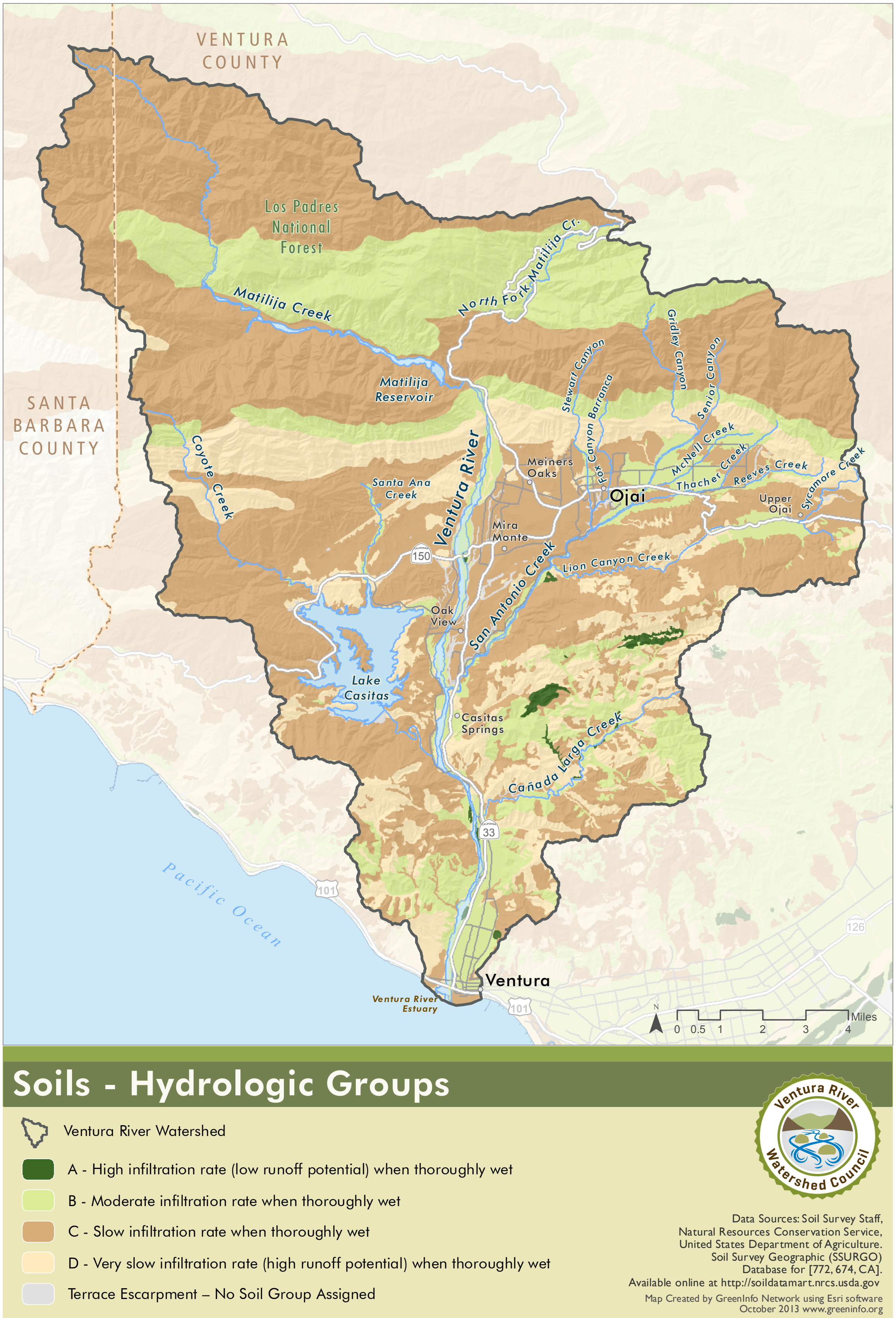


Figure 3.2.2.2.1 Soils – Hydrologic Groups Map

3.2.2.3 Petroleum

Tar Seep, Sulphur Mountain Road
Natural oil seeps and tar are found throughout the area.

The petroleum-rich sedimentary rocks of the Transverse Ranges, of which the watershed is a part, make this geologic province an important oil-producing area in the United States (CGS 2002).

The Ventura field is the watershed's major oil field, covering approximately 3,410 acres on both sides of Highway 33 near the coast. The Ojai Oil Field comprises 1,780 acres of small, active oil fields located primarily in the Upper Ojai areas of Sulphur Mountain and Sisar Creek, with smaller fields in the Lion Mountain area and in Weldon Canyon. Cañada Larga also has a small, 40-acre oil field (DOGGR 1992).

Ventura Oil Field. The Ventura Oil Field is the major oil-producing field in the watershed. The watershed contains several other smaller oil fields, the next most significant being the Ojai Oil Field, located mostly in Upper Ojai.

3.2.2.4 Faults

Intense tectonic forces have uplifted, twisted, and folded the watershed's mountains, creating multiple faults that crisscross the watershed. These faults influence the watershed in several important ways. For example, faults that cross streams can act like underground dams of bedrock that hold back or redirect streamflow, sometimes causing groundwater to surface as springs. Some of the favorite swimming holes in the watershed are upstream of such bedrock-surfacing occurrences.

Rock Outcrops at Ventura River Swimming Holes. Faults can sometimes cause the river channel pattern to abruptly bend around the faulted zone, often widening the upstream floodplain (Ferren, Fiedler & Leidy 1995).
Photo courtesy of Rick Wilborn

San Antonio Creek typically runs longer into the year than the upper Ventura River in part because it runs along a fault block and in places the creek bottom is bedrock. Some of the "walls" or boundaries of the watershed's groundwater basins are also formed by faults. The Santa Ana Fault, for example, forms the southern boundary of the Ojai Valley Basin (Kear 2005).

Bedrock in the San Antonio Creek Bottom
Photo courtesy of Santa Barbara Channelkeeper

Figure 3.2.2.4.1 Major Faults Map

Significant accumulations of accessible oil and gas deposits in the watershed are also associated with its fault structures. The large area of oil wells along Ventura Avenue and surrounding hills in the lower watershed is directly associated with the Ventura Avenue anticline.

