizard	SC	Chaparral, riparian scrub.	Can be found in open riparian scrub, but chiefly associated with upland habitats.	High potential to occur in appropriate habitats throughout The Santa Clara River.
Phrynosoma coronatum blainvillei	Coast horned lizard	SC, SSC	Chamise chaparral.	This species is unlikely to occur in riparian habitats in the project area, but can be found in uplands.	High potential to occur in appropriate habitats throughout the Santa Clara River.
Thamnophis hammondii	Two-striped garter snake	SC, SSC	Riparian habitat.	May be found throughout project area.	High potential to occur throughout project area. Forages widely, and usually active during the day on highly vegetated stream banks.
Amphibians					
Bufo californicus	Arroyo toad	FE, SE	Sandy alluvial stream courses and adjacent uplands.	Possible throughout project area. Known in Reaches 3 and 6 and Castaic and San Francisquito Creeks.	Medium potential to occur since the species will be locally abundant in the few areas it is found, and thorough surveys of the entire project area are lacking.
Rana muscosa	Mountain yellow-legged frog	FE	Montane streams at higher elevations.	None	Species does not occur in the project area.

Scientific Name	Common Name	Status	Habitat	Potential to Occur in Each Reach/Tributary	Potential to Occur (High, Medium, Low) and Why
Scaphiopus hammondii	Western spadefoot toad	SC, SSC	Upland and riparian habitat. Breeds in ephemeral pools.	Potential to occur throughout the project area.	High potential to occur, where intact native upland habitat contacts riparian areas.
Rana aurora draytonii	California red-legged frog	FT, SSC	Prefers permanent water with vegetated edges.	Known only from remnant population in San Francisquito Creek, but could occur elsewhere.	High potential in San Francisquito Creek where current population exists, low potential elsewhere.
Fishes					
Catostomus santaanae	Santa Ana sucker	FT	Swift flowing stretches of Santa Clara River.	Primarily in upstream reaches, but can be found elsewhere during high flows.	High potential to occur when water is present, but low detectability in the absence of trapping/netting surveys.
Gasterosteus aculeatus williamsoni	Unarmored threespine stickleback	FE, SE, DFG: Fully Protected	Typically in slow moving water with vegetated edges.	Possible throughout entire project area.	High potential to occur when water is present, but low detectability in the absence of trapping/netting surveys.
Gila orcutti	Arroyo chub	SC, SSC	Prefers slow water with sand or mud bottom.	Possible throughout project area.	High potential to occur when water is present, but low detectability in the absence of trapping/netting surveys.

FE: federally listed as endangered
FT: federally listed as threatened
SC: state candidate
SE: state listed as endangered
SSC: state species of special concern
ST: state listed as threatened
DFG Fully Protected: The Fish and Game Codes sections dealing with Fully Protected species state that these species "...may not be taken or possessed at any time and no provision of this code or any other law shall be construed to authorize the issuance of permits or licenses to take any fully protected" species, although take may be authorized for necessary scientific research. This language arguably makes the "Fully Protected" designation the strongest and most restrictive regarding the "take" of these species. In 2003, the code sections dealing with fully protected species were amended to allow the Department to authorize take resulting from recovery activities for state listed species. More information on Fully Protected species and the take provisions can be found in the Fish and Game Code (birds at §3511, mammals at §4700, reptiles and amphibians at §5050, and fish at §5515). Additional information on Fully Protected fish can be found in the California Code of Regulations, Title 14, Division 1, Subdivision 1, Chapter 2, Article 4, §5.93. The category of Protected Amphibians and Reptiles in Title 14 has been repeated. The Fish and Game Code is available online at: http://www.leginfo.ca.gov/cgibin/calawquery?codesection=fgc. Title 14 of the California Code of Regulations is available at http://ccr.oal.ca.gov

Species Act (FESA).

5.0 Project Planning

Coordinated removal projects can lead to control of an invasive plant species in the entire watershed. However, before implementing a removal project, it is important to consider the various project elements, which include:

- integrated weed management
- project prioritization
- working with landowners
- public outreach
- surveys and mapping
- methods
- regulatory requirements
- scheduling
- costs
- funding

5.1 Integrated Weed Management

Integrated Weed Management (IWM) is a comprehensive strategy for the control of weeds. It considers each of the various factors influencing a weed removal strategy, such as different removal methods, the timing of the project, the location of the project, and potential impacts to the environment. There are also other factors such as overall project goals, specific agency policies, and local politics. The federal Noxious Weed Act further narrows the concept of Integrated Weed Management. It defines IWM as "a system for the planning and implementation of a program, using an interdisciplinary approach, to select a method for containing or controlling undesirable plant species or groups of species using all available methods, including education, prevention, physical or mechanical methods, and general land management practices."

Integrated Weed Management is vital for the control and potential eradication of invasive plant species. Removal projects often achieve the most success when a variety of strategies are implemented. For example, it may be effective to implement herbivory as a control measure in one section of a removal project area, while other sections undergo eradication measures. Active surveying can assist with controlling outlier populations of invasive plants that have not established yet. Strategies to prevent the spread of invasive species are also part of IWM. This can be approached from a cultural aspect as educating the public about the threat invasive species pose to the environment may help to avoid the use of these species in residential landscaping.

With IWM practices in place, it is also important to minimize the project impacts. Individual projects will utilize Best Management Practices to reduce impacts to the environment, ensure public health and safety, and increase worker safety. These BMPs are listed in Chapter 14. BMPs can be adapted and modified for each individual project depending upon the removal techniques and sensitive habitat and species present.

The Best Available Technologies are used in addition to the BMPs to achieve successful management strategies. The Best Available Technologies will change over time, as research, technologies, and methods are updated. Geographic Information Systems (GIS) and Global Positioning System units (GPS) assist with surveying and mapping while new methods and equipment can increase removal efficiency. The SCARP is a living document and will be revised as necessary to incorporate the Best Available Technologies.

5.2 Prioritization

Individual projects can be conducted anywhere in the upper Santa Clara River watershed. However, since arundo and tamarisk tend to spread downstream, it is best to begin projects at the headwaters of the mainstem of the Santa Clara River and smaller tributary watersheds such as San Francisquito Canyon to ensure effective invasive plant removal. Ideally, the collective effect of the individual projects will eventually be to control invasive plant populations in the watershed.

There are other factors that influence the project site beyond its location in the watershed. These include landowner cooperation, budget, scheduling, regulatory requirements, and many others. Prioritization of projects beyond starting at the highest known establishment should be oriented toward: 1) early detection and control of outlier establishments, 2) control and restoration of limited infestations where sensitive resources are located, and 3) control and restoration of large infesta-

tions.

Early detection and control of outlier establishments

This strategy concentrates on areas where arundo or tamarisk have small, limited infestations and do not have any upstream source populations. This strategy may be more time and labor intensive due to potentially difficult logistical issues such as hard to reach locations and/or careful hand-removal techniques of arundo or tamarisk to avoid impacts to wildlife. However, this strategy prevents dense establishment of invasive plant species where there is moderate to good habitat.

Control and restoration of limited infestations where sensitive resources are located

This strategy concentrates on areas where arundo or tamarisk have limited infestations and where sensitive resources are located. This strategy may be more time and labor intensive due to careful implementation of hand-removal techniques of arundo or tamarisk to avoid impacts to wildlife. However, this strategy also prevents dense establishment of invasive plant species where there is moderate to good habitat.

Control and restoration of large infestations

This strategy concentrates on areas where arundo or tamarisk are dense monocultures in order to completely eradicate their presence and to restore habitat. It may be easier and/or more cost-efficient to use mechanical removal techniques or broadcast foliar spraying in areas with thick infestations. This strategy allows the restoration of large areas, which previously had no habitat value.



6.0 *Surveying and Mapping*

Project applicants should develop detailed maps for their specific project areas. Maps are integral to effective eradication of establishments of invasive plant colonies. They are important for documenting the current vegetation status, detecting and tracking pioneer colonies of invasive plant clusters, and monitoring the level of success after invasive plant removal.

Effective mapping is a result of organized and consistent data collection. In planning an invasive species removal project, applicants should follow an established protocol for their data collection efforts. Data collection can be accomplished using field forms, aerial maps, photo documentation, and/or GPS units. Utilization of established protocols for data collection also facilitates the sharing of weed information with other agencies that have a stake in controlling and eradicating invasive plant species.

There are numerous mapping techniques with different protocols and different nomenclature (naming) systems. Maps can be prepared manually via the annotation of aerial photographs, or via various GIS software packages in tandem with GPS hand-held units for data capture. Maps may simply reflect the extent of infestations, or may also contain additional attribute information that further characterizes the infestation. Resources for current mapping protocols include the CDFA weed mapping handbook and The Nature Conservancy's Weed Inventory and Mapping System (WIMS), which is currently being adapted by Cal-IPC for California's wildland weeds. CDFG promotes vegetation mapping according to A Manual of California Vegetation (Sawyer and Keeler-Wolf 1995).

AMEC Earth and Environmental performed mainstem vegetation surveys and a preliminary tributary overview in Winter 2004-2005, which are both discussed within the text of this document. Condor Environmental performed tributary vegetation surverys in Fall 2005. Detailed maps are provided as individual files in the Appendices.

The vegetation mapping surveys undertaken by the VCRCD for the Upper Santa Clara River identified 43 vegetation series located within the 500-year floodplain of the mainstem. Vegetation falling outside of the 500-year floodplain was not mapped. Most of the mapped vegetation series were delineated on maps created from aerial photographs following the vegetation series listed in A Manual of California Vegetation (Sawyer and Keeler-Wolf 1995). However, several of the vegetation series incorporated in the SCARP were not derived from the preceding document, but were rather based on the dominant and associated plant species present (e.g., Pepper Tree).

The VCRCD has a long-term interest in the removal of invasive species from the Upper Santa Clara River watershed. As such, the VCRCD recommends that applicants follow an established protocol of data collection so that consistency of data can be achieved, and for ease of future monitoring efforts. Project applicants are encouraged to use the existing VCRCD maps not only for refer-



ence, but also as models for their own map products.

7.0 Working With Landowners

The majority of the mainstem of the upper Santa Clara River as well as the lower middle reaches of the tributaries are privately owned. A cooperative working relationship with private landowners is critical in order to address the areas of heavy infestations. Several large landowners such as Lennar-LNR and various sand and gravel mining companies own substantial portions of the Santa Clara River. Hundreds of small- and mid-sized parcels are also located throughout the Santa Clara River's middle and upper reaches as well as the lower tributaries. These parcels include private campgrounds, mobile home parks, small ranches, and residential estates. The cooperation of both large and small landowners is essential for successful eradication. Landowners may not be aware of the impacts caused by invasive plants to public safety, property, and the environment. Education and outreach will increase knowledge of these impacts.

Landowners can work with Non-Governmental Organizations (NGOs), Resource Conservation Districts (RCDs), or other groups to perform removal work on their property. Agencies such as RCDs can assist with the regulatory process as well. Project applicants that do not own the property they wish to work on should request a cooperative landowner agreement prior to starting a project.

8.0 Public Outreach

Members of the public are often not aware of the negative impacts that invasive species bring to an ecosystem. The public typically assumes that the presence of any variety of greenery in the environment is beneficial and associates scenic value to it. Therefore, increasing public awareness of the impacts from these invasive species and support for their eradication is a critical component of project success. Public outreach activities should focus on a particular audience and have a specific goal, and individual projects should focus on outreach efforts prior to initiating removal. For example, local residents who live adjacent to removal sites should be notified of project activities, removal techniques, and potential impacts such as noise or visual changes before the commencement of the project.

