FINAL SUISUN CREEK WATERSHED ASSESSMENT AND ENHANCEMENT PLAN

Surveying Suisun Creek Channel

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Funded by the California State Coastal Conservancy

February 2004

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Introduction

Suisun Creek watershed encompasses 53 square-miles of land in Napa and Solano County. The watershed has no incorporated cities. Two major creeks, Wooden Valley and Suisun Creek, drain a watershed of steep mountainous terrain and several large valleys into the Suisun Marsh, a major habitat area for waterfowl and other wildlife. Steelhead trout, a federally-listed threatened species have been found in both Wooden Valley and Suisun Creeks.

The focus of this enhancement plan is restoration of aquatic and riparian habitat to support and sustain steelhead habitats and including the improvement of water quality. The enhancement plan does not address all issues in the watershed. Specifically, flood control issues and water rights issues are not evaluated. Steelhead trout (*Oncorhynchus mykiss*) are anadromous cold water fish. The species uses two very different environments – the ocean and freshwater streams and creeks.

For the anadromous life cycle of the steelhead trout to be fulfilled successfully, the freshwater environment must support all steps in their lifecycle - in-migration and spawning of adults, egg incubation and emergence of young, juvenile rearing over the hot summer months and out-migration by juveniles.

The freshwater environment, particularly aquatic and riparian (streamside) habitats are created and sustained by watershed and creek processes. For example, spawning habitat requires deposits of gravel within the creek. Gravel is deposited, moved and sifted by flood events and changes in the natural form of the creek, its meanders and banks. The gravel needs to be relatively free of fine silt, often a product of excessive erosion in the watershed. If the creek receives few flood events due to reservoirs, or has been straightened and managed as an urban creek, spawning habitat is compromised. Similarly, if erosion from roads and gullies is too great, spawning may occur, but the eggs are smothered with silt.

Similarly, rearing habitat requires adequate cold groundwater to support the small fish. The shade of dense riparian tree cover, deep pools, and cold groundwater help to keep the water below 65°F when summer air temperatures exceed 100°F. Groundwater availability is a function of the watershed's ability to infiltrate and store rainfall, the geology of the drainage, the condition of the creek, and the extent and timing of water storage and diversions. The ability of the Suisun Creek watershed to support aquatic life results from natural and man-made watershed conditions and processes, as well as whatever direct management is practiced on the creek, its vegetation and floodplain.

This watershed plan includes various studies of the factors that limit steelhead trout and affect aquatic and riparian habitats and water quality in the Suisun Creek watershed. Data was collected on in-stream habitat conditions, water flows, the size, extent and species diversity of the riparian corridor, water temperatures, water quality, siltation in the stream channel, sediment sources in the watershed, bank erosion, fish passage barriers and other features. In addition, the watershed was assessed for erosion sites, roads, vegetative cover, land use, soils, geology and other features. This assessment and data collection were used to formulate recommendations for enhancing and sustaining conditions that support aquatic and riparian habitats and endangered steelhead trout.

Monitoring and Assessment Methods

A Geographic Information System (GIS) was created for the Suisun Creek watershed. Digital ortho-photo quarter quadrangles (DOQQs) were acquired from the United States Geological Survey (USGS). Additional data layers depicting perennial and seasonal streams, major roads, major reservoirs and canals were acquired.

A number of additional layers were created including: erosion sites, dirt roads, stream miles for the two major creeks, extent of riparian corridor, areas with little or no riparian corridor, seasonally dry streams, fish passage barriers recorded in stream surveys, locations of monitoring and survey sites used in this plan, locations of monitoring sites used by the Regional Water Quality Control Board. In additional to collecting existing information and assessing certain features of the watershed, monitoring and surveying were carried out at both point locations and study reaches.

Locations for study reaches were determined from an analysis of channel slope, channel confinement, location and size of significant tributaries, a field check of channel conditions and availability of landowner access. Detailed surveys of channel cross sections were completed in 2001 and 2002 on the Wooden Valley Creek study reach and in 2001, 2002 and 2003 on the Suisun Creek study reach. Pebble count and embeddedness measurements were completed in the two study reaches in 2002. The V-star protocol was used to measure residual pool volume at two locations in Suisun Creek. The portions of Wooden Valley and White Creeks where access was available were not appropriate for use of this protocol.