> Many of the streams in the Oak View–Ojai area have a complex history that is intimately related to recent tectonics. When the Oak View terrace was being deposited (about 40,000 years ago) the watershed of the Ventura River included the Santa Paula Creek and Sisar Creek drainages, along with the upper Ojai Valley, which was continuous with the lower Ojai Valley. Santa Paula and Sisar Creeks were eventually captured by headward erosion of a tributary of the Santa Clara River. However, in view of activity of the faults in the area, it seems reasonable to speculate that tectonics probably were a significant factor in the drainage history. For example, after uplift along the Santa Ana fault, separating the upper and lower Ojai Valleys, and after capture of Santa Paula and Sisar Creeks by a tributary of the Santa Clara River, the drainage of the lower Ojai Valley was directed along the scarp of the Santa Ana fault.
>
> —*Tectonic Geomorphology and Earthquake Hazard, North Flank, Central Ventura Basin, California* (Keller et al. 1980)

3.2.2.5 Geologic and Seismic Hazards

Earthquakes

The Ventura River watershed is a dynamic landscape that is continually experiencing uplift, folding, and faulting, and with these powerful forces often come earthquakes. A number of faults within and near the watershed are capable of producing magnitude 7.0 earthquakes, and the nearby San Andreas Fault—the longest and most significant fault in California—is capable of producing a magnitude 8.3 earthquake along some of its segments (USACE 2004b).

A 2004 study of historical earthquakes, conducted as part of the Matilija Dam removal project, summarized earthquakes with a magnitude of 5.0 and greater that have occurred within a 50-mile radius around Matilija Dam between the years 1800 and 2000 (Table 3.2.2.5.1), and the magnitude seven and greater earthquakes that have occurred within a 100-mile radius of the dam (Table 3.2.2.5.2).

Table 3.2.2.5.1 Earthquake Magnitude and Exceedances within a 50-Mile Radius of Matilija Dam

Earthquake Magnitude	Number of Times Exceeded
5.0	49
5.5	21
6.0	10
6.5	5
7.0	4
7.5	1

Source: USACE 2004b

Table 3.2.2.5.2 Magnitude 7 and Greater Earthquakes within a 100-Mile Radius of Matilija Dam

Earthquake Date	Magnitude	Distance (miles)
12/08/1812	7.0	94.8
12/21/1812	7.0	34.2
09/24/1827	7.0	37.8
11/27/1852	7.0	39.7
01/09/1857	7.9	62.9
11/04/1927	7.5	84.1
07/21/1952	7.7	39.3

Source: USACE 2004b

Liquefaction

Liquefaction occurs when ground shaking causes loose, saturated soil to lose cohesive strength and act as a viscous liquid for several moments. Engineered structures including roads, bridges, dams, houses, and utility lines are subject to potential damage from liquefaction (VCPD 2011a).

Given the number of active faults in the area and the alluvial nature of the sediments, damage to the Casitas Dam from liquefaction has been a concern. Between 1999 and 2001, Casitas Dam underwent a major modification to prevent a liquefaction-induced failure from seismic activity. Seismic hazard evaluations conducted in the 1990s indicated that the potential earthquake loading was much higher than evaluations conducted in the 1980s indicated. Additionally, groundwater levels had also risen since the 1980s. To address this hazard, the liquefiable materials at the downstream toe of the dam were excavated and replaced, an overlying stability berm was constructed, and the crest of the dam was widened to provide additional protection (USBR 2001).

> Liquefaction has occurred in this area and can be expected to potentially occur again whenever an earthquake of sufficient intensity occurs. Areas with high liquefaction potential have had water table levels within 15 feet of the ground surface sometime in the last 50 years.
>
> —*Matilija Dam Ecosystem Restoration Project EIS/EIR* (USACE2004)

Areas where groundwater tables are more than 40 feet below the ground surface are typically not considered potential liquefaction zones (CGS 2003).