Various organizations and municipalities are already engaged in outreach activities supporting the removal of invasive plants as well as the preventative measures that help reduce the spread of these plants. CAL-IPC is a non-profit organization that works with the California Department of Food and Agriculture's (CDFA) Weed Management Areas (WMA) and other local agencies to educate the public and municipalities on invasive plants and their eradication. Additionally, the Los Angeles Weed Management Area has created a Best Management Practices for Vegetation Removal as well as a children's booklet on invasive plants. There are numerous brochures from the various agencies on how to prevent the spread removal invasive plants. See Chapter 19.0 for resource information.

Where arundo is targeted for removal from private parcels, personal contact with parcel owners must be made to in order to gain access to removal sites. Landowners are often concerned about the impacts the removal activities will cause, and care should be taken to acknowledge and address their concerns. While one-on-one meetings may be time consuming, they are a beneficial investment towards a successful removal program. Typical landowner concerns include issues relating to privacy, liability, property damage, impacts to natural resources, erosion, and regulatory problems.

When removal projects are planned for sites that

are adjacent to developed areas, especially residential zones, it is important to notify or otherwise communicate with residents about the removal activities. Tolerance and support of residents for removal projects is enhanced via outreach and education efforts. This can be achieved via an informational postcard mailing, or by distributing brochures or handouts on a door-to-door basis.

The success of outreach efforts can be enhanced by incorporating the following points:

- Understand Your Audience: Do not assume individuals are versed in issues pertaining to invasive plant species. Present the information in a manner that is informative and engaging. Photographs and other visual cues are often very helpful in illustrating important points.
- Keep It Basic: Focus on primary issues. Over whelming your audience with information may not necessarily inspire them to join your cause. However, casting illumination on the most important issues will initiate a constructive increase in awareness of the problem.
- Be Context Aware: If members of the public initiate casual dialogue about a removal project with you, a casual response will be more appropriate than a technical monologue.
- Signage: Post signs where removal work is already underway. Incorporate photos that illustrate "before" and "after" scenarios to reinforce the benefits of the project.

For its own arundo removal efforts, the VCRCD has initiated several public outreach activities; selected examples are listed below:

- Prepared and distributed brochures containing information about arundo and tamarisk and the problems they cause, as well as the benefits of removal.
- Held public workshops such as those associated with the EIR/EA scoping in January 2005, as well as more recent workshops in Santa Clarita and Acton about the infestation problem in general.
- Created the SCARP Working Group to facilitate community and agency coordination on this issue.
- Contacted local schools to educate students about invasive plants and Weed Awareness Week.
- Sent out postcards to local residents around the Santa Clarita project site to inform them about the various aspects of the individual project.
- Held two public hearings inviting comments regarding the EIR/EA.
- Participated in the Santa Clara River Rally, a river clean-up event organized by the City of Santa Clarita.

Another important aspect of public outreach is the utilization of local resources. Various organizations and municipalities already support the removal of invasive plant species, and many have implemented preventative measures to reduce the spread of these species. The events they organize help raise public awareness about specific environmental hazards and the measures being taken to remove them. The VCRCD has participated in many such events in an effort to bring additional attention to the Upper Santa Clara River project . The various agencies and/or events that address invasive species are listed below:

- City of Santa Clarita sponsored events such the Santa Clara River Rally, Arbor Day, and Earth Day
- Los Angeles County sponsored events such as the County Fair and Earth Day
- Los Angeles County Weed Management Area Meeting
- Southern California Wetlands Recovery Project (SCWRP) Task Force Meetings
- Santa Clarita Organization Planning for the Environment (SCOPE)
- Friends of the Santa Clara River
- The Nature Conservancy
- Sierra Club
- California Native Plant Society
- Audubon Society
- Santa Clarita Well Owners Society
- Local Schools

9.0 REGULATORY SETTING

A primary goal of the SCARP is to facilitate the permitting of arundo and tamarisk removal projects by state and federal regulatory agencies, consistent with protection of sensitive resources. VCRCD is coordinating with regulatory agencies to develop a programmatic regulatory framework for future removal projects. As this process may take several years, individual permits may be necessary for removal projects. The following discussion provides an overview of the primary existing regulatory structure covering removal projects. Table 5 provides guidance for individual project applicants for regulatory compliance on their projects.

9.1 U.S. Army Corps of Engineers

Under Section 404 of the Clean Water Act (CWA), a permit is required by USACE for any activity that results in discharge of dredged or fill material into "waters of the United States (U.S.)" and associated wetlands. Waters of the U.S. refers to water in drainages that occurs below the plane of the ordinary high water mark. Examples of dredged or fill material for the SCARP projects that would be subject to USACE regulation would include earthmoving associated with temporary water diversions, temporary access roads, and below-ground biomass removal. Different permitting options are available through the USACE. For example, Regional General Permit (RGP) 41 is an existing permit for no or minimal impact invasive plant removal projects for infestations greater than 50 percent cover. Project sites with infestations lower than 50 percent or which have more than minimal impacts require another type of 404 permit such as a nationwide or individual permit.

9.2 U.S. Fish and Wildlife Service

Species listed as endangered or threatened by the USFWS are protected under the Federal Endangered Species Act (FESA). If listed species could be affected by removal activities, consultation with the USFWS is required. Consultations result in a set of formalized protection measures that become a part of the project.

9.3 California Department of Fish and Game

Streambed Alteration Agreement

Pursuant to Section 1602 2 of the Fish and Game Code, the CDFG has jurisdiction over activities that affect the "bed, channel, or bank of any river, stream, or lake that has or benefits fish or wildlife". CDFG jurisdiction includes streamside (riparian) habitat on top of banks as well as the drainage itself.

California Endangered Species Act

The California Endangered Species Act (CESA) provides protection to endangered and threatened species in California. If a project may affect state-listed species, coordination with CDFG is required. In some cases, an incidental take permit may be required.

9.4 Regional Water Quality Control Board

A project that requires a Section 404 permit from the USACE will also require a Water Quality Certification (401 certification) from the RWQCB. A 401 permit certifies that the proposed activity will not violate state or federal water quality standards.

9.5 Southern California Air Quality Management District

Projects that propose controlled burning or incineration of biomass require consultation of the Southern California Air Quality Management District.

9.6 California Department of Transportation Encroachment Permit

The use of California State highways for other than normal transportation purposes may require written authorization from the Department of Transportation. As the responsible Department for protecting the public's investment in the State highway system, CalTrans reviews all requests from utility companies, developers, volunteers, nonprofit organizations, etc., desiring to conduct various activities within the right of way.

9.7 Los Angeles Department of Public Works Encroachment Permit

Project sites that utilize areas owned by or having easements by the Los Angeles Department of Public Works will require an encroachment permit. Road Construction permits are necessary for the construction of driveways, curb drains, sidewalks, curbs and gutters and other types of surface construction. Road Excavation permits are necessary when digging within the road right-of-way, which often includes the portion of land beyond the curb and all the way to the sidewalk. Road Encroachment permits are necessary when you wish to place anything in the road right-of-way temporarily or long term.

9.8 Los Angeles County Grading Permit

The Los Angeles County Building Code requires a grading permit to perform any grading except for the following work:

An excavation that: 1) is less than 2 feet (61 cm) in depth or; 2) does not create a cut slope greater than 5 feet (1.5 m) in height and steeper than 1 unit vertical in 2 units horizontal (50% slope) and does not exceed 50 cubic yards (38.3 m^3).

A fill not intended to support structures and which does not obstruct a drainage course if such fill (a) is placed on natural grade that has a slope not steeper than five horizontal to one vertical and is less than 1 foot (30.5 cm) deep, or (b) is less than 3 feet (91.4 cm) in depth at its deepest point, measured vertically upward from natural grade to the surface of the fill, and does not exceed 50 cubic yards (38.2 m^3), or (c) does not exceed 20 cubic yards (15.3 m^3) on any one lot.

9.9 California Environment Quality Act

The California Environmental Quality Act (CEQA) is intended to provide information to public agencies, decision-makers, and the public regarding the environmental impacts from implementation of a proposed project. CEQA compliance is required for all local and state public agencies, municipalities, and private entities that undertake an activity, which requires a permit, or discretionary approval from a government agency, or that may cause either a direct physical change in the environment or a reasonably foreseeable indirect change in the environment.

The environmental review process was established to enable public agencies to evaluate a project in terms of its environmental consequences, to examine and implement methods of eliminating or reducing any potentially adverse impacts, and to consider alternatives to the project. While CEQA requires major consideration be given to avoid environmental impacts, the lead agency and other responsible public agencies must balance adverse environmental effects against other public objectives, including social and economic goals, in determining whether and in what manner a project should be approved.

Projects using the methods in this long-term plan may utilize the SCARP programmatic EIR once the programmatic permit structure has been developed. Other projects may require a CEQA exemption, negative declaration, mitigated negative declaration, or environmental impact report.

9.10 National Environmental Protection Act

The National Environmental Protection Act (NEPA) requires federal agencies to consider potential environmental consequence of proposed actions in their decision-making process. The law's intent is to protect, restore, or enhance the environment through well-informed federal decisions. Projects which require a permit or discretionary approval from a federal agency will also require NEPA compliance.

The regulatory process may involve a significant investment of time. Table 5 is provided as a planning aid and offers an example illustration of the amount of time applicants can expect to use for this phase of their projects.

Table 5: Guide to Regulatory Compliance

Timeline	Task
1-2 months	Use SCARP to develop project and choose removal or control method.
1-6 months depending on scope and scale of project, engineered design, and other project elements.	Develop project description, including analysis of impacts, avoidance, and minimization measures.
1- 2 months	Complete and submit application materials for: 404 permit (USACE); 401 certification (RWQCB); 1602 Streambed Alteration Agreement (CDFG)
1-3 months depending on agency availability	Agencies require additional information or modification to application or project description. Coordinate with agencies to modify application or project description as necessary.
1-2 months	Agencies accept revised application or project description.
After receipt of complete application	USACE begins consultation with USFWS
3 months to over a year depending on type of consultation	USFWS issues Letter of Concurrence or Biological Opinion.
Usually within 3 months of completed applications and completed consultation with USFWS	Agencies issue permits.
Upon receipt of all permits	Implement project



10.0 Removal Methodology

A wide range of techniques is currently used in the control and removal of arundo and tamarisk. These include hand removal, mechanical removal, herbicide application, tarping, controlled burning, and biological control, as well as various combinations of these techniques. Based upon a review of available literature and contact with different agencies and specialists, it has been determined no single method has been proven most effective for every situation. Different agencies and organizations involved in control of arundo and tamarisk tend to favor differing approaches to control and removal based on their experience, resources, and local environmental and policy circumstances. This is also reflected in the literature, where different researchers have noted variable findings for the effectiveness of different techniques.

For example, the Santa Margarita and San Luis Rey Watersheds Weed Management Area (SMSLRWMA) rely primarily on a fall-period foliar spray application, followed by spring biomass removal for arundo removal. The SMSLRWMA reports this method as having the highest success rate for their arundo infestation problem (Giessow 2005). In contrast, in its initial focused projects, the VCRCD has used various methods, including foliar spray application or the cut and daub technique accompanied by biomass removal, with chipping and reuse of the arundo mulch outside the stream channel. Other groups, such as Circuit Rider Productions, prefer tarping as a non-herbicidal approach, and have found it highly effective on smaller stands of arundo.