Twenty-one stations were established for water temperature monitoring, twelve of which were also used for water quality monitoring. Water temperature was monitored with continuous recording data loggers from June to October in 2002 and 2003. Canopy cover was measured at each station using a spherical densiometer. The width and depth of the wetted channel was also recorded. In addition, at each temperature monitoring station, riparian vegetation, the presence of invasive plant species, bank heights and channel conditions were noted over the 2001-2003 period.

Water quality parameters were monitored including dissolved oxygen, temperature, ammonia, nitrate, phosphate and pH at twelve stations on a monthly basis for June to October 2002. Data from two other water quality monitoring programs was reviewed and summarized.

A stream habitat survey was completed for Wooden Valley and White Creeks following the methodology established by the California Department of Fish and Game. Hanson Environmental, Inc. completed a stream survey of Suisun Creek in 2001, which was reviewed and summarized. Riparian plant transects and habitat evaluations were completed in several locations.

Watershed Assessment

Watershed Features The Suisun Creek watershed has two distinct tributaries – Wooden Valley Creek and Suisun Creek. Wooden Valley Creek extends approximately 7.0 miles from its origins 1.5 miles north of Wooden Valley to its confluence with Suisun Creek. The Wooden Valley subbasin encompasses 14 square miles. There are a number of tributary creeks that drain the steep mountains surrounding Wooden Valley and conduct flow into Wooden Valley Creek. White Creek is the longest of these tributaries.

The headwaters of Suisun Creek are located to the north of Lake Curry in the mountainous northeastern portion of the watershed. Lake Curry is the only large reservoir in the watershed and covers 377 acres. Suisun Creek stretches 4.9 miles from its headwaters to its confluence with Lake Curry. From the Lake Curry outlet, Suisun Creek stretches 11.5 miles to Interstate 80, and a total of 14.5 miles to Suisun Marsh.

Geology Three geologic formations make up the Suisun Creek watershed – Great Valley Sequence, Sonoma Volcanics and ultramatic rock. The geologic make up of the watershed gives an indication of the particular features occurring in each subbasin. The Sonoma Volcanic formation is likely to have springs and more abundant summer groundwater than the sedimentary Great Valley Sequence formation. Wooden Valley Creek and its tributary, White Creek is likely to have cold groundwater in the summer months for salmonid rearing. Suisun Creek may also have springs in tributaries, but this subbasin overall is likely to have less summer groundwater than the Wooden Valley subbasin under natural conditions. There is the large area of landslide deposits dissected with faults along the western side of Suisun Valley, Wooden Valley and upstream of Lake Curry where larger erosion problems may occur.

Soils The Soil Surveys for the watershed indicate the predominant soil types for the watershed are in the 15-50% slope class and have high to severe erosion hazard ratings and rapid to very rapid runoff rates giving the mountainous areas of the watershed conditions prone to excessive erosion from disturbance or along road cuts.

Hydrology and Geomorphology The stream network of the Suisun Creek watershed consists of two major subbasins – Wooden Valley Creek and Suisun Creek. An evaluation of the slope class and natural confinement of these two creeks was completed to define several basic characteristics about each creek. Suisun Creek, from the Lake Curry outlet to Suisun Marsh is a low slope (<1%), unconfined, alluvial channel, which under natural conditions would probably have a pool/riffle pattern and an adjacent floodplain where stormflows spread out and slow down. Under natural conditions, Suisun Creek would probably support significant riparian forest and spawning habitat for salmonids, and depending on the availability of cold water in summer, rearing habitat for salmonids.

Wooden Valley Creek varies from a set of steep headwater creeks to an unconfined alluvial channel in Wooden Valley to a low slope bedrock gorge to an unconfined channel. Because the channel does not become steep in its bedrock section, and flow is year round, it can support spawning and rearing habitat for salmonids, but has a limited area for riparian forest. Under natural conditions, the unconfined channel areas should support significant riparian forest, and salmonid spawning habitat and, if summer cold water is available, rearing habitat for salmonids.

Lake Curry's effect on small flood events (two-year flood) that shape and change the stream channel and aquatic habitats was evaluated. Records of the frequency and duration of flows over the spillway in a twelve-year period show a major effect on reducing bankfull flows and affecting stream morphology for many miles downstream. During this same period the nearby Napa River experienced bankfull flows in seven of the twelve years. This condition can cause a build up of fine sediment in Suisun Creek and impairment of spawning habitat

Comparison of annual channel cross sections surveyed on Wooden Valley and Suisun Creek from 2001-2003 showed little change due to low rainfall and the likely effects of Lake Curry on Suisun Creek. Fine sediment levels measured in both creeks were very high and indicate the need for erosion control and soil conservation projects in the watershed.