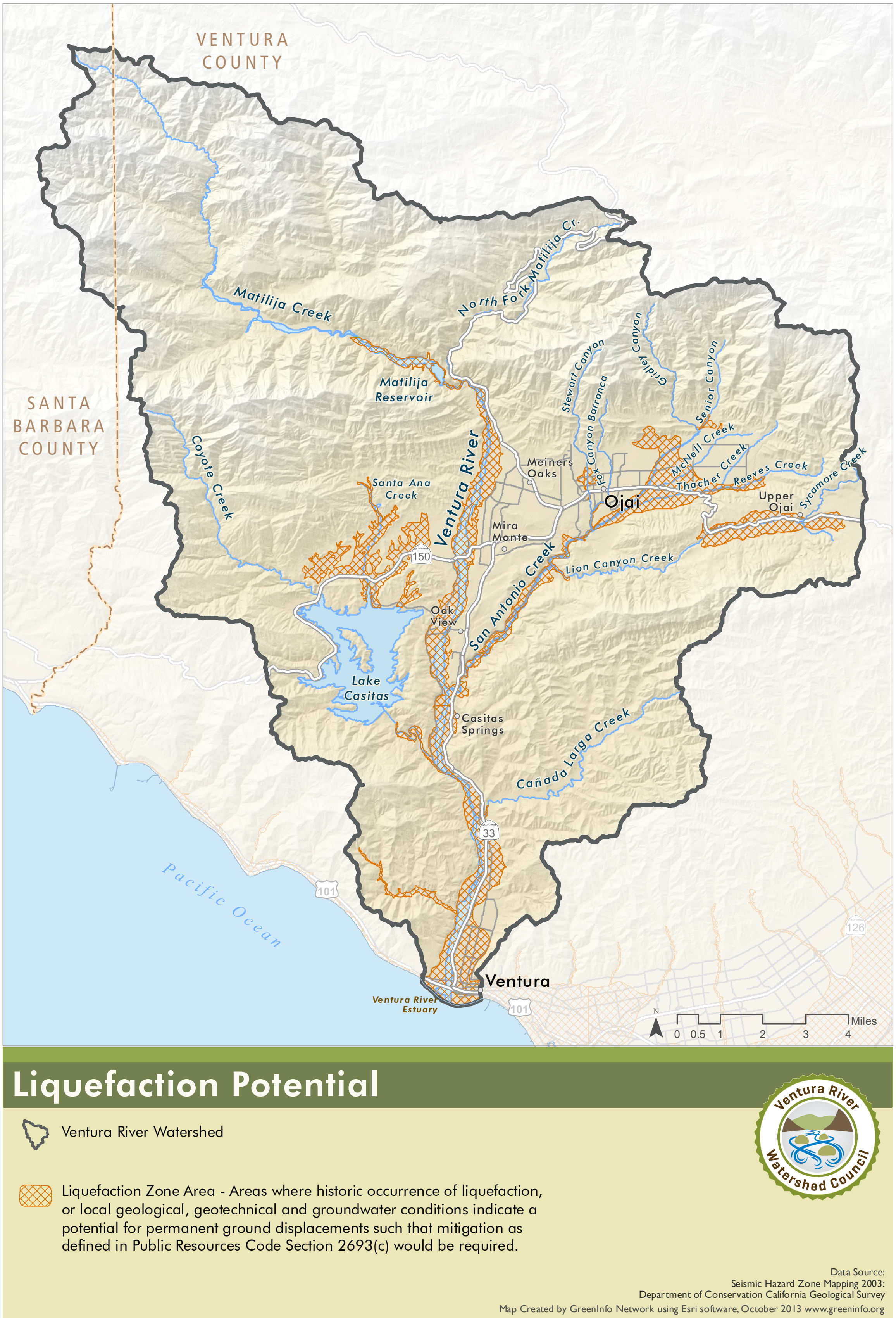


Figure 3.2.2.5.1 Liquefaction Potenial Map

Landslides and Debris Flows

Landslides and debris flows are types of "mass wasting." Mass wasting is the downward movement of soils and rock under gravity, and it requires source materials, a slope and a triggering mechanism. Source materials include fractured and weathered bedrock and loose soils. Triggering mechanisms include earthquake shaking, heavy rainfall and erosion (URS 2010).

The following discussion about landslide hazard is taken from the Ventura County General Plan:

> In general, the highest propensity for landsliding is found in weak rock formations along the more prominent fault zones, near anticlinal folds, and in areas of the younger geologic formations. It is apparent that the combination of these three factors has resulted in relatively intense areas of landsliding such as along the Rincon.
>
> Landslides and potentially unstable slopes are especially common in weak rock formations in hillside areas underlain by sedimentary bedrock of the Pico, Santa Barbara, Monterey/Modelo, and Rincon Formations. These formations are generally soft and contain abundant silt and clay strata.
>
> Many landslides are also associated with steep slopes that have been undercut by erosion and downslope inclination of bedding planes (such as in the Ventura Anticline area). The presence of subsurface water is also a contributing factor to slope instability in the great majority of landslide occurrences.
>
> Landslides and slope instability are widespread throughout the hillside areas. They are subject to potential renewal movement if triggered by poorly planned grading, earthquake ground motions, or increases in ground moisture by any one of numerous factors including, sewage disposal, irrigation, rainfall, etc.
>
> —*Ventura County General Plan, Hazards Appendix* (VCPD 2011a)

Rockslides from steep slopes are the most abundant type of earthquake-induced landslide. Less abundant are shallow debris slides on steep slopes, along with slumps and block slides on moderate to steep slopes (USACE 2004).

3.2.2.6 Key Data and Information Sources/ Further Reading

Below are some key documents that address geology in the watershed. See "4.3 References" for complete reference citations.

Botanical Resources at Emma Wood State Beach and the Ventura River Estuary, California: Inventory and Management (Ferren et al. 1990)

California Oil, Gas, and Geothermal Resources: An Introduction (Ritzius 1993)

Chronology and Rates of Faulting of Ventura River Terraces, California (Rockwell et al. 1984)

Design Hydrology Manual (VCWPD 2010a)

Draft Environmental Impact Statement/Environmental Impact Report for the Matilija Dam Ecosystem Restoration Project (USACE 2004)

Erosion and Sediment Yields in the Transverse Ranges, Southern California (Scott & Williams 1978)

Hydrology, Hydraulics and Sediment Studies of Alternatives for the Matilija Dam Ecosystem Restoration Project (USBR 2007)

Lake Casitas Final Resource Management Plan Environmental Impact Statement (URS 2010)

Matilija Dam Ecosystem Restoration Feasibility Study Final Report (Appendix C – Geotechnical Report) (USACE 2004b)

Quaternary rate of folding of the Ventura Avenue anticline, western Transverse Ranges, Southern California (Rockwell et al. 1988)

Seismic Hazard Zone Report for the Matilija 7.5-Minute Quadrangle, Ventura County, California (CGS 2003)

Status and Understanding of Groundwater Quality in the Santa Clara River Valley, 2007 – California GAMA Priority Basin Project: US Geological Survey Scientific Investigations Report (Burton et al. 2011)

Tectonic Geomorphology and Earthquake Hazard, North Flank, Central Ventura Basin, California (Keller et al. 1980)

The Monterey/Modelo Formation & Regional Water Quality (Orton 2009)

Ventura County General Plan, Hazards Appendix (VCPD 2011a)

Ventura River Flood of February 1992: A Lesson Ignored? (Keller & Capelli 1992)

Ventura River Steelhead Restoration and Recovery Plan (Entrix & Woodward Clyde 1997)

Wetlands of the Central and Southern California Coast and Coastal Watersheds: A Methodology for their Classification and Description (Ferren, Fiedler & Leidy 1995)

Acronyms Used in this Section

NRCS—Natural Resources Conservation Service

USDA—United States Department of Agriculture

VCWPD—Ventura County Watershed Protection District

3.2.3 Geomorphology and Sediment Transport

3.2.3.1 Sediment Production and Transport

The watershed's mountains are composed largely of geologically young marine sedimentary rock—sediments that were at the bottom of a sea floor not very long ago, geologically speaking. These weak, highly erodible rocks are set at very steep angles, causing the watershed to have exceedingly high rates of erosion. In fact, the Ventura River has the highest suspended load and bed load yield of sediment per unit area of any watershed in southern California (Keller & Capelli 1992).