Ultimately, the selection of the appropriate removal method for each project will depend upon:

- the time of year
- severity of infestation
- the presence of native plants and wildlife
- the degree of intermixing of invasive species with sensitive native habitats
- the presence of sensitive native species
- access
- proximity to surface water
- budget
- permitting standards

Regardless of the method chosen, all projects will require follow-up treatments and monitoring, and have the potential to impact sensitive species in certain habitat areas. Due to the range of variables that influence the control and removal of these invasive species, and the differences among opinion on which techniques are the most effective and environmentally appropriate for a given circumstance, the SCARP presents a menu of options for different removal techniques. Each technique is described in terms of typical procedures involved and the general circumstances where it is usually employed including a discussion of the general pros and cons of each approach, which is summarized in Table 6.

The general analysis of the pros and cons of available control options is further refined in terms of their potential utility for application to various reaches of the Santa Clara River and its associated tributaries. For planning purposes, the Santa Clara River has been subdivided into six reaches (Chapter 3) based on similar traits such as channel morphology, water availability, vegetation types, and surrounding uses and access. Each major tributary is treated individually with the major tributaries broken into upper, middle, and lower reaches where appropriate based on differing physical characteristics.

The Santa Clara River's reaches and its tributaries vary considerably not only in terms of physical and ecological characteristics, but also in degree of infestation, intermixing of invasive species with native habitats, environmental sensitivity, and access. These factors in turn guide, but not entirely limit, the choice of removal options preferable for a certain reach. For example, the environmental sensitivity of a certain reach may warrant use of more labor intensive but environmentally sensitive techniques (e.g., cut and daub) and limit the widespread use of more intrusive techniques (e.g., mechanical clearing), particularly during the bird breeding season. However, sub-sections of this reach may be less sensitive and warrant consideration of mechanical clearing or other more invasive approaches. For this reason, the methods section is generally inclusive in terms of available techniques. However, regardless of the technique selected, all potential options are accompanied by an extensive list of BMPs in Chapter 14.



Table 6: Summary of Removal Method Options

Method	Appropriate Use	Timing	Tools	Instructions	Advantages	Disadvantages
Hand Removal (Above-Ground only)	Small infestations where there is concern regarding herbicide use.	Removal can be performed anytime, but most effective time to cut arundo and tamarisk is during the growing season (spring through fall). Rain and high water can limit wet season access.	Loppers, machete, chainsaw, bladed weed whipper, or similar equipment.	Stems, canes, and trunks are cut as close to the ground as possible. Cut biomass is generally removed from the project site and chipped, burned, or disposed of at a landfill to prevent reestablishment of cuttings. Roots and rhizomes are left in the ground.	Specific, minimizes damage to native plants/ animals. Minimizes soil disturbance.	Labor and time intensive. Very low mortality rates require repeated re-treatment (>5 years) to be effective which increases the project cost and frequency of disturbance to sensitive areas. Extensive debris removal.
Hand Removal (Above and Below-Ground)	Young plants and small stands, or when there is concern about herbicide use.	Removal can be performed anytime. Rain and high water can limit wet season access.	Pick-axe, mattock, shovel, loppers, machete, chainsaw, picks, or similar equipment.	Above-ground trunks, stems, or canes are first cut near the base. After clearing the material, roots and rhizomes are dug up using hand tools.	Specific, minimizes damage to native plants/animals. Effective if rhizomes and root masses are thoroughly cleared from site.	Labor and time intensive. Requires careful cleaning of roots/ rhizomes and debris removal. Soil disturbance and erosion potential.
Mechanical Removal (Above-Ground only)	Areas with easy access for heavy equipment and on stands not intermixed with native plants.	Removal can be performed anytime, but most effective time to cut arundo and tamarisk is during the growing season (spring through fall). Rain and high water can limit wet season access.	Tractor-mounted mower, towed disc, plow, flail mower, or similar equipment.	The stalks, stems, and canes are cut using the mower, disc or plow as close to the ground as possible. Cut biomass is removed from the project site immediately following cutting to prevent reestablishment of the cut material. Roots and rhizomes will remain in the ground.	Effective biomass removal for extensive stands.	Very low mortality rate requires repeated re-treatments. Extensive manual debris removal necessary when biomass is large enough to resprout. Requires site access by equipment.
Mechanical Removal (Above and Below-Ground)	Areas with easy access for heavy equipment and on stands not intermixed with native plants.	Removal can be performed anytime. Rain and high water can limit wet season access.	Backhoe, excavators or other heavy machinery.	A backhoe or tractor is to be used to simultaneously remove the plants and their root system. If roots/rhizomes remain, the equipment can be used to excavate these larger segments. Hand crews using shovels can dig out smaller fragments.	Effective if rhizomes and root masses are thoroughly cleared from site. Effective for removing very large establishments in open and accessible terrain.	Extensive debris removal. Major soil disturbance and erosion potential. Possible impacts to native wildlife and plant species. Requires site access by equipment.
Tarping	Small stands (<0.25 acres) not intermixed with native plants.	Tarps applied in late spring/ early summer and remain for up to 5 months, usually from June to November.	Chainsaws, machetes, loppers, or similar equipment to cut plants. Opaque thick tarps or pond liners, stakes or weights to hold tarps down.	Stalks and branches should be cut within inches of the ground. Chipped biomass should be placed over cut stalks. The opaque tarp or pond liner is laid over the cut material and secured with stakes or weights. The tarp remains on the target area for a period of five months and is then removed. Dead biomass is removed from the project area and roots and rhizomes are left in the ground.	High success rate when properly applied. Available for active channel areas. Minimizes soil disturbance. Effective on small stands.	Application of method is limited by size of stand. May damage soil microorganisms. Not appropriate for areas that may flood (i.e. channel).
Foliar Spray or Basal Bark Treatment	Any size stand not intermixed with native plants or where herbicide applicators can avoid native plants.	Apply herbicide anytime, but most efficient in early fall through winter when plant energy is transferred to roots. Herbicide should be applied on dry days and during low winds.	Herbicide, applicators such as backpack sprayer, ATV-mounted boom sprayer, spray rig, helicopter, or similar equipment.	Crews apply herbicide using sprayers or wicking on leaves and stems of arundo and foliage or basal bark of tamarisk. Follow herbicide label instructions. Personnel must be trained in the use and handling of herbicides. Timing of application is dependent upon type of herbicide used.	Short duration of labor. Low concentrations of herbicide. Effective on any size of stand. Minimizes soil disturbance.	Risk of drift to non-target plants and wildlife or adjacent sensitive receptors. Herbicide application should not be used in areas where there is great concern regarding herbicide use. Weather conditions must be suitable for herbicide application.

Method	Appropriate Use	Timing	Tools	Instructions	Advantages	Disadvantages
Cut and Paint/Daub	Any size stand. Allows– allows controlled application of herbicide on stands heavily intermixed with native plant species.	Apply herbicide anytime, but most efficient in early fall through winter when plant energy is transferred to roots. Herbicide should be applied on dry days and during low winds.	Chainsaws, loppers, or similar equipment can be used for cutting. Herbicide. Paintbrushes, sponge daubers, or similar equipment for herbicide application.	Trunks, stems, and canes of arundo and/or tamarisk are cut within one foot of the ground and removed. Herbicides is applied to the cut stem surface using brushes or daubers. Timing of application is dependent upon herbicide used. Follow herbicide label instructions. Personnel must be trained in the use and handling of herbicides.	Very high mortality rate. Efficient use of herbicide. Highly selective with little risk of drift of herbicide onto non-target plants or sensitive wildlife species. Little soil disturbance.	Very labor intensive. High concentrations (90-100%) of herbicide. Extensive debris removal is often required. Higher initial labor and herbicide costs than other methods, although less retreatment is required. Weather conditions must be suitable for herbicide application.
Cut, Resprout, and Spray or Paint/Daub	Any size stand not intermixed with native plants or where herbicide applicators can avoid native plants.	Cut one to two months prior to spraying. Apply herbicide when resprouts are 2-4 feet tall, but most efficient in early fall through winter when plant energy is transferred to roots. Herbicide should be applied on dry days and during low winds.	Loppers, chainsaws, flail mower, or similar equipment for cutting. Herbicide. Paintbrushes, sponge daubers,, applicators such as backpack sprayers, ATV-mounted boom sprayers, spray rigs, helicopter, or similar equipment for herbicide application.	Trunks, stems, and canes of arundo and/or tamarisk are cut within one foot of the ground and removed. Herbicide is applie Apply herbicide after a sufficient period has elapsed (approximately one to two months) to allow for re-sprouting. Follow herbicide label instructions. Personnel must be trained in the use and handling of herbicides.	Low soil disturbance associated with this method if hand tools are used. Less risk of herbicide drift than when spraying full-grown canes.	Waiting for resprouts after cutting can be impractical when working in remote areas. Large equipment (such as flail mowers) can substantially disrupt the soil and damage native, non-target species and habitat. Weather conditions must be suitable for herbicide application.
Cut and Spray	Any size stand not intermixed with native plants or where herbicide applicators can avoid native plants.	Apply herbicide anytime, but most efficient in early fall through winter when plant energy is transferred to roots. Herbicide should be applied on dry days and during low winds.	Loppers, chainsaws, flail mower, or similar equipment for cutting. Herbicide. Backpack sprayers, applicators such as backpack sprayer, ATV-mounted boom sprayers, spray rigs, or similar equipment for herbicide application. .	Crews will cut plant to four or five feet and then apply herbicide using hand held sprayers on leaves and stems of arundo and foliage or basal bark of tamarisk. Personnel must be trained in the use and handling of herbicides.	Moderate mortality rate. Minimizes soil disturbance. Minimizes risk of drift onto non-target species.	Biomass removal is labor intensive. Stalks intended for spraying may be trampled. Weather conditions must be suitable for herbicide application.
Controlled Burning	Large stands of pure arundo and tamarisk or for girdling of individual tamarisk trees.	Removal can be performed anytime.Anytime. Burning is most effective during growing season.	Flamethrowers weed burners, or similar equipment. Fuel.	Crews to either broadcast burn large stands or employ flamethrowers or weed-burners to spot treat small clusters, or heat-girdle stems at the base of individual plants. For larger controlled burns, fire crews would likely be required to monitor fires to prevent unintentional spread. . Fires applied during the rain season may help prevent spread of wildfires.	Highly effective in removing biomass.	Requires permits to perform burns and repeated burning to control biomass. Low mortality rates make it ineffective as sole or primary tool. Large potential for regrowth. Potential for associated collateral impacts to native habitat and wildlife. Risk of fire spread to non-intended targets. Arundo and tamarisk readily recover from fire which allows them to out-compete native riparian vegetation in post-fire circumstances.