Riparian Forest The riparian corridor averages 120 feet in width along Suisun Creek and 172 feet in Wooden Valley. The riparian corridors have a diversity of large and small native trees and habitat elements such as snags, logs and wildlife food plants. However the riparian corridor is relatively narrow. The riparian corridor provides shade to the creeks and keeps water temperature cool.

There are several locations where there is little to no riparian corridor and water temperatures are high. At Suisun Creek stream mile 4.5, the process of channel entrenchment is evident with bank erosion undercutting large oaks and much of the riparian corridor from the former, now abandoned, floodplain. This process will result in a wider, deep channel with a new floodplain and seedling riparian trees offering little shade for many years. Active revegetation projects could provide both native plants and more stable banks.

Several invasive non-native species were found. Giant reed (*Arundo donax*) occurs in isolated clumps on Suisun Creek, but was not found on Wooden Valley Creek. Understory invaders – Himalayan blackberry, blue periwinkle and Harding grass are widespread along both creeks and their tributaries.

<u>Water Temperature</u> Water temperature has a large effect on aquatic life and aquatic habitats. In a Mediterranean climate, water temperatures are cold during the late fall, winter and early spring rainy months. In the hot, dry summer months, water temperatures can increase greatly. There are a number of factors that affect water temperature – the volume of flow; the daily hours of sunlight; ambient air temperature; the amount of shade over the water surface, typically called canopy cover; the width and depth of the stream channel and water flow; and the source and temperature of summer water flow – groundwater or surface water releases. Steelhead trout require temperatures of 65° F or below.

The water temperature monitoring indicates that overall, Wooden Valley and White Creek have the coldest water temperatures and potentially best steelhead rearing habitat. There are areas of each creek (Wooden Valley Creek Stations 1 and 2a; White Creek Stations 2 and 3), where riparian canopy is inadequate to maintain shade and retain summer pool habitat. The remaining areas of Wooden Valley Creek (Stations 2-6) have very good to excellent cold water temperatures and canopy cover for steelhead rearing. White Creek has several locations that have very cool water temperatures and dense canopy cover for steelhead rearing.

Suisun Creek has cool water temperatures for steelhead rearing at only two locations, Stations 9 and 10, immediately below the dam and approximately one-half mile downstream. Water temperatures at Stations 1-8 vary from marginal to too warm for steelhead rearing with average daily maximum temperatures of 70°F, a very small range of daily temperature and many hours per day of temperatures over 70°F. Canopy cover at many of Stations 1-8 is inadequate and in some cases has been eroded out by the process of channel incision. The increase in the reservoir releases from 2.0 cfs in 2002 to 3.0 cfs in 2003 does not appear to be a large enough volume increase in flow to maintain cold water conditions. A higher volume release may create a large enough mass of water that it can attenuate solar inputs and maintain cold temperatures in summer.

<u>Water Quality</u> Basic ambient water quality parameters of water temperature, pH, dissolved oxygen, nitrate-nitrogen, ammonia-nitrogen and phosphorous were monitored at twelve stations in 2002. In addition the Regional Water Quality Control Board Surface Water Ambient Monitoring Program monitored water quality at eight stations for two weeks at a time in 2002 and Hanson Environmental, Inc., monitored dissolved oxygen (DO), pH, conductivity, and temperature at three stations from December 2000 to August 2001.

Water quality data show low levels of nutrients (nitrogen and phosphorous) and adequate levels of dissolved oxygen at many stations to support steelhead trout rearing. Several stations on Suisun Creek demonstrated DO levels in the 6.0—6.5

mg/l range below the 7.0 mg/l recommended level for steelhead. Since DO levels increase with water temperature, stations without adequate canopy cover showed the lower DO levels.

Aquatic Habitat Stream surveys observed steelhead juveniles in Wooden Valley, White and Suisun Creeks. The surveys also found a need for more habitat complexity in the stream, a reduction in fine sediment levels a need for more canopy cover and more spawning areas. Fish passage barriers consisted of beaver dams and a few concrete structures.

Land Use and Planning The majority of the Suisun Creek watershed is private agricultural land used for livestock, vineyard, orchards and row crops. Agricultural land management practices need improvement through voluntary efforts with landowners to reduce soil erosion. Roads in the watershed, both public and private, are also likely sources of erosion and fine sediment into creeks. General Plans for Napa and Solano Counties indicate open space and agricultural land uses for most of the watershed.