The Watershed's Steep Mountains
Photo courtesy of Les Dublin

The headwaters and upper tributaries of the watershed—including Matilija Creek, North Fork Matilija Creek, Cozy Dell Creek, and streams on the East End of Ojai (e.g., Thacher and Senior Canyon creeks)—produce large amounts of cobble and sediments that flow downward and are deposited on the valley floors. These sediments form most of the alluvium that underlies the watershed's streams and comprises its groundwater basins in the flatter portions of the watershed.

As the river flows downstream, boulders become more rounded, coarse sands give way to finer sands, which eventually partially erode into silts and clays as the river nears the Pacific Ocean. Flash floods and heavy storm flows help to move larger material downstream, so cobbles and small boulders continue to be scattered throughout the river's path.

A number of geomorphic processes contribute sediment to the watershed's streams including sheet erosion (water flowing over land as a sheet rather than in distinct channels), dry land sliding, earthflows, and debris flows (Hill & McConaughy 1988). Wildfire intensifies all of these processes.

Headwater Boulders, Matilija Creek

Dry Landslide, Matilija Canyon

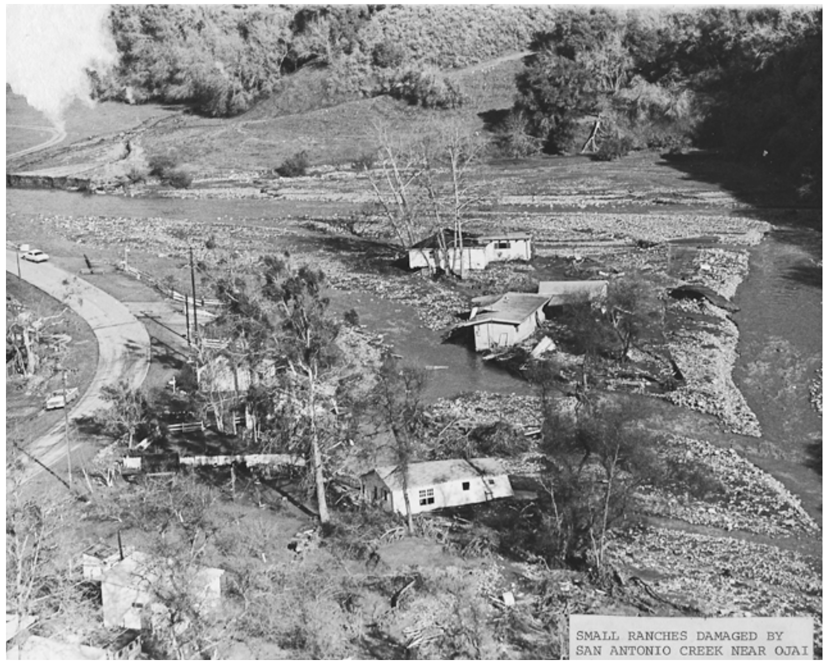
Sediment Transport in Ventura River at Highway 150 Bridge, Winter 2006

Photo courtesy of Scott Lewis

Ventura River, Scoured After 2005 Flood

Photo courtesy of Santa Barbara Channelkeeper

Sediment Transport and Deposition in San Antonio Creek, 1969
Photo by Dan Poush



It has been estimated that the sediment transported to the ocean by the Ventura and Santa Clara rivers during the 1969 floods was greater than all the sediment transported during the previous 25 years.

The vast majority of sediment transport, and the resulting changes to channel shape and location, occurs during relatively infrequent major storms. A 1988 analysis of sediment transport over a 12-year period found that 92% of the sediment transported in the Ventura River occurred during five storms averaging 10 days each (Entrix & URS 2004).

During periods without major storms, stream channels undergo more-or-less continuous fill; eroded sediments that have made their way into stream channels gradually build up. Then, during large storm events, these built up channel sediments are mobilized and channels undergo substantial scour (Scott & Williams 1978).

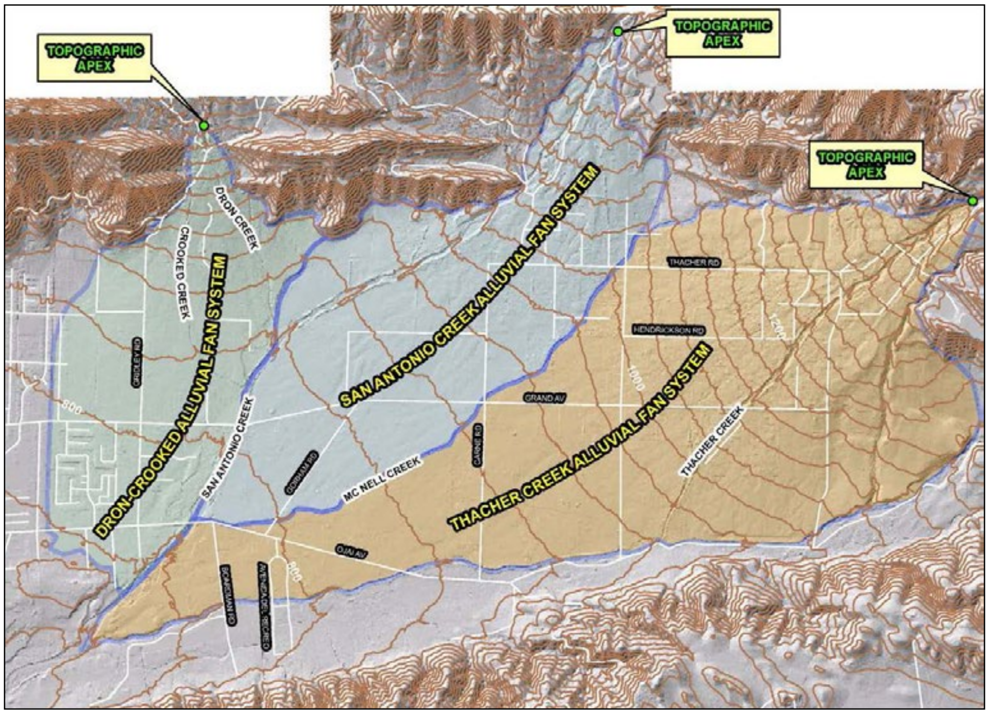
The difference between the movement of sediment during a “normal” year and during a winter dominated by very large storms cannot be exaggerated: it can be as large as 30:1. It has been estimated that the sediment transported to the ocean by the Ventura and Santa Clara rivers during the 1969 floods was greater than all the sediment transported during the previous 25 years (Inman & Jenkins 1999).