Method	Appropriate Use	Timing	Tools	Instructions	Advantages	Disadvantages
Controlled Burning with Herbicide Treatment	Large stands of pure tamarisk.	Removal can be performed anytime.Anytime. Burning is most effective during growing season. Herbicide application most effective in the fall through winter.	Flame throwers or weed burners, or similar equipment. Fuel. Herbicide, sponge daubers, paintbrushes, and backpack sprayers.	Crews Controlled burning involves using crews to either broadcast burn large stands or employ flamethrowers or weed-burners to spot treat small clusters, or heat-girdle stems at the base of individual plants. For larger controlled burns, fire crews would likely be required to monitor fires to prevent unintentional spread. Fires applied during the rain season may help prevent spread of wildfires. Herbicide is then may be applied to cut canes or stumps, or applied to resprouts after a sufficient period has elapsed (approximately one to two months). Personnel must be trained in the use and handling of herbicides.	Highly effective in removing biomass.	Requires permits to perform burns. Potential for associated collateral impacts to native habitat and wildlife. Risk of fire spread to non-intended targets. Weather conditions must be suitable for herbicide application.
Grazing	Large stands of pure arundo or tamarisk where herbicide use is a concern.	Anytime. Most effective during growing season.	Grazing animals such as goats, temporary fencing.	Although grazing can be used to reduce or eliminate tamarisk sprouts and reduce arundo growth, this technique requires focusing the grazers on areas with high densities of the target vegetation. This may require fencing, herding, or other techniques to ensure that the method is effective and that grazers do not target native vegetation.	If grazing animals are readily available, then may be effective temporary control of new growth. Provides animal forage.	Labor and time intensive. Very low mortality rates require repeated re-treatment (>5 years) to be effective which increases the project cost and frequency of disturbance to sensitive areas. May be difficult to focus grazing on target species. Concentrated areas of animal waste may cause negative impacts to treatment areas.
Biological Control	Control of large infestations.	Dependent upon pathogen or species released.	Dependent upon pathogen or species released.	Biological control would involve the controlled release of a pathogen, or insect species from these plants' native range to feed upon, create disease in, or otherwise impair the growth, spread, and/or reproduction of arundo and tamarisk. All such biological controls are monitored and regulated by the USDA and it would be necessary to coordinate with that agency.	When implemented, biological control is expected to be effective in controlling the spread of infestations, but may not be extremely effective in the eradication of the target species populations.	No biological control agent is approved for use in the upper Santa Clara River for either arundo or tamarisk as of this writing.





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11.0 Herbicides

The range of herbicides available for use on arundo and tamarisk infestations is limited due to the label restrictions of application to wildlands. However, application of herbicides can be one of the most effective tools for control and eradication of these invasive plants. Most herbicides work by disrupting amino acid production in plants. As humans and wildlife do not share these same metabolic pathways, herbicide function is not directly relevant to health risk assessment. Herbicides are effective when used alone to control infestations, but are often used in conjunction with other techniques such as cutting or mowing. The use of herbicides can substantially increase mortality rates of persistent invasive plants, reducing the need for invasive hand or mechanical excavation of roots and rhizomes and associated soil disturbances. However, the utility of herbicide application in control of arundo and tamarisk can be affected by its relatively high initial cost, restrictions on use in proximity to water, the degree of intermixing of invasive plants with natives, and the presence of sensitive species. These factors can all restrict the type of herbicide allowed, the location and timing of use, and the method of application.

The success of herbicide application primarily depends upon selecting the appropriate herbicide for the task and closely adhering to label directions. Many herbicides are prohibited for use around open water and all may exhibit seasonal variations in effectiveness. The most effective method of application can vary between brands and types of herbicides. Most herbicides require the use of a surfactant, which may be included in the product or added prior to application to increase effectiveness. Colorants are also often added to herbicide solutions to enable spray crews to see where they have sprayed after initial evaporation of the solution. The USEPA and the California Department of Pesticide Regulation (CDPR) must register the herbicides prior to their use in California. Further, the large-scale application of herbicides must be overseen by a licensed professional. Appendices 9 and 10 contain detailed descriptions of herbicides, issues surrounding application, and appropriate techniques for application.

The three herbicides most commonly used in the eradication of arundo and tamarisk in riparian areas of Southern California are glyphosate, triclopyr, and imazapyr. While these herbicides are available under a variety of brand names, the focus of our discussion pertains specifically to these respective active ingredients. Formations of glyphosate and triclopyr for use near aquatic habitats are available, and a formulation of imazapyr is pending for use near water. Different mixtures of these herbicides are effective under different circumstances as discussed in more detail in Appendix 9.

11.1 Glyphosate

Glyphosate can be used to treat arundo and tamarisk is the active ingredient in the retail products such as Aquamaster®, Rodeo®, Glypro®, and Roundup®. The USEPA has approved Rodeo® and Aquamaster® for use in aquatic environments, making glyphosate one of the primary herbicides currently available for use when surface water is present. Roundup®, conversely, is only approved for use in areas where water is not present.

Glyphosate is most effective when used on perennial plants, such as arundo and tamarisk, when applied in the late summer and fall when the plant is entering dormancy, as this permits transmission of the herbicide to the plant's root system (Sonoma Ecology Center 1999).

11.2 Imazapyr

Imazapyr can also be used to treat arundo and tamarisk and is the active ingredient in Stalker® and the new aquatic habitat formulation, Habitat®. Imazapyr is a non-selective herbicide used for the control of a broad range of weeds including terrestrial annual and perennial grasses and broadleaved herbs, wood species, and riparian and emergent aquatic species (Tu, et al. 2001). a low potential for leaching into groundwater. It has low toxicity to invertebrates and is non-toxic to fish, mammals, and birds (USFS 1995). Unlike glyphosate, it can damage adjacent non-target plants, with the exception of conifers, by transfer between root networks.

11.3 Triclopyr

Triclopyr can be used to treat tamarisk and is a selective systemic herbicide. It has little or no impact on

grasses (e.g. arundo). Triclopyr is the active ingredient in Garlon® and Pathfinder® formulations, and is known as Access® in other states. Garlon® 4 and Pathfinder® II are approved for terrestrial habitats. Garlon® 3A is approved for use in closed aquatic habitats such as wetlands and lakes. It is not allowed for use on streams and rivers. It is recommended for use within 300 feet of water by the USFWS.

11.4 Adjuvants

Herbicides generally need to be applied with an adjuvant. There are several types of adjuvants including surfactants, non-foaming agents, and colorants. A surfactant is any compound that is added to an herbicide formulation or tank mix to facilitate the emulsifying, dispersing, spreading, wetting, or other properties of a liquid by modifying its surface characteristics (Vencill 2002). Surfactants, also known as stickers/spreaders, are similar to detergents in their action, reducing water surface tension to allow wetting and penetration of the plant tissues. The surfactant helps to achieve optimum herbicide adsorption into and adherence from the herbicide onto the plant. Surfactants may also improve an herbicide's efficacy so that the concentration or total amount of herbicide required to achieve a given effect is reduced, sometimes as much as five- or ten-fold (Tu et al. 2001). In this way, adding an appropriate surfactant can decrease the amount of herbicide applied and lower total costs for weed control (Tu et al. 2001). All herbicide labels recommend surfactants and other additives to improve herbicide effectiveness. In some cases, the herbicide will already have the surfactant included, but in other cases, it will be necessary to buy one. Herbicide applicators should check the label prior to adding surfactant. USEPA regulated adjuvants should be approved by the regulatory agencies. Non-ionic surfactants, such as Agridex®, are recommended by the USFWS.

12.0 Access and Staging Areas

Staging areas are often utilized during larger removal projects. Staging areas are used for the storage of and servicing of equipment, the chipping and temporary storage of biomass, and the subsequent loading of chipped material onto trucks for removal from the project area. Staging areas are typically 0.25 to 0.5 acres in size.

Staging area selection is based on available space, ease of access from surrounding roads, ease of access to the eradication site, and the least potential to conflict with adjacent land uses. Permission for use of each staging area may need to be coordinated with the appropriate landowner. Staging areas are typically enclosed with orange construction fencing, or by a six-foot-tall chain link fence to prevent unauthorized access and to ensure public safety.

Staging areas should be located outside of the 25-year floodplain on the upper terrace, levee, or bank of the river or tributary where removal is occurring. In staging areas where chipping is not compatible with surrounding land uses (i.e., near residences, schools, and parks), chipping should occur at the nearest staging area that is appropriate for chipping. Each staging area may be used to accommodate equipment storage and maintenance, portable sanitation facilities, emergency decontamination kits, and handheld equipment when not in use. Unsecured herbicides should be removed from the staging areas each night. All handheld equipment, including chainsaws and backpack sprayers, should be removed from the staging area at the end of each work day and not left at the project site. If large equipment, including ladders, tractors, chippers, and booms, are to be left at the work site overnight, they should be stored in the staging area. Large equipment should also be kept in the staging area when not in use. All maintenance and refueling activities should be performed within the staging areas to minimize risk of leakage/spills.

13.0 Disposal Options

Arundo and tamarisk biomass may be disposed of in a variety of ways.

13.1 Drying

Treated biomass is stacked at staging areas and completely dried, so it is no longer viable and able to resprout. The dried biomass can be left at the site, burned, chipped, or taken to a landfill for permanent disposal. Biomass may be left in piles in upland areas outside the 25-year floodplain to enhance wildlife habitat for small mammals only if cut prior to seed production. If left on site, biomass should be monitored for re-growth. Drying may not be appropriate for rhizomes due to their ability to resprout when exposed to moisture, even after long periods of drying,

13.2 Chipping

A chipper is used at the staging area, or on the banks of the river or tributary, or within the river channel itself (often directly into the back of trucks) to shred the arundo canes or smaller tamarisk branches. The chipper should be placed at an appropriate distance from potentially sensitive groups and all noise reduction accessories should be employed. The biomass may either be stacked and dried before being fed into the chipper, or may be fed into the chipper while still green. It is recommended that a large chipper be used as arundo can break the blades of smaller chippers. Chipped arundo biomass is suitable for beneficial reuse as mulch if chips are less than four inches, as longer segments often still remain viable Chipped tamarisk biomass may be contaminated with seed or salt (from foliage). It is recommended that tamarisk mulch be allowed to dry for two weeks to ensure seeds are no longer viable. Chipped biomass of arundo or tamarisk may also be disposed of off-site in a landfill for permanent disposal.

13.3 Incineration

Disposal of biomass occurs by burning cut material (that has not been chemically treated) at the staging area after the biomass has dried. Incineration requires obtaining a permit from the Los Angeles County Fire Department and the Los Angeles Air Quality Management District and would only be appropriate outside of fire season. Incineration should only be used under low wind conditions. Necessary fire control equipment (e.g., extinguishers, water hoses, etc.) should be on hand to prevent any unintended spread of the fire.

13.4 Landfill Disposal

The cut biomass is transported off-site to a landfill for permanent disposal. Chiquita Canyon Landfill is the closest landfill to the project area available for use. Landfills typically charge per load or by ton, which can add to the overall project cost.

13.5 Beneficial Re-use

13.5.1 Commercial and Cottage Industries

Removed arundo stalks may occasionally be sold for commercial purposes. Manufacturers of reeds for woodwind instruments, as well as those producing pressed board and paper products often have an interest in aquiring cut arundo canes. Arundo biomass may also be used to handcraft flutes, walking canes, and other such items as part of a cottage industry. However, as the overall goal of any removal project is to eradicate arundo, the sale of cut arundo for profit, and the development of commercial distribution channels is not encouraged. Project applicants who are approached by commercial entities who either wish to acquire the cut biomass, or who offer cutting/harvesting services, should only undertake such arrangements after entering into contract negotiations with the commercial entity. Appendix 12 lists guidelines that should be included in such a contract.

13.5.2 Cogeneration

Dried arundo and tamarisk biomass may be used as an environmentally friendly fuel in cogeneration power plants. However, and as mentioned above, the establishment of arundo for commercial applications is not encouraged as the overall goal is to eradicate arundo.