Summary of Watershed Assessment and Monitoring

The 53 square-mile Suisun Creek watershed is largely rural, dominated by wild land and agricultural land. Unlike most urban Bay area creeks and watersheds, the rural nature of this watershed creates many of the conditions required to create and sustain aquatic and riparian habitats and steelhead trout. The assessment and monitoring for Suisun Creek watershed identified a number of conditions that need to be improved to enhance aquatic and riparian habitats and steelhead trout survival.

These conditions include:

- Summer water temperatures are marginal to too warm for steelhead rearing in many areas of Suisun Creek below Lake Curry and in several isolated locations in Wooden Valley and White Creeks; however, cold water conditions dominate much of Wooden Valley and White Creeks.

- Riparian canopy cover is inadequate on much of Suisun Creek, lower Wooden Valley Creek and parts of White Creek contributing to the high summer water temperatures. The riparian corridor is narrow in most locations.

- Several invasive non-native plant species – giant reed, blue periwinkle, Himalayan blackberry and Harding grass have spread into many areas of the riparian corridor. Invasive plants are a major problem for riparian habitats.

- There was a high level of fine sediment in the channel in the areas monitored. Soil erosion from a wide variety of sources such as public and private roads, bank erosion, agricultural and urban lands needs to be reduced.

- There are a number of fish passage barriers in Suisun and Wooden Valley Creeks that need to be altered or removed. In addition, many areas of the creek need additional large wood to create productive complex habitat for steelhead trout.

- Lake Curry affects the magnitude and frequency of stormflows on Suisun Creek, especially the smaller two-year floods. As the number of small flood events is diminished, fine sediment can build up on the channel bed in spawning and rearing habitats. The large number of beaver dams on Suisun Creek that block fish passage may also be supported by the lack of regular scouring stormflows on Suisun Creek.

- Lake Curry releases water in summer from the lower outlets in the reservoir. Water temperature measurements for the 2.0 and 3.0 cfs releases into Suisun Creek in 2002 and 2003 indicate a need to increase the volume of flow and canopy cover. A larger volume or mass of water in Suisun Creek can likely attenuate solar inputs and maintain a lower water temperature than the current level release.

- Additional monitoring of water temperatures, water quality and fine sediment levels along with surveying of channel study reaches is needed to implement an adaptive management approach in the watershed.

- Monitoring information collected should inform the next set of enhancement actions. A more thorough survey of the Suisun Creek channel is need to evaluate the locations and extent of channel entrenchment and its potential effects on both downstream flood problems and riparian and aquatic habitats. This type of survey should be completed in cooperation with landowners and the Solano County Water Agency Flood Control Committee.

- All projects need to be developed with landowner involvement and cooperation to implement and sustain long term improvements in the watershed and aquatic and riparian habitats.

- Cooperation between the City of Vallejo, environmental and fishery groups, agricultural groups, state and federal agencies and elected officials is needed to evaluate alternatives for re-operation of Lake Curry. The preferred alternative needs to provide for: use of the municipal water supply in Lake Curry, continued local water service, and protection and enhancement of riparian and aquatic habitats and endangered steelhead trout habitats.

Enhancement Actions

The monitoring and watershed assessment found a number of conditions in the creeks and watershed that, if enhanced, could improve aquatic, riparian and steelhead habitats. Aquatic habitat is affected by many processes and conditions in the watershed and creek. For this reason, no one type of project can serve to provide all the actions needed to restore and sustain aquatic and riparian habitats and support steelhead trout. Instead a number of varied actions are needed.

The current monitoring and assessment information was used to identify the following enhancement actions. As these actions are implemented, monitoring should continue and identify different or additional enhancement actions. This process is termed adaptive management and requires both an array of scientific monitoring at long-term stations and community and landowner involvement to implement the program. The approach to implementation of improvements must be through cooperative relationships with landowners in the watershed. Since the majority of land management decisions are made by local landowners then cooperation with the land manager is the most effective way to improve the conditions in the watershed and creeks.

1. Restoring Riparian Forest on Denuded Channel Areas to Reduce Water Temperature

Several areas on Wooden Valley and White Creeks have little to no riparian cover and therefore have very high water temperatures or dry conditions. The landowners of these areas need to support revegetation and the projects would need to be designed to take into account the landowner's needs as well as the practical aspects of native plant revegetation. Riparian trees such as willow, white alder, box elder, Oregon ash, California bay laurel and oak should be included in the revegetation design. Planting locations should reflect each species' relationship to the bankfull channel in a natural system.