The high rates of erosion and landslides in the watershed present significant challenges to flood management and to protection of water and wastewater infrastructure.

Alluvial Fans

Alluvial fans are a significant geologic feature of the Ojai Valley formed by the transport of sediment by water. Alluvial fans are cone-shaped fans of rock and sediment that have built up at the mouths of mountain

Figure 3.2.3.1.1
Alluvial Fans Map, East Ojai Valley
Source: VCWPD 2009



and foothill canyons. Three distinct alluvial fans in the East End of Ojai have been identified: Dron-Crooked Creek Fan, San Antonio Creek Fan, and Thatcher Creek Fan (see Figure 3.2.3.1.1). As discussed more in "3.3.2 Flooding," alluvial fans present a special kind of flood hazard risk because the stream channels associated with alluvial fans are shallow and not well defined, and their movement is unpredictable.

Alluvial fans present a special kind of flood hazard risk because the stream channels associated with alluvial fans are shallow and not well defined, and their movement is unpredictable.

Following are excerpts from a 2009 study by the Ventura County Watershed Protection District on the alluvial fans on Ojai's East End:

> Active fans [where fan building is still active or potentially active] exist mostly in the floor of the valley where ground surface slopes become milder and channels lose their ability to carry sediments further downstream. The geological soil type in these parts of the fans is mainly fluvial deposits. Geological conditions indicate that most of the alluvial fans in East Ojai were formed during the last 12,000 years.
>
> Typical of alluvial fan flooding, flood water from relatively high mountain areas where slope is steep and energy is abundant, carries a large amount of sediment. Some of which are deposited in the channels at floors of alluvial fans. As a result, most of the channels at floors of alluvial fans are wide, shallow and unstable. Overbank flooding occurs frequently and can cause a significant amount of property damages. In fact, many parts of the East Ojai floodplain have been designated by FEMA as repetitive flooding areas.
>
> —*Alluvial Fan Floodplain Mapping, East Ojai FLO-2D Floodplain Study* (VCWPD 2009)

3.2.3.2 Fluvial Geomorphology – Rivers Sculpting Landform

Fluvial geomorphology is the study of the processes that operate in river systems and how they shape stream channels and other landforms overtime. Many factors play a role: tectonics, climate, geology, topography, wildfires, land use, and more.

The Ventura River watershed's fluvial geomorphic story is, in a word, dynamic. Steep, tectonically active mountains, intense storm flows, and erosive sediments all add up to stream channels that are moving and changing.

Floodplain Terrace, Meiners Oaks. Graphic examples of fluvial geomorphic processes at work are the series of floodplain terraces along the Ventura River in Meiners Oaks and near the river's mouth. These terraces were shaped by cycles of relatively rapid vertical uplift followed by downcutting of the river over the last 60,000–80,000 years (Ferren et al. 1990). These terraces also show that the river has migrated to the west over time.

The Braided Ventura River, 2005 Flood. Fluvial geomorphic processes have shaped the main stem of the Ventura River: it is a braided river (meaning numerous channels split off and rejoin each other to give a braided appearance) that flows through riverbed cobble and sometimes crosses bedrock and active geologic structures (Keller 2010).
Photo courtesy of David Magney

Ventura Riverbed Cobble

In its natural state, the Ventura River had a dynamic equilibrium wherein the river channel shape changed from flood to flood, and the river would yield major supplies of sand to the Ventura coastline (USACE 2004). The river's elevation rose between floods from sediment deposits, only to be scoured out during large floods. This natural state of the river has been modified, in part due to impediments to sediment transport as described later in this section.

Flood Scour and Cycles of Vegetation Growth, Ventura River at Main Street Bridge. The river's cycle of sediment buildup followed by scour influences many other processes, including the growth of riparian vegetation, aquatic plants, and algae, and the extent and adequacy of fish habitat. The left-hand photos show the river after big, scouring winters (top 2005, bottom 2008); algae is growing and aquatic plants are minimal. Gradually, without scouring winter flows, aquatic plants become dominant.
Source: Leydecker 2010b

A notable feature on maps of the Ventura River dating from the late 1800s is the presence of large, well-defined islands in the river—ranging in area from about one to over 35 acres. Contemporary accounts from the early 20th century mention residents camping during the summers on an island located between Coyote Creek and the Ventura River (Beller et al. 2011).

Fluvial geomorphic processes also directly influence the shape and extent of the river's delta. One characteristic of deltas formed by rivers carrying high loads of sediment is that their channels tend to migrate over time when deposited sediments interfere and redirect water flow (Keller & Capelli 1992).

These dynamic fluvial geomorphic processes significantly influence the land and watershed. They can directly affect flood control, water quality, habitat protection, land use, water supply, and many other aspects of watershed management.

Islands in the River

Ventura River Estuary, Second Mouth. Just west of the main channel of the Ventura River is a currently inactive channel called the "Second Mouth" of the Ventura River. The multiple channels of a delta system, called "distributary channels," may be active for a period of time, become inactive, and then become active again at a later date (Keller & Capelli 1992).

3.2.3.3 Impediments to Sediment Transport

While the general pattern of sediment buildup followed by flood scour persists today and still defines many river processes, in-channel and floodplain developments have constricted flow and reduced the availability of sediment.

The Ventura River watershed has two dams and a river diversion that inhibit the natural downstream flow of water and sediment: Matilija Dam (built in 1947) interferes with sediment flow from the Matilija Creek subwatershed and Casitas Dam (built in 1959) traps almost all of the sediment of the Coyote Creek subwatershed. The associated Robles Diversion Facility in the Ventura River (built in 1959) also interferes with sediment transport from watershed areas above the diversion.

Matilija Dam

Photo courtesy of Mark Capelli

Casitas Dam

Photo courtesy of Bruce Perry, Department of Geological Sciences, CSU Long Beach

Together these features block the natural drainage of about 37% of the watershed and thereby impede over half of all sediment delivery (Beller et al. 2011).