14.0 BEST MANAGEMENT PRACTICES AND MITIGATION MEASURES

Although the primary goal of arundo and tamarisk eradication programs is to improve habitat quality, some eradication techniques have the potential to negatively impact native habitat surrounding, and within, the project footprint. BMPs are intended to reduce the ecological cost of eradication projects and minimize deleterious impacts, while allowing the most appropriate eradication techniques to be used. Regulatory permits require implementation of BMPs. Most BMPs are implemented at the time work is conducted in the field, however some can be implemented prior to commencement of work.

The BMP project checklist provided below (Table 7) is designed to facilitate the application of BMPs for all possible projects. The list is based on three elements that will need to be considered for each project before it is implemented:

(1) how invasive species are to be removed from the project site;
(2) how the biomass of dead invasive plants will be disposed of and removed from the project site after treatment; and
(3) what types of sensitive species are either present or have the potential to be present on the site.

Note that all general BMPs shall be applied to all projects, no matter how small, in order to ensure that removal of invasive species does not adversely affect the remaining habitat quality. To use the checklist, answer the questions in gray bars, and see the text sections of the SCARP referred to next to the answer.

14.1 General BMPs

The following general BMPs are applicable to all removal scenarios and must be implemented for all related projects.

14.1.1 Limits to Site Disturbance

- All projects will coordinate with the regulatory agencies to obtain appropriate permits.
- Work area will be limited to smallest area possible.
- Vehicle use will be limited to the maximum extent possible. If vehicles are to be used, rubber-tired vehicles are preferred over tracked equipment.
- Soil disturbance will be limited to the maximum extent possible.
- Native vegetation and tree damage or removal will be limited to the maximum extent possible.
- No project activities will occur in flowing or ponded water.
    - If water must be crossed, an appropriate spanning method such as a temporary bridge consisting of planks or a steel grate/plate is to be used.
    - If work must occur in areas of flowing or ponded water, approved techniques for water diversion are to be used prior to beginning project activities.
- Staging areas will be located outside the active channel on the upper terrace, levee, or bank of the river or tributary.
- Staging areas will be located in compacted and de graded areas, preferably near access points when site conditions allow.
- Movement of personnel and equipment will be limited to designated work zones, staging areas, and access roads.
- Access points will be located at pre-existing ramps/roads, in areas infested with non-native or invasive plant species, or in areas that are already degraded. Areas with compacted soil will be used preferentially over areas with loose soils. Soil from access points infested with noxious species will be compacted, and biomass from such access points will be mulched to avoid distribution of seeds.

14.1.2 Site and Personnel Management

- All OSHA (Occupational Safety and Health Administration) regulations will be followed by project personnel.
- Chemical toilets for personnel shall be kept in staging areas during removal activities.
- Project activities will be limited to normal business hours.
- Extraneous noise will be limited to the maximum

extent possible (e.g., radios for entertainment).
- Equipment and machinery use will comply with all applicable local noise ordinances and policies.
- Smoking will not be allowed on site.
- Pets of project personnel will not be allowed on site.
- Prior to removal activities, treatment areas will be marked, and signs will be clearly posted along access points to the project site.
- Signs will be posted on affected trails for a sufficient time to warn trail users of heavy-duty equipment crossings. The signs will be posted on either side of the active access and shall be maintained for the entire period of project-related trail use.
- Signs and flaggers shall be used in areas where equipment use would access high speed roads (e.g. blind corners).
- All neighbors within 100 feet of proposed areas will receive notice of proposed projects one month before start of work.

14.1.3 Personnel Education

- All project personnel will be briefed on environmental concerns regarding the project, including the use of herbicides, appropriate work practices (including spill prevention and response mesures), and other measures needed to minimize project impacts. Personnel will be informed of the

Table 7: BMP Checklist

*	All general BMPs (Section 14.1 and all sub sections) must be adhered to at all times.	
1	How will invasive species be removed from the project site?	
	Biomass Removal	14.2.1
	Herbicides	14.2.2
	Foliar Application	14.2.3
	Cut and Paint	14.2.4
	Cut and Spray Resprouts	14.2.5
	Tarping	14.2.6
	Controlled Burning	14.2.7
	Biological Control	14.2.8
	Grazing and Herbivory	14.2.9
2	What method of biomass disposal will be used?	
	Drying	14.3.1
	Chipping	14.3.2
	Incineration	14.3.3
	Landfill Disposal	14.3.4
3	If sensitive species are present on site, what type? (For a description of sensitive species see Section 4.0, Biological Resources.)	
	Birds	14.4.1
	Amphibians/Reptiles	14.4.2
	Fish	14.4.3
	Plants	14.4.4

locations of foot and vehicle access paths, areas that are sensitive, and areas that are closed to access. The construction contractor shall monitor all construction-related activities to ensure that all of the environmental protection measures are followed throughout initial project activities and subsequent activities.

- All project personnel will participate in an educational program to identify the target plant species (arundo or tamarisk), incidental noxious plant species on the site, and native plant species on the site prior to proposed activities. This training will include how the target and incidental plant species are distributed in order to prevent spread of viable biomass.
- If special status plant or wildlife species (or species of concern) occur on site, a qualified biologist will conduct an educational program on how to avoid impacts to these species for all project personnel prior to proposed activities. This training will cover a description of all listed species (or species of concern), which occur within the project boundary and their habitats. This training shall also include a description of the applicable regulations such as the ESA and the State Fish and Game regulations, the need to adhere to these regulations, penalties associated with violations, and measures being implemented to conserve the species within the project area.

14.1.4 Air and Water Quality And Site Contaminant Prevention and Control

- All vehicles will observe a maximum speed limit of 15 miles per hour or lower at the project site and staging areas to avoid generation of dust.
- Appropriate dust suppression methods will be used during on-site removal activities. Recommended methods include application of water, use of wind break enclosures, covers on soil piles and dump truck loads, use of silt fences, and suspension of earth-movement activities during high wind conditions.
- Emissions from construction equipment will be controlled by adherence to the recommended maintenance schedules for each individual equipment type. Repairs to malfunctioning equipment will be made as soon as possible.
- All trash items will be enclosed in sealed containers and regularly removed from the site.
- Disposal of project waste materials such as trash, used equipment, oil, grease, and chemicals will be done in accordance with federal, state, and local regulations.
- Erosion control measures (e.g., silt fencing, mulch, matting, soil binder, seeding) will be implemented as appropriate to inhibit sediment transport into the waterways.
- If work is to occur during the rainy season, no work will occur unless there is a three-day clear weather forecast. No work will occur during rain events.
- No unchipped biomass greater than four inches in length will be left overnight within the stream channel.
- Stockpiled biomass, loose soil, or other debris will not be left overnight within the stream channel or on its banks. If stockpiled biomass must be left overnight, it will be moved to staging areas.
- All equipment and clothing will be inspected and cleaned at the end of each work day to prevent the further spread of invasive species.
- Herbicide storage during application, and the fueling and lubrication of mechanical equipment will be confined to staging areas.
- All vehicles and equipment shall be moved to a staging area or removed from the site overnight.
- Immediate control, containment, and cleanup of fluids and herbicides due to spills or equipment failure (broken hoses, punctured tanks, etc.) will be implemented. All contaminated materials will be disposed of promptly and properly to prevent contamination of the site. To reduce the potential for spills, the refueling of portable equipment shall occur within a contained area. Where that is not possible, barriers shall be placed around the site where the fuel nozzle enters the fuel tank. The barriers shall be such that spills shall be contained and easily cleaned up. Refueling activities shall ensure that the potential for spillage from overfilling, nozzle removal, or other action is minimized to the extent feasible.

14.1.5 Biological Resources (If Listed Species or Species of Concern Have Potential to Occur)

- If listed species or species of concern have potential to occur in the area, the project manager shall coordinate with the appropriate resource agencies and a qualified biologist to conduct surveys and implement measures to avoid impacts.
- If listed species or species of concern are known to occur in the area, a qualified biologist will be retained to recommend measures to protect these species such as the project scheduling, delineation of the work area, staging area, and access points.
- If listed species are present, a qualified biologist will monitor project activities as directed by regulatory agencies.
- Impacts to nesting birds per Migratory Bird Treaty Act (MBTA) will be avoided by:
- the cessation of work during bird breeding season (March 15 – September 15);
- the performance of surveys by a qualified biologist to determine presence/absence of nesting birds prior to undertaking work;
- the establishment of appropriate exclusionary buffers around nests, if present.

14.2 Technique-Specific BMPs

14.2.1 Biomass Removal

- Target species' canes/trunks will be cut to less than twelve inches in height and straight across to prevent sharp points from injuring project personnel or the public.

14.2.2 Herbicides

- A DPR licensed Pest Control Advisor (PCA) will prepare a written recommendation for the use of all materials/herbicides on agricultural areas (as defined by CDPR); the recommendation will be submitted to the Los Angeles County Agricultural Commissioner's Office.
- All material/herbicide usage on agricultural areas (as defined by CDPR) will occur only as directed by the written recommendation from a licensed PCA.
- Only herbicides registered for use in California by the EPA and the DPR will be used.
- Only herbicides approved for aquatic use may be used within the banks of rivers and tributaries. Roundup® may not be used within the active channel of rivers and tributaries.
- All adjuvants will be registered by the EPA and approved for use by the resource agencies.
- Herbicide application will be conducted only by personnel with an operator identification number from the Agricultural Commissioner's Office or supervised by a DPR certified or licensed Qualified Applicator (QAC or QAL).
- Herbicide usage will be limited to the minimum amount required to be effective.
- Herbicides shall be applied according to the manufacturer's label specifications.
- Herbicides will be colored with a biodegradable dye to facilitate visual control of application.
- Avoidance measures such as pulling back or temporarily tarping desired vegetation will be used to the extent feasible to prevent unintended herbicide impacts.
- Herbicides will be secured or removed from staging areas at night.

14.2.3 Foliar Application (Full Stands, Cut Stands, Resprouts)

- Herbicide will not be applied when conditions are windless or greater than ten miles per hour (mph).
- Herbicide will not be applied if air temperature exceeds volatization limits of herbicide, unless adjacent native species are protected (e.g., tarped).
- Tarps shall be used to cover desired vegetation (to the extent feasible) to prevent unintended herbicide impacts.
- Booms or ladders will not be employed for foliar spraying within 200 feet of residences, parks, schools or similar sensitive receptors. Foliar spray applications shall be limited to the cut and spray technique within this setback.

14.2.4 Cut-and-Paint

- See BMPs for biomass removal and herbicides.

14.2.5 Cut and Spray Resprouts

- See BMPs for biomass removal and herbicides.

14.2.6 Tarping

- Target species' canes/trunks will be cut to less than twelve inches in height and straight across to prevent sharp points from injuring project personnel or the public.
- Mechanical equipment will not be driven over tarped areas.
- Tarps shall be manually transported into seasonally and perennially wet areas.
- Tarping material will be removed and disposed of properly after completion of the project.

14.2.7 Controlled Burning

- This method will be used in compliance with all local laws and regulations and will be conducted in conjunction with the local fire department and AQMD.
- Adjacent land uses and land ownership will be considered prior to implementing controlled burns.
- All controlled burns will be conducted during the rainy season.
- All controlled burns will be supervised by qualified fire personnel.
- All controlled burns will be conducted during low-wind conditions.
- Adjacent landowners will be notified prior to implementing controlled burns.

14.2.8 Biological Control

- Biological control vectors will not be released without USDA approval.