2. Controlling Invasive Species in the Riparian Corridor to Enhance the Corridor, Reduce Water Temperatures and Reduce Pierce's Disease Problems for Grapegrowers

2A. Giant Reed (Arundo donax) Mapping, Eradication Strategy and Implementation of Removal Projects

In the watershed assessment, small clumps of giant reed (*Arundo donax)* were noted. This indicates the beginning of a larger infestation. *Arundo* grows in dense clumps up to 25 feet in height and spreads rapidly through clonal reproduction. *Arundo* out-competes many native plant species and provides little to no wildlife habitat. *Arundo* infestations remove the essential functions of native riparian plants to shade the creek and to provide large wood and insects for fish habitat.

The location, extent and acreage of the infestation should be mapped and evaluated and an eradication strategy formulated using mechanical and chemical eradication methods. The strategy should extend from upstream to downstream to reduce the potential for re-infestation.

Once several eradication concepts have been developed, the landowners on the creek need to be involved and have input. It will be critical to work closely with landowners to eradicate this plant and continue follow-up activities.

2B. Native Riparian Revegetation and Demonstration Invasive Plant Removal Projects

In addition to *Arundo donax*, several other invasive non-native species were found to be widespread in the riparian corridor – blue periwinkle (*Vinca major*), Harding grass (*Phalaris aquatica)* and Himalayan blackberry (*Rubus discolor*). These invasive plants cover over native understory and stream bank areas impairing regeneration of native plants. Native tree seeds cannot germinate through the thick mat of invasive plants. As the riparian forest grows old and dies with little to no regeneration, the invasive species are all that remain. Blue periwinkle and Himalayan blackberry are of specific concern to grapegrowers as they harbor Pierce's Disease, a bacterial disease fatal to grapevines, the primary agricultural crop on the creek floodplain.

Many landowners are interested in having demonstration projects completed on their riparian corridor to remove invasive plants and replant with natives. In some locations, these projects would increase native riparian tree cover and thus reduce water temperatures. Several sites were selected encompassing up to 12 acres on both Suisun and Wooden Valley Creeks for demonstration projects. As part of the demonstration projects, workshops for local landowners should be held to explain eradication methods and revegetation projects.

3. Reducing Fine Sediment in Creeks and Improving Land Management Measures

Excess sediment was identified as a problem for aquatic habitats in the watershed assessment. The sources of the excess sediment are likely to be many sites throughout the watershed managed by a number of different landowners. The most effective way to reduce the fine sediment is to work with the landowners/managers to improve management practices and to assess and repair sediment sources such as roads and major erosion sites.

3A. Farm Conservation Planning Program

Several landowners in the Suisun Creek watershed have requested the Fish Friendly Farming (FFF) Program from the Russian, Navarro and Napa River watersheds be implemented in the Suisun Creek watershed. The FFF Program, or a similar effort should employ a comprehensive approach to improving the conditions and management practices on agricultural lands through the collaboration of the land manager or farmer with a technical expert to produce a farm conservation plan. The farm conservation plan identifies sediment sources with roads assessments, road repair and management measures, erosion site repair and evaluation of soil erosion from agricultural lands. Improvements would be implemented through specific projects and changes to management measures. Projects should be eligible for public funding cost share.

3B. Community Workshops for Rural Residential Landowners

In addition to agricultural landowners, rural residential landowners would be invited to a series of workshops focusing on roads, erosion control, pesticide use, invasive plants, creek care and other subjects. The workshop would instruct rural residential owners in methods to conserve soil and reduce sediment runoff. Rural roads are often a major source of sediment and will be one focus of the workshop. The workshops would provide the tools for rural residential owners to reduce sediment, pesticide runoff, invasive plants, improve creek habitats and remove fish passage barriers.

3C. Coordination with County Road Departments and CalTrans

The pubic roads in the watershed in several locations are causing increased erosion at culvert outlets and, due to their locations next to creeks, directly transmit sediment and pollutants into Suisun and Wooden Valley Creeks.

To address this problem meetings with county road maintenance personnel and CalTrans planners and maintenance personnel are needed to discuss changes in road practices to reduce sediment sources and pollutant loading and removal of fish passage barriers.