The Matilija Dam originally provided for 7,018 acre-feet of water storage. Rapid sedimentation, however, reduced this to only 500 acre-feet as of 2003 (Tetra Tech 2009). The vast majority of this sediment was deposited during a few big storm years; the floods of 1969 alone contributed a large proportion of the sediment (USACE 2004b).

> From 1947 to 1964, it is estimated that the [Matilija] dam trapped about 95% of the total sediments from the watershed. Today, it is estimated that the trapping efficiency has dropped to approximately 45% of the total sediment load from Matilija Creek, although the trap efficiency for sand sizes and greater is still practically 100%.
>
> —*Matilija Dam Ecosystem Restoration Feasibility Study Final Report* (USACE 2004b)

The following excerpt describes the impact that the dam has had on the river:

> Trapping sediment in the dam substantially reduces the sediment supply to the stream downstream of the dam. As a result, the stream, which still has a similar sediment transport capacity, makes up the difference by obtaining sediment for transport from the channel bank and bed. The removal of this sediment, without replacement by sediment from upstream, causes the bed elevation to drop over the long term, and increases the potential for bank erosion. In-stream structures such as bridges and utility crossings

Robles Diversion Facility

Stewart Debris Basin. Several debris basins at the base of foothills in the watershed trap sediment.

Photo courtesy of David Magney

> could be adversely affected, as could structures located adjacent to the stream. As the smaller-sized sediments in the channel bed are more easily transported than larger sediments, the channel bed composition would change to become more dominated by cobbles and boulders rather than sand. The delivery of sand to the beach would be reduced.
>
> —*Draft Environmental Impact Report for the Matilija Dam Ecosystem Restoration Project* (USACE 2004)

As stated in the excerpt below, the effect of the dam is significant, but no less significant than streamflow.

> Matilija Dam does not block all the sand from the Ventura River. San Antonio and North Fort Matilija still contribute large amounts of sand. However, it does block a significant portion of sand and its removal will increase the size of the beaches. How much is hard to tell, but the sand loads input into the Ventura River will be about 50% larger than they are now because Matilija Dam blocks about ⅓ of the total watershed area. Matilija Dam is still trapping almost all the sand that enters the reservoir. There is still sand being eroded from the bed of the Ventura River that currently replaces some of the sand that is trapped behind Matilija. However, the sand in the bed is of limited quantity and will eventually run out.
>
> It should be remembered that the biggest variable of beach sand is simply the flow in the river. Without river flows, the beaches erode. The beachline in 1947 (prior to Matilija Dam) is essentially identical to the beachline now because the 40s were relatively dry. Beaches will erode in this area with or without Matilija Dam if there is no rain.
>
> —*Blair Greimann, Hydraulic Engineer, Matilija Dam Ecosystem Restoration Project* (Greimann 2014)

3.2.3.4 Beach and Delta Sediments

Sand and other sediments get deposited on the beaches by both longshore drift and direct buildup from the Ventura River. A longshore current, called the Santa Barbara Littoral Cell, transfers sediment along beaches in the Santa Barbara Channel in a west-to-east direction from Ellwood Beach in Santa Barbara County to Point Mugu in Ventura County. This current is supplied with sediment from coastal cliff erosion and the floodwaters of streams and rivers, with steep-gradient creeks and rivers being the primary sources of sediment (BEACON 2009).