14.2.9 Grazing and Herbivory

- The use of grazing animals shall be restricted to areas outside of flowing water with a minimum setback of 50 feet for grazing from any flowing water.
- Grazing will be controlled by erection of temporary fencing to restrict grazing animal to the target area.

14.3 Storage and Disposal Methods

14.3.1 Drying

- Drying of biomass will occur outside of the active channel at designated staging areas.

14.3.2 Chipping

- All chipped biomass will be disposed of off site in a landfill or will be used as mulch.
- All measures shall be taken to reduce the noise of chipper and to prevent noise disturbance to potentially sensitive receptors.
- Necessary measures shall be taken to reduce and control dust generated by chipping.
- Chipping shall occur on staging areas only with prior approval of the appropriate landowner and/or agency.

14.3.3 Incineration

- All federal, state, and local laws and provisions regarding incineration of biomass shall be followed, including those of the local fire department and AQMD.
- All incineration will take place at appropriate designated locations.

14.3.4 Landfill Disposal

- Cut biomass is transported off-site to a landfill for permanent disposal. Chiquita Canyon Land fill is the closest landfill to the project area avail able for use. Landfills typically charge per load or by ton, which can add to the overall project cost.

14.4 Threatened and Endangered Species-Specific BMPs

14.4.1 Birds (Western Yellow-Billed Cuckoo, Southwestern Willow Flycatcher, California Condor, Least Bell's Vireo, Coastal California Gnatcatcher)

- Project activities (e.g., application of herbicide, mechanical trimming, and/or removal, etc.) shall be conducted between 15 September and 15 March to avoid impacts to listed bird species such as least Bell's vireo and southwestern willow

flycatcher during the breeding season, or shall provide a 500 foot radius buffer around each nest, if either species is present.
- Noise levels will not exceed 60 dBA (A-weighted decibel scale) within 500 feet of nests.

14.4.2 Amphibians (Arroyo Toad, California Red-legged Frog)

- No work will be conducted within areas of known or potential arroyo toad habitat during the breeding season (February to August).
- Vehicles and equipment shall be removed from the habitat before sunset in sensitive amphibian areas.
- Stockpiles of biomass will not be kept in habitat areas, but will be moved to upland areas outside the 25-year floodplain immediately to minimize amphibian and reptile usage.

14.4.3 Fish (Unarmored Threespine Stickleback, Santa Ana Sucker)

- No work will occur in flowing or ponded water.
- Grading and excavation will be set back a minimum of 50 feet from the edge of the active channel. Grazing areas will be fenced to prevent animals from entering water. The boundaries of excavated projects will be demarcated by temporary construction fencing or flagged stakes.

14.4.4 Plants (e.g., Nevin's Barberry, Slender-Horned Spineflower, Spreading Navarretia)

- All listed plant locations will be fenced to avoid disturbance and accidental damage/mortality.
- Herbicides will not be used near known or probable locations of sensitive plant species.

Areas identified as potential special status plant habitat will be surveyed by a qualified botanist prior to commencing work.



15.0 MAINTENANCE AND MONITORING

Arundo and tamarisk are aggressive invasive plants with an extraordinary ability to spread, reproduce, and thrive under a wide range of conditions. As such, any removal program for substantial infestations requires a long-term commitment of resources, repeated treatments, and ongoing monitoring in order to be successful (Table 8). This adds to the overall cost of removal efforts, but without such repeated treatments and monitoring, successful removal projects can quickly experience reinvasion, with the potential for a treated area to return to a pre-removal condition, sometimes within a few years.

The issue is exacerbated within the upper Santa Clara River watershed because extensive infestation increases the chance of re-infestation from offsite sources. Therefore, all removal methods will require at least three years of continuous monitoring and follow-up treatments. Even approaches with high initial mortality rates such as cut and daub/paint will require this extent of monitoring, and likely follow-up treatments in spots. For methods with lower mortality rates, monitoring times and the number of required re-treatments may increase to five years. Monitoring site visits are recommended quarterly for the first year and biannually for years two to five.

Table 8: Comparison of Re-Treatment Requirements of Removal Methods

Method	Average 1st Year Mortality Rate	Level of Re-Treatment Effort Required	Average Number of Re-Treatments Required
Hand Above-Ground Removal	<50%	Same as initial treatment.	>5
Hand and Mechanical Above-Ground Removal	5-50%	Varies depending on success of initial treatment. Potentially the same as initial treatment.	>5
Mechanical Above-Ground Removal	<50%	Same as initial treatment.	>5
Mechanical Above- and Below-Ground Removal	5-50%	Varies depending on success of initial treatment. Potentially the same as initial treatment.	>5
Tarping	50-95%	Few resprouts – little effort.	At least 3
Foliar Spray	50-95%	Few resprouts – little effort.	3-5
Cut and Spray or Paint/Daub	50-90%	Few resprouts – little effort.	3-5
Cut, Resprout, and Spray	~50%	Some resprouts – close to the same amount of effort as initial treatment.	3-5

The level of intensity, duration, and frequency of required re-treatment depends on many factors such as the skill of the crews involved, initial budget, etc. As such, this table is provided for general reference only.
Source: Sonoma Ecology Center 1999.

16.0 Habitat Restoration and Revegetation

There are two types of revegetation: passive and active. Passive revegetation means there will be natural recruitment from native species while active revegetation means introducing native species by planting seeds, cuttings, or container stock.

Passive revegetation means replanting by natural processes. Surrounding native plant habitats provide seed sources for propagation. Once the competition of arundo or tamarisk is removed, native species will continue to propagate and grow there. This method requires the least effort and expertise to restore native riparian vegetation. It also doesn't require repeated disturbance for maintenance and ensures the revegetation of local genetic stock. However, passive revegetation may take several years or more to become established. If invasive plants are established upstream of the project area or in surrounding areas, the site is at risk of being repopulated by invasive plants.

Passive revegetation is most appropriate when:

- There are native plant and seed sources, either on-site or upstream.
- The site does not contain extensive disturbed, unvegetated, exposed ground that would attract non-native pest plants.
- The soils are stable and at low risk of erosion.
- The site tends to flood each year, allowing nearby native plant material to settle and become established.

If these conditions exist, passive revegetation may be a more appropriate use of time and resources than active revegetation.

Active revegetation means collecting and planting seeds, cuttings, or container stock. Active revegetation is recommended for sites are located on upper banks where natural recruitment is unlikely to occur or on areas which have erosion problems. Project sites should be monitored during removal activities for natural recruitment of native species. Supplemental water or irrigation may be required. Active revegetation is often planned after removal activities have been completed to avoid impacts to newly planted vegetation. Active revegetation may take from three to five years.

Active revegetation is most appropriate when:

- The site is located downstream from, or near invasive plant species. In such cases, prompt revegetation with natives may be necessary to prevent reinvasion of the treated site.
- The soil or stream bank is unstable and at high risk of erosion.
- A landowner strongly desires a privacy screen.
- There are special status species utilizing the project area.
- Natural recruitment is not providing species diversity.

There are several different revegetation techniques. Depending upon the project site conditions and desired habitat diversity, a combination of revegetation techniques may be used. Active revegetation alone may not provide sufficient soil or bank stabilization. Soil retention materials and stabilizing structures may be needed to adequately prevent erosion and bank failure. In such cases, materials such as erosion control fabrics and engineered structures should be considered before engaging in invasive plant removal. For structural changes, consult with a professional engineer or landscape architect, or a government agency such as Resource Conservation Districts.

Depending upon the level of habitat restoration desired and various individual project factors, the project costs will vary. A successful revegetation project will provide habitat, include a diverse set of plant types and species, reduce erosion, and require minimal annual management (CDFG 2003). If revegetation of a project site is intended, it is advisable to plan ahead to obtain local native plant material, grow container stock if necessary or prepare seeds for planting, and create a schedule for planting and maintenance. Planting cuttings or container stock usually works well for species that do not germinate well from seed or need intensive seed preparation. Seeding can be applied to species that germinate well from seed. It is important to consider the species diversity and local genetics when planning the plant palette. Native plant material such as seeds and cuttings should be obtained from the project site or as close as possible. Site preparation may include reducing the weed seed bank in the soil by herbicide application or disking prior to seed set. If there is a large

weed seed bank, this process may be performed several times. Planting or seeding is usually performed in the fall season to take advantage of rains for germination and encourage root growth. If rains are late, revegetation may occur in the winter or early spring. If planting or seeding is performed at another time of year, supplemental water or irrigation should be considered (Sonoma Ecology Center 1999).

Revegetation techniques include:

- Hand broadcasting of native grass, forb, and/or shrub seed mixes
- Hydroseeding of native grass, forb, and/or shrub seed mixes, may also contain binders for erosion control
- Drill, imprint, or pit seeding
- Direct planting of tree or shrub seeds
- Planting of tree and/or shrub cuttings
- Planting of tree, shrub, forb, and/or grass container plants

Depending upon the level of habitat restoration desired and various individual project factors, the project costs will vary. A successful revegetation project will provide habitat, include a diverse set of plant types and species, reduce erosion, and require minimal annual management (CDFG 2003). If revegetation of a project site is intended, it is advisable to plan ahead to obtain local native plant material, grow container stock if necessary or prepare seeds for planting, and create a schedule for planting and maintenance. Planting cuttings or container stock usually works well for species that do not germinate well from seed or need intensive seed preparation. Seeding can be applied to species that germinate well from seed. It is important to consider the species diversity and local genetics when planning the plant palette. Native plant material such as seeds and cuttings should be obtained from the project site or as close as possible. Site preparation may include reducing the weed seed bank in the soil by herbicide application or disking prior to seed set. If there is a large weed seed bank, this process may be performed several times. Planting or seeding is usually performed in the fall season to take advantage of rains for germination and encouragement of root growth. If rains are late, revegetation may occur in the winter or early spring. If planting or seeding is performed at another time of year, supplemental water or irrigation should be considered (Sonoma Ecology Center 1999).

16.1 Planting Methods

16.1.1 Broadcast Seeding

Broadcast seeding can be performed by hand, with hand-held or rolling broadcast seeders, or larger broadcasters towed by all-terrain vehicles or tractors. The soil bed should be prepared prior to seeding. If there is compaction, the soil should be disked or tilled. Also, the soil should be raked before and after seeding to incorporate the seeds into the soil. If available, large equipment such as a harrow and a ring roller can assist with working the seeds into the soil and enhance soil compaction after seeding. The seeding rate for broadcast seeding is usually 25 to 30 pounds per acre.

Drill or Imprint Seeding

Dry seeding can also be performed with large equipment such as drills, imprinters, or pitters. A tractor-drawn drill makes small furrows, deposits seeds in the furrows, and covers the seed with soil. Drills come in different sizes and types with attachments to improve seeding different species. Imprinters have a hydraulic wheel system with different seed boxes and a roller with teeth. These allow for diverse seed mixes and fertilizer or mycorrhizal inoculum to be applied at the same time. Both of these seeding applications can be faster and more uniform than broadcast seeding. The seeding rate for drilling or imprinting is usually 12 to 18 pounds per acre.