4. Improving Riparian Corridors; Removing Fish Passage Barriers; Increasing Large Wood in Creeks for Fish Habitat and Improving Land Management Measures

4A. Farm Conservation Planning Program

The watershed assessment identified a need for greater canopy cover and a wider riparian corridor to provide shade to the creeks. In addition, a number of fish passage barriers were identified along with and a need in nearly all the creeks to increase large wood in pool areas as a fish habitat improvement. Since the watershed is primarily private land increasing and improving riparian corridors and removing fish barriers should be carried out with the landowner/manager.
These revisions to private land can also be addressed through the Fish Friendly Farming (FFF) Program or a similar farm conservation plan program.

The following steps are needed:

- ❑ Use the FFF Program or develop a comprehensive science-based program that includes Best Management Practices and a farm conservation plan evaluation to address:
    - Revegetation of riparian corridors with appropriate native species
    - Revisions to channel form, if required, and adequate width and diversity to provide ecological functions and bank stabilization functions
    - Removal of invasive species
    - Removal of fish barriers
    - Placement of large wood both as part of streambank stabilization and habitat improvement
    - Monitoring and maintenance of plantings and mature trees

Riparian corridor and aquatic habitat restoration should be implemented through specific projects identified in the farm conservation plan and through management and maintenance practices to continue control of invasive plants, irrigation of new plantings, weeding and other actions. Projects would be eligible for cost chare funding. The farm conservation plan outlines actions for revegetation of riparian corridors, water conservation and other measures needed to produce high water quality and improve the aquatic and riparian ecosystem for fish and wildlife.

4B. Additional Riparian Revegetation and Aquatic Habitat Enhancement Projects

As part of the landowner workshops in action #2, information would be provided so that interested landowners can meet with the project manager and a riparian revegetation, barrier removal or wood placement project can be developed.

5. Development and Evaluation of Re-Operation Alternatives for Lake Curry

Lake Curry, the reservoir created by Gordon Valley Dam in 1926, has a surface area of 377 acres, and an original design volume of 10,700 acre feet. Given the area and volume, the mean depth is approximately 28 feet, with the original maximum depth likely to be around 100 feet. It is not known if sedimentation from the upper watershed has led to a decrease in the lake volume or depth.

In summer, surface water in the reservoir experiences elevated temperatures that are typically higher than in the streams that drain to the reservoir. If this heated surface water is subsequently discharged into Suisun Creek, it can raise stream temperatures, lower dissolved oxygen levels, and create water quality problems. Water temperatures measured in Lake Curry and Suisun Creek have indicated that the shallow depths of the upstream end of Lake Curry limit the size of the pool of cold water for releases into the creek. The outlet works for Lake Curry, which date from 1926, limit the ability to release cold water from the deeper area of the reservoir for fish and use warmer surface layers for water supply. Suisun Creek water temperature monitoring indicates that summer flows are marginal to too warm with releases of 2.0 and 3.0 cfs. A larger release may be required to reduce water temperatures by increasing the mass of water flowing in the creek. A greater volume of flow is able to absorb the heat from solar radiation and attenuate it and maintain cooler temperatures under current canopy cover and channel conditions. The low volume summer flow on Suisun Creek demonstrates little heat attenuation with water temperatures dropping little over a 24-hour period and thereby maintaining warm conditions.

Additionally, increasing the depth and capacity of Lake Curry needs to be evaluated to increase the available pool of cold water. A greater volume release is worth evaluating especially if the outlet works can be retrofitted to allow releases from the deepest area of the reservoir and increased storage capacity can create an adequate cold water pool.

Several features of the reservoir – its bathymetry, major upstream sediment sources, operational constraints and seasonal temperature variations in low, medium and high rainfall years need to be established. Data from this watershed assessment can then be used with a model to simulate a set of operational alternatives calibrated with the quantified data.

Prior to analyzing reservoir operations, a feasibility analysis of various project alternatives would be developed. The analysis would focus on the feasibility of implementing various physical and operational changes to Lake Curry. The feasibility analysis would identify opportunities and constraints for each element. The elements would include, but are not limited to: modifying the outlet works to provide for withdrawal of water from different depths in the reservoir, raising the dam to increase storage, modifying or replacing the spillway or outlet works to change the magnitude and frequency of flood flows, and dredging the reservoir to restore water storage capacity and increase the size of the cold water pool.

This analysis should produce a thorough evaluation of the potential for improving Lake Curry to assure a reliable water supply that minimizes environmental effects and actually benefits Suisun Creek. The use of a simulation model would quantify