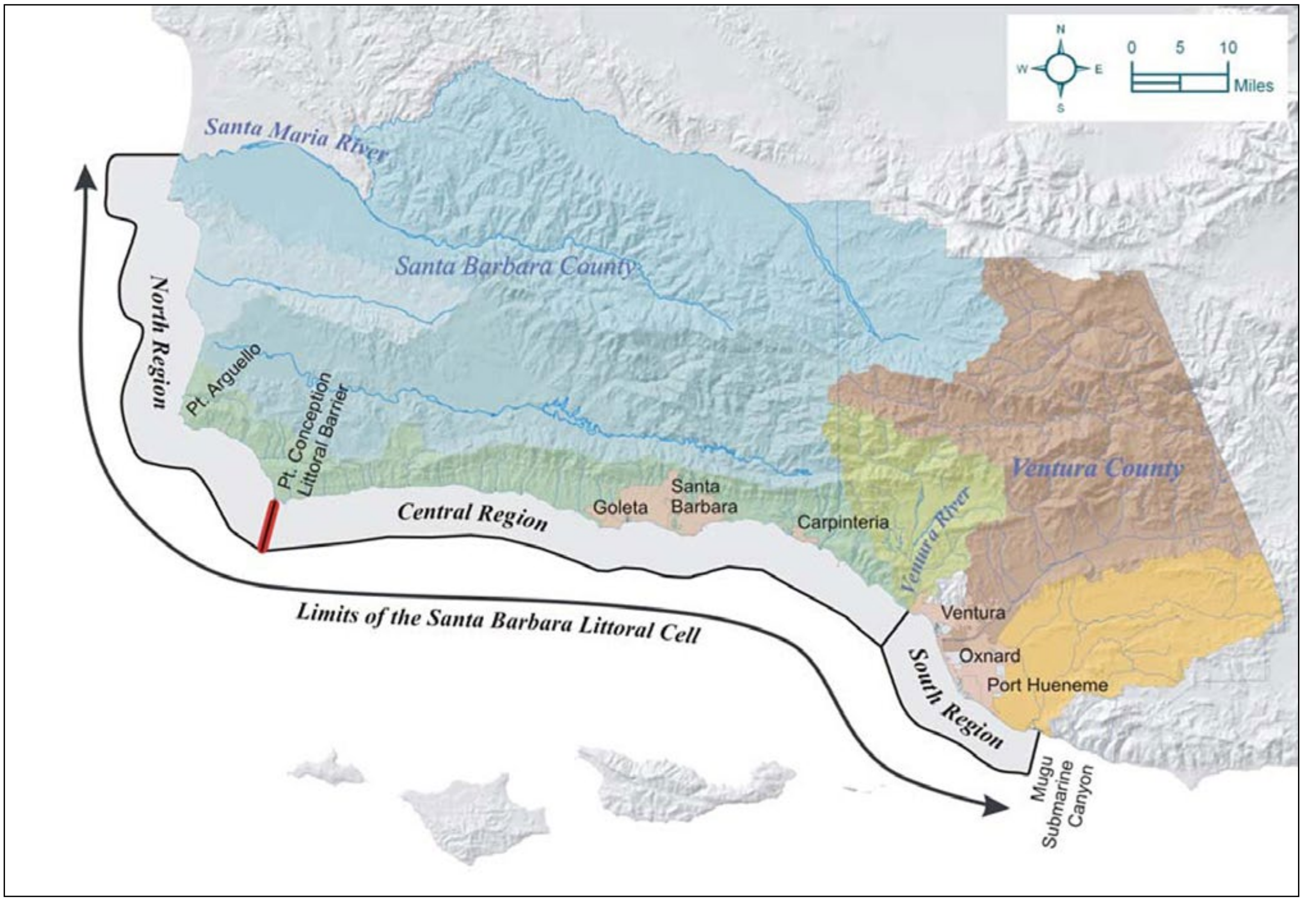


Figure 3.2.3.4.1 Santa Barbara Littoral Cell
Source: Coastal Regional Sediment Management Plan (BEACON 2009)

Beach Cobble Delta,
Seaside Wilderness Park

Sediment transport to the ocean from coastal southern California streams is highly episodic and correlated with flood flows, and this variability is reflected in the amount of beach that exists at any given time.

This natural cycle of sediment buildup and erosion has suffered from a lack of replenishment sediment, however, and this has resulted in growing erosion of beaches in the region (USACE 2004b). Another contributor to beach erosion is coastline armoring—the erection of seawalls and rock revetments (structures used to support embankments) to prevent erosion.

The Rincon Parkway, located between Rincon Point and the Ventura River delta, is one of the most fortified sections of coastline within the entire Santa Barbara Littoral Cell (BEACON 2009): 77% of this 17-mile stretch of coastline is armored with seawalls and revetments (CDBW & SCC 2002).

Rincon Parkway Armoring

Table 3.2.3.4.1 Estimated Sediment Supply Delivered to the Coast from Rivers and Streams of the Santa Barbara Littoral Cell

Watershed	Fluvial Delivery Volume (cubic yards/year) Pre-dam	Post-Dam	Reduction (%)
Santa Maria River	811,000	261,000	68
San Antonio Creek	60,000	(no dams)	0
Santa Ynez River	713,000	347,000	51
Santa Ynez Mountains Watershed	195,000	(no dams)	0
Ventura River	216,000	102,000	53
Santa Clara River	1,634,000	1,193,000	27
Calleguas Creek	65,000	(no dams)	0

Data Source: Coastal Regional Sediment Management Plan (BEACON2009)

Such armoring has been documented to ultimately reduce beach widths via several mechanisms. For example, sediment from previously eroding coastal bluffs that would otherwise be available for transport and deposit by the littoral current is impounded by shoreline armoring.

Another mechanism is passive erosion:

> Whenever a hard structure is built along an eroding coastline, the shoreline will eventually migrate landward on either side of the structure. The effect will be gradual loss of the beach in front of the seawall or revetment as the water deepens and the shoreface profile migrates landward. This process is designated as *passive erosion* and has been well documented along many different shorelines. Passive erosion takes place regardless of the type of protective structure emplaced. This process is perhaps the most significant long-term effect of shoreline armoring.
>
> —*The Effects of Armoring Shorelines, The California Experience* (Griggs 2010)

Beach and delta erosion is a watershed management concern. The Matilija Dam removal project is an effort to return the river to more natural conditions, increasing sediment flow downstream, creating more alluvial floodplain habitat, and replenishing the sand-starved beaches along the coast. In concert with the Matilija Dam removal project, the Surfers' Point Managed Shoreline Retreat Project is designed to restore the beach profile to more natural and sustainable conditions (City of Ventura & Rincon Consultants 2003).

Surfers' Point Managed Shoreline Retreat Project

In 1992, winter storms eroded a new beachfront bike path, owned by the California Department of Parks and Recreation, and damaged the adjacent parking lot for the Ventura County Fairgrounds. Fairgrounds officials proposed the construction of a sea wall to stop further erosion. The local chapter of the Surfrider Foundation and the California Coastal Conservancy opposed the sea wall plan, which would have reduced the habitat and recreational value of the site and, by altering wave patterns, likely increased erosion rates on nearby beaches.

In 2001, the many parties with an interest in the site agreed on a managed retreat approach for the site. With leadership from Surfrider, funding assistance from the California Coastal Conservancy, a land contribution from the state of California's fairgrounds, and management by the City of Ventura, a progressive "managed retreat" project was designed and implemented at Surfers' Point in order to give the beach sand more room to behave like a natural seasonally growing and shrinking beach. Phase 1 construction, covering a 900-foot reach, was completed in 2011. Phase 2 is awaiting additional funding as of 2014.

(continues on next page)

Coastal Erosion, Surfers' Point

"Every Stone Helps" Sign, Surfers' Point

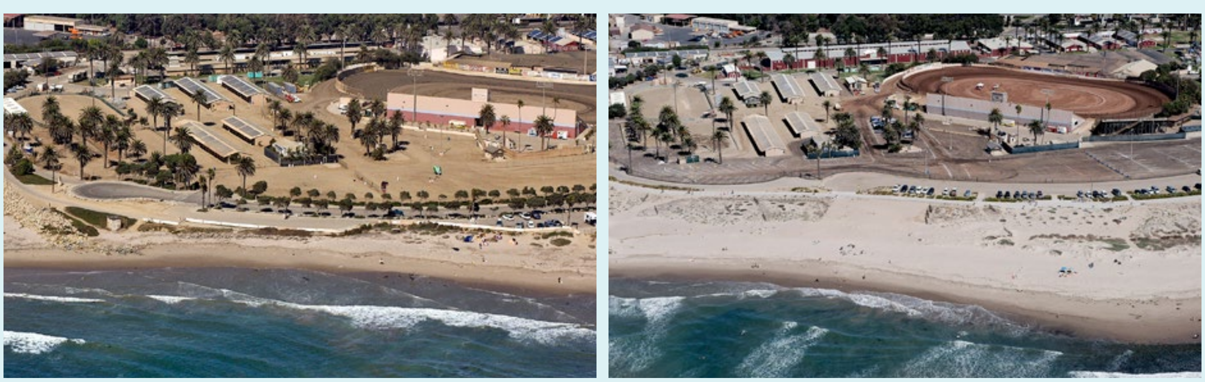
Surfers' Point Managed Shoreline Retreat Project *(continued)*