16.1.2 Hydroseeding

Hydroseeding uses hydraulic equipment to spread a wet mixture of seeds, fertilizer, mycorrhizae, erosion control binder, and green daya dye. This method can seed a large area quickly. The hydroseed mixture can be applied from a turret on top of a truck while driving or with a hose. Hydroseeding is most effective during the fall or early spring when rains will encourage germination. However, if supplemental water is available, it can be applied at other times of the year. It is important for the components of the hydroseed mixture to be correctly combined in appropriate proportions and the soil

bed is prepared prior to application. The California Native Grass Association recommends a two step process: 1) applying seed, a small amount of virgin wood fiber mulch, mycorrhizal inoculum, compost , and an organic time-released fertilizer first and; 2) applying a second layer of wood fiber and compost to cover. If erosion control is necessary on steep slopes, apply a third layer of rice or native straw with a tackifier.

16.1.3 Transplanting Emergent Plants

Rushes, sedges, and tulles are often called "emergent" plants since they usually emerge from water. These plants may grow from seeds or spread by rhizomes, which makes them good candidates for transplanting. Plants with intact rhizomes should be harvested in the winter or early spring. Several small clumps from a variety of larger clumps should be taken to ensure the parent population will survive and to include genetic diversity in the new planting area. Collected plant material should be stored in moist soil and transplanted within a reasonable time. Collected specimens should be planted in a large enough hole to accommodate the entire rhizome, soil should be packed around the rhizome, and thoroughly watered. Above ground portions of plant should be trimmed to stimulate growth.

16.1.4 Planting Cuttings

Willows, cottonwoods, Mexican elderberry, and many other riparian species can be planted from cuttings. These plants have the ability to grow roots from stems. Cuttings should be made when plants are dormant during winter months. Cuttings should be sliced so that the inner side of the branch is at an angle to indicate the end that will be planted in the ground. The cuttings may be a variety of sizes with different diameters and lengths depending upon the plant species and the location of the planting. Cuttings should have several viable buds along the stem in order to ensure new growth. Cuttings may be stored in water until ready to use, grown in water until roots appear, or planted as container stock. Cuttings should be planted in soil with angled, cut side down (buds should be pointing up) with three-quarters of the cutting in the ground and one-quarter exposed. If holes are augured, fertilizer or mycorrhizal innoculum may be added to the hole or mixed with the backfill soil before planting. Cuttings can also be driven into the ground with a mallet if soil is soft. Damage to the top of cuttings may be, sliced off.

16.1.5 Planting Container Plants

Container plants may be ordered in a wide variety of species from a native plant nursery. Ideally, container stock with be grown from locally collected plant material. Container plants will require supplemental water – from either winter rains or irrigation. Holes should be dug twice as wide and twice as deep as the container plant. In addition, fertilizer or mycorrhizal innoculum may be added to the hole or mixed with the backfill soil before planting. The hole should be firmly backfilled to depth of the rootball, and then the container plant placed inside.



17.0 Developing a Budget and Schedule

17.1 Cost of Removal

Removal costs vary greatly and are influenced by many factors including the extent and degree of infestation, labor rates, the ease of site access, the removal method employed, the frequency, duration, and level of effort required for follow-up treatments, biomass transport distances, and disposal techniques. Typical costs associated with various arundo and tamarisk removal methods are not well documented and can vary greatly from project to project. Removal of minor or isolated stands of arundo or tamarisk can often be accomplished relatively inexpensively (less than $2,000 per acre). However, current available methods which are suitable for successful removal of major infestations are all relatively expensive, ranging in price from approximately $2,500 to $9,500 per acre, depending on many variables. Techniques with the highest initial mortality rates and the lowest resultant follow-up monitoring and retreatment costs tend to be the most expensive in terms of up-front costs, but the least expensive over longer periods. A project checklist is provided in Table 9.

Because such a wide range of factors affect removal project cost, it is not possible to provide precise estimates. Similar removal methods employed under generally similar circumstances can even exhibit variations in cost if just one key factor, such as difficulty of access or material transport, increases substantially due to factors such as distance or variable landfill tipping fees.

17.2 Cost Effectiveness

The SCARP proposes several methods for removal. Each method has advantages and disadvantages in different respects. Public agencies need to balance needs across the entire geographic area under their jurisdiction, as issues of social justice and environmental justice are important considerations in public and private policy and planning. (LAWMA 2005).

Although there may be certain concerns over the use of herbicides in the environment, this method may be more cost-effective in terms of funds and time. However, local communities or organizations may choose non-chemical methods of control, which may not be as cost-efficient. These groups have options to obtain additional funding for alternative methods of control such as volunteer programs and grants.

Development of a project schedule is an integral component to any removal project. Table 9 is provided as a planning aid and offers examples of the steps applicants can expect to incorporate in their projects.

18.0 Funding

There are several ways to fund invasive plant removal projects. Local agencies and non-profit organizations may apply for funding through grants, restoration loans, cost-share programs, in-lieu fees, mitigation banking, or through alternative sources. Individual landowners should contact their local agencies or NGOs for grant or cost-share opportunities.

18.1 Grants

Grants are provided by governmental agencies or NGOs. There is usually a lengthy process for the application of grants. The process may take up to two years before funding is obtained. Each source will have different applications and contract requirements. There may be a two-part application, which consists of a pre-proposal or conceptual proposal and a final proposal if the pre-proposal is accepted. Grants often need to have matching funds provided by donated cash, labor, or equipment.

Some agencies and organizations that provide grants are listed below:

- State Water Resources Control Board
- National Fish and Wildlife Foundation
- State Resources Agency
- California Department of Parks
- Recreation Land and Water Conservation Fund
- Habitat Conservation Fund
- Natural Resource Conservation Service

Websites, which provide information regarding available grants, are listed below:

- http://www.epa.gov/watershedfunding
- www.calwatershedfunds.org
- http://www.invasivespecies.gov/toolkit/grants-info.shtml

Table 9: Project Checklist

PREPARATION	
	Choose site - from headwaters down
	Obtain Landowner Cooperative Agreement
	Perform site assessment - level of infestation, potential for wildlife, staging areas, access
	Prepare project description - site plan, maps, choose removal/disposal methods, BMPs
	Survey project boundary
	Determine level of CEQA and which permits are necessary
	Complete vegetation/habitat surveys
	Complete wildlife surveys
	Complete sensitive species surveys
	Prepare CEQA - Initial Study, Negative Declaration, Mitigated Negative Declaration, Environmental Impact Report
	Contact resource agencies and prepare permits, including fees - CDFG, USACE, RWQCB, USFWS, AQMD, LADPW
	Prepare SWPPP
	Prepare specifications - safety, access to water, ingress/egress, removal methods, transport, disposal
	Prepare maintenance and monitoring plan
	Prepare bid package
	Contact youth groups such as CCC or City Corps for labor
	Notify and educate any surrounding residents via postcards, brochures, or handouts.
CONSTRUCTION	
	Mobilization - move in equipment, portable restrooms, signage, security fencing
	Clear & grub - staging areas, access roads, debris removal
	Construct access roads - equipment, dust/weed issues, watering truck for dust control
	Dewatering, if necessary
	Remove invasive species - labor, equipment, & herbicides
	Biological monitoring
	Transportation - to staging area (equipment & labor)
	Disposal - landfill, chipping/landfill, chipping - onsite/offsite mulch, incineration (equipment, landfill fees, transportation costs)
	Clean up, deconstruct access roads
	Demobilization - move out equipment, portable restrooms, signage, security fencing
MAINTENANCE & MONITORING (3- 5 years)	
	Remove invasive species - labor, equipment, & herbicides
	Biological monitoring
	Transportation - to staging area (equipment & labor)
	Disposal - landfill, chipping/landfill, chipping - onsite/offsite mulch, incineration (equipment, landfill fees, transportation costs)
	Annual reports to resource agencies
	Management

- http://www.wcb.ca.gov
- http://www.cdfa.ca.gov/phpps/ipc/weedmg-mtareas/Funding/funding_hp.htm

Further information regarding available public and private grants can be obtained from the Foundation Center Libraries (http://fdncenter.org). Locations of these libraries include:

Ventura County Community Foundation
Funding and Information Resource Center
1355 Del Norte Road
Camarillo, CA 93010
(805) 988-0196

California Community Foundation
Funding Information Center
606 S. Olive St. Suite 2400
Los Angeles, CA 90014-1526
(213) 413-4042

Los Angeles Public Library
West Valley Regional Branch Library
19036 Vanowen Street
Reseda, CA 91335
(818) 345-4393

Santa Monica Public Library
1343 Sixth Street
Santa Monica, CA 90401-1603
(213) 458-8859

18.2 Resource Loans

The State Water Resource Control Board has low interest loans for restoration and conservation projects. The Federal Water Pollution Control Act (Clean Water Act or CWA), as amended in 1987, provides for establishment of a State Revolving Fund (SRF) loan program. The program is funded by federal grants and State bond funds. The purpose of the SRF loan program is to implement the CWA and various State laws by providing financial assistance for the construction of facilities or implementation of measures necessary to address water quality problems and to prevent pollution of the waters of the State. The SRF Loan Program provides low-interest loan funding for construction of publicly-owned wastewater treatment facilities, local sewers, sewer interceptors, water reclamation facilities, as well as, expanded use projects such as implementation of non-point source (NPS) projects or programs, development and implementation of estuary Comprehensive Conservation and Management Plans, and storm water treatment. There is more information available on the website: http://www.swrcb.ca.gov/funding/srf.html.

18.3 Cost-Share Programs

The NRCS has two cost-share programs to assist private landowners perform restoration and conservation projects.

18.3.1 Environmental Quality Incentives Program – EQIP

The Environmental Quality Incentives Program (EQIP) provides a voluntary conservation program for farmers and ranchers that promote agricultural production and environmental quality as compatible national goals. EQIP offers financial and technical help to assist eligible participants install or implement structural and management practices on eligible agricultural land.

EQIP offers contracts with a minimum term that ends one year after the implementation of the last scheduled practices and a maximum term of ten years. These contracts provide incentive payments and cost-shares to implement conservation practices. Persons who are engaged in livestock or agricultural production on eligible land may participate in the EQIP program. EQIP activities are carried out according to an environmental quality incentives program plan of operations developed in conjunction with the producer that identifies the appropriate conservation practice or practices to address the resource concerns. The practices are subject to NRCS technical standards adapted for local conditions. The local conservation district approves the plan.

EQIP may cost-share up to 75 percent of the costs of certain conservation practices Incentive payments may be provided for up to three years to encourage producers to carry out management practices they may not otherwise use without the incentive. However, limited resource producers and beginning farmers and ranchers may be eligible for cost-shares up to 90 percent. Farmers and ranchers may elect to use a certified third-party provider for technical assistance. An individual or entity

may not receive, directly or indirectly, cost-share or incentive payments that, taken together, exceed $450,000 for all EQIP contracts entered during the term of the Farm Bill.

18.3.2 Wildlife Habitat Incentives Program - WHIP

This program is available for all landowners with less than $2 million income. The Wildlife Habitat Incentives Program (WHIP) is a voluntary program for people who want to develop and improve wildlife habitat primarily on private land. Through WHIP, USDA's Natural Resources Conservation Service provides both technical assistance and up to 75 percent cost-share assistance to establish and improve fish and wildlife habitat. WHIP agreements between NRCS and the participant generally last from five to 10 years from the date the agreement is signed.

WHIP has proven to be a highly effective and widely accepted program across the country. By targeting wildlife habitat projects on all lands and aquatic areas, WHIP provides assistance to conservation minded landowners who are unable to meet the specific eligibility requirements of other USDA conservation programs.