Features of this project include:

- Removing all existing improvements seaward of Shoreline Drive, including the damaged bike path and eroded public parking lot, and relocating them farther inland;
- Modifying Shoreline Drive to allow for retreat of the existing parking facilities and preserve public access to Surfers' Point;
- Improving parking by constructing two new "low impact development" parking lots that incorporate runoff treatment controls—including appropriate landscaping, permeable surfaces, and a stormwater treatment system—and installation of an entry kiosk and bicycle parking;
- Improving recreational amenities by constructing a new multi-use trail to replace the existing path, creating a new interpretive area, and expanding an existing picnic area; and
- Restoring the retreat zone and providing protection for the new improvements by recontouring the retreat area with natural beach materials and re-creating sand dunes.

Dune Restoration Sign, Surfers' Point

The Surfers' Point Managed Shoreline Retreat project is one of the first managed retreat projects to be implemented in California. Developed in response to coastal erosion, it serves as a model of sustainable shoreline management for other similar projects up and down the California coast. The project was featured at the California and the World Ocean Conference in 2006 and as a case study for managed retreat by NOAA's Office of Ocean and Coastal Resource Management. The California Coastal Commission has cited the project as an example for other locations including Goleta Beach and Pacific Beach (Jenkin 2013).



Before (2008) and After (2013) Managed Retreat Project, Surfers' Point

3.2.3.5 Key Data and Information Sources/ Further Reading

Below are some key documents that address geomorphology in the watershed. See "4.3 References" for complete reference citations.

Alluvial Fan Floodplain Mapping, East Ojai FLO-2D Floodplain Study (VCWPD 2009)

Botanical Resources at Emma Wood State Beach and the Ventura River Estuary, California: Inventory and Management (Ferren et al. 1990).

Channel Geomorphology and Stream Processes (Entrix 2001a)

Coastal Regional Sediment Management Plan (BEACON 2009)

Draft Environmental Impact Statement/Environmental Impact Report for the Matilija Dam Ecosystem Restoration Project (USACE 2004)

Draft Ventura River Habitat Conservation Plan (Entrix & URS 2004)

Erosion and Sediment Yields in the Transverse Ranges, Southern California (Scott & Williams 1978)

Historical Ecology of the lower Santa Clara River, Ventura River and Oxnard Plain: an analysis of terrestrial, riverine, and coastal habitats (Beller et al. 2011)

Hydrology, Hydraulics and Sediment Studies of Alternatives for the Matilija Dam Ecosystem Restoration Project (USBR 2007)

Matilija Dam Ecosystem Restoration Feasibility Study Final Report (USACE 2004b)

Sediment Loads in the Ventura River Basin, Ventura County, California, 1969–1981 (Hill & McConaughy 1988)

Surfer's Point Managed Shoreline Retreat Environmental Impact Report (City of Ventura and Rincon Consultants 2003)

The Effects of Armoring Shorelines—The California Experience (Griggs 2010)

Ventura River Flood of February 1992: A Lesson Ignored? (Keller & Capelli 1992)

Acronyms Used in this Section

NOAA—National Oceanic and Atmospheric Administration

Further Reading: Geomorphic Assessment of the Santa Clara River Watershed

In addition to the resources listed here, a comprehensive fluvial geomorphological study was undertaken on the Santa Clara River watershed, which is adjacent to the Ventura River watershed to the southeast. There are enough similarities between these watersheds that this study can be informative for the Ventura River watershed.

Stillwater Sciences. 2011. Geomorphic assessment of the Santa Clara River watershed: synthesis of the lower and upper watershed studies, Ventura and Los Angeles counties, California. Prepared by Stillwater Sciences, Berkeley, California, for Ventura County Watershed Protection District, Los Angeles County Department of Public Works, and the U.S. Army Corps of Engineers–L.A. District. April 2011

3.3 Hydrology

Ventura River Downstream of Santa Ana Bridge

Photo courtesy of Scott Lewis

3.3 Hydrology

Hydrology is the study of water and its properties, distribution, and circulation—in the air, on the ground, and beneath the surface. This chapter addresses primarily the distribution and circulation of surface water and groundwater in the watershed. Water quality is addressed in "3.5 Water Quality." Other important factors that affect hydrology are described in other sections, including rainfall ("3.2.1 Climate"), vegetation ("3.6.1 Habitats and Species"), and land use ("3.7.3 Land Use").

3.3.1 Surface Water Hydrology

3.3.1.1 Drainage Network

The Ventura River drainage network includes five significant tributaries that feed into the Ventura River: Matilija Creek, North Fork Matilija Creek, San Antonio Creek, Coyote Creek, and Cañada Larga. A notable feature of the Ventura River watershed is that its primary stream network remains largely unchannelized, with relatively natural stream shape and hydrologic patterns in many reaches (Beller et al 2011). Two dams, three levees, and high rates of runoff from urban areas have modified stream shape and hydrologic patterns in other reaches.

Table 3.3.1.1.1 Summary of Primary Drainages in the Ventura River Watershed

	Drainage Area (Square Miles)	Drainage Area (Acres)	Length (Miles)
Ventura River Mainstem	44.0	28,143	16.23
Matilija Creek[1]	54.6	34,927	17.31
North Fork Matilija Creek	16.1	10,291	8.14
San Antonio Creek	51.2	32,746	9.66
Coyote Creek[1]	41.3	26,414	14.62
Cañada Larga Creek	19.2	12,312	7.85
Total	**226.4**	**144,833**	**73.81**

1. Includes the area under the reservoirs built on these creeks.

Ventura River

The Ventura River mainstem covers a distance of 16.2 miles on its journey from the mountains to the ocean. In that short distance the river can look and behave quite differently. The river's five distinct reaches are described in the following sections.