18.4 In-Lieu Fee Program

The in-lieu-fee program is a program run by the USACE to offset impacts to Waters of the United States, which are permitted under Section 404 of the CWA. In-lieu-fee mitigation occurs in circumstances where a permittee provides funds to an in-lieu-fee sponsor instead of either completing project-specific mitigation or purchasing credits from a mitigation bank approved under the Banking Guidance. Funds collected from the permittees under in-lieu-fee arrangements are used for replacing wetland and riparian functions and values and are not used to finance non-mitigation programs and priorities such as education projects or research. Currently no in-lieu-fee program agreements exist within the SCARP project area. To further research the in-lieu-fee program option or to develop an in-lieu-fee program, contact the USACE Los Angeles District office.

18.5 Mitigation Bank

Invasive weed removal can serve as compensatory mitigation for certain projects affecting aquatic resources and can be incorporated into the BMPs of many projects. The USACE, RWQCB, and CDFG can require permittees whose activities involve temporary or construction-related disturbance of aquatic areas to ensure that the disturbed areas are not invaded by arundo, tamarisk, or other weeds. This can help reduce proliferation of infestation, as often happens in recently disturbed areas. When on-site mitigation is not appropriate, the Corps can direct permittees to mitigate the impacts of their activities by removing invasive weeds in strategic areas of the watershed; thereby contributing to the overall control program. Wetland mitigation banks strive to establish large, contiguous wetland areas, which can be used to mitigate for a number of independent impacts. This allows eligible permittees to purchase compensatory mitigation credits from another entity that has already produced and banked them, thereby eliminating the need to produce compensatory mitigation areas on-site (ELI and IWR 1994). Mitigation banks advance effective regional habitat conservation by encouraging the bundling of mitigation "credits" at sites recognized to be high priorities for habitat protection and restoration in watersheds and ecosystems and provide a mechanism that assigns a monetary value to habitat, which in turn allows a landowner to obtain a financial return for conserving land rather than developing it. The USACE has been an active participant in the establishment a mitigation bank in the Santa Ana River, which is focused on invasive weed removal. The goal of the Santa Ana River Mitigation Bank (SARMB) is to reestablish native riparian ecological diversity and other riparian functions through the removal of invasive weeds. Currently, a mitigation bank has not been established for the Santa Clara River, although the SARMB may serve as a template for the development of one in the future.

19.0 Resources

The following list of resources provides further information and guidance to project applicants.

19.1 Local Agency and NGO Contacts

Large amounts of material already exist on the problems posed by arundo and tamarisk including the benefits of removal, and general approaches and techniques to successful removal. When combined with the detailed information contained in the SCARP document, ample information is available both to the public and to future project applicants. The primary points of contact for the public would be:

Ventura County Resource Conservation District
P.O. Box 147 (Mailing address)
3380 Somis Road (Street Address)
Somis, Ca 93066
(805) 386-4685

Antelope Valley Resource Conservation District
44811 N. Date Ave., Suite G
Lancaster, CA 93534
(661) 945-2604

Other agencies and organizations that can provide assistance are provided in Table 10.

Table 10: Agencies and Organizations Assistance

Agency or Group Name	Assistance Available	How to Contact
Los Angeles County Agricultural Commissioner	Regulates herbicide use. Provides information to obtain certification or licenses. Also provides Operator Identification Number and safety training for application of non-restricted materials.	(626)575-5471 12300 Lower Azusa Road Arcadia, CA 91006-5872 http://acwm.co.la.ca.us/
Southern California Air Quality Management District	May require permit for controlled burning or incineration of biomass. Advises days when burning can occur.	(909)396-2000 21865 Copley Dr Diamond Bar, CA 91765 http://www.aqmd.gov/
County or Local Water Districts	May require a permit to access properties.	(661)259-3610
California Conservation Corps (CCC) (Camarillo/Los Angeles/ Norwalk)	Eradication of invasive plants and restoration of native plants	(805)484-4345 1878 South Lewis Rd. Unit 60 Camarillo, CA 93010 http://www.ccc.ca.gov/
Los Angeles Conservation Corps	Eradication of invasive plants and restoration of native plants	(213)747-1872 P.O. Box 15868 Los Angeles, CA 90015 http://www.lacorps.org/
Concerned Resource Environmental Workers (CREW)	Eradication of invasive plants and restoration of native plants	(805)646-5085 P.O. Box 1532 Ojai, CA 93024 (No Website)
California Department of Fish and Game (San Diego)	Issues Streambed Alteration Agreements and consults for impacts to state listed species.	(916)445-0411 1416 Ninth Street Sacramento, California 95814 http://www.dfg.ca.gov/
California Invasive Plant Council	Provides information on non-native invasive plants in California.	(510)843-3902 1442-A Walnut St., #462 Berkeley, CA 94709 http://www.cal-ipc.org/

Agency or Group Name	Assistance Available	How to Contact
Los Angeles County or local Fire Department	Provides information for fire safety. May issue a burn permit.	(818)890-5783 12605 Osbourne St Pacoima, CA 91311 http://www.lacofd.org/
Natural Resource Conservation Service (Lancaster)	Provides information for erosion control, non-native plant removal, habitat restoration, and funding	(661)945-2604 44811 N. Date Avenue, Suite G, Lancaster, CA 93534 http://www.ca.nrcs.usda.gov
Antelope Valley and Ventura County Resource Conservation District	Provides information for non-native plant removal, habitat restoration, permitting, and funding	(805)386-4685 P.O. Box 147 Somis, CA 93066 http://www.vcrcd.org
Los Angeles County Public Works	Issues encroachment permits	(626)458-4300 900 South Fremont Avenue Alhambra, CA 91803 http://ladpw.org/wmd/
Team Arundo del Norte (Sonoma Ecology Center)	Provides information on eradication techniques, biology, grant information, regional eradication coordination	(707)996-0712 P.O. Box 1486 Eldridge CA 95431 http://www.sonomaecologycenter.org/
Arundo Task Force	Provides information on eradication techniques, biology, and grant information.	(805)386-4685 P.O. Box 147 Somis CA 93066 http://www.arundotaskforce.org
US Army Corps of Engineers (Los Angeles Region)	Issues Section 404 permit (for earthmoving or fill in stream)	213) 452-3908 P.O. Box 532711 Los Angeles CA 90053-2325 http://www.spl.usace.army.mil/
US Fish and Wildlife Service (San Diego)	Provides consultations for potential impacts to federal listed species and may have potential funding through Partners for Wildlife or Santa Clara River Trustee Council	1-800-344-WILD 2493 Portala Road, Suite B Ventura, CA 93003 http://www.fws.gov/
Regional Water Quality Control Board (Los Angeles)	Provides information on water quality issues and issues 401 Water Quality Certification (for earthmoving or fill in stream)	(213) 576-1364 P.O. Box 2815 Sacramento, CA 95812-2815 http://www.calepa.ca.gov/
US Bureau of Land Management	Potential funding through War on Weeds	(202) 452-5125 1849 C Street, Room 406-LS Washington, DC 20240 http://www.blm.gov/nhp/index.htm
City of Santa Clarita, Environmental Services Division	Provides information on City activities	(661)222-7222 23920 Valencia Boulevard, Ste. 300 Santa Clarita, California 91355 http://www.santa-clarita.com/
Los Angeles Weed Management Area	Provides information on weed management	(626)575-5471 12300 Lower Azusa Road Arcadia, CA 91006-5872 http://acwm.co.la.ca.us/

Agency or Group Name	Assistance Available	How to Contact
The Nature Conservancy	Provides information on eradication methods	(805)642-0345 3639 Harbor Boulevard, Suite 201 Ventura, CA 93001 http://www.tnccalifornia.org
California Native Plant Society (Ventura)	Provides information on California native plants	(916) 447-2677 2707 K Street, Suite 1 Sacramento, CA 95816-5113 http://www.cnps.org/
Society for Ecological Restoration (SER Cal)	Provides information on California native habitat restoration	2701 20th Street Bakersfield, CA 93301-3334 Tel. (661) 634-9228 http://www.sercal.org/
Chiquita Canyon Landfill	Closest landfill to the project area	3 miles west of Interstate 5 on State Route 126 in Santa Clarita Valley. http://www.chiquitacanyon.com

19.2 Books

The Nature Conservancy Handbook:

Weed Control Methods Handbook: Tools & Techniques for Use in Natural Areas

Cal IPC Handbook:

The Weedworker's Handbook: A Guide to Techniques for Removing Bay Area Invasive Plants

Team Arundo del Norte Handbooks:

Arundo: A Landowner Handbook

Controlling Arundo in Your Watershed: A Guide For Organizations

19.3 Web Resources

ARUNDO

NPS PCA	http://www.nps.gov/plants/alien/fact/ardo1.htm
SAWPA	http://www.sawpa.org/arundo/
SMSLRWMA - Arundo Biology	http://www.nps.gov/plants/alien/fact/ardo1.htm
Team Arundo del Norte	http://teamarundo.org/
TAdN Arundo Reference Library	http://teamarundo.org/research_reference/index.html#biblio
TNC - Arundo Stewardship Abstract	http://tncweeds.ucdavis.edu/esadocs/documnts/arundon.html
TNC - Arundo Images	http://tncweeds.ucdavis.edu/esadocs/arundona.html
USDA	http://plants.usda.gov/cgi_bin/plant_profile.cgi?symbol=ARDO4
USACE - Arundo Removal	http://www.wes.army.mil/el/pmis/plants/html/arundo_d.html

TAMARISK

CAIN NBII - Tamarisk	http://cain.nbii.gov/crisis/crisiscat/viewResource?resource=http://cain.nbii.gov%2Fcrisis%2Finvasive_terms%23Tamarix
Earlham College	http://www.earlham.edu/~biol/desert/invasive.htm
Invasive Species.gov - Saltcedar profile	http://www.invasivespecies.gov/profiles/saltcedar.shtml
Proceedings Saltcedar Workshop June 12, 1996	http://www.invasivespecies.gov/education/workshopJun96/index.html
NPS	http://www.nps.gov/plants/alien/fact/tama1.htm
TNC – Tamarisk Stewardship Abstract	http://tncweeds.ucdavis.edu/esadocs/tamaramo.html
USFS	http://www.fs.fed.us/database/feis/plants/tree/tamspp/all.html
WA NWCB	http://www.nwcb.wa.gov/weed_info/saltcedar.html
USACE	http://www.wes.army.mil/el/pmis/plants/html/tamarix_.html

INVASIVE PLANT ORGANIZATIONS

Cal IPC	http://www.cal-ipc.org/
California Weed Management Areas	http://www.cdfa.ca.gov/phpps/ipc/weedmgtareas/
L.A. County Weed Management Area	http://acwm.co.la.ca.us/scripts/wma_2.htm
Santa Barbara County Weed Management Area	http://www.countyofsb.org/agcomm/wma/
Santa Margarita & San Luis Rey Weed Mgmt	http://smslrwma.org/
Invasive Species Information Node (ISIN) of the NBII	http://invasivespecies.nbii.gov/
Noxious Weed Information Project	http://www.cdfa.ca.gov/phpps/ipc/noxweedinfo/noxweedinfo_hp.htm
Center for Invasive Plant Management	http://www.weedcenter.org/
NPS - Monitoring Invasives	http://science.nature.nps.gov/im/monitor/invasives.htm
USACE Aquatic Plant Control	http://www.wes.army.mil/el/aqua/
SFWI NIS Guidebook	http://www.sfei.org/nis/NISguidebook.pdf
TNC Weed Removal Handbook	http://tncweeds.ucdavis.edu/handbook.html
Global Invasive Species Specialists Groups	http://www.issg.org/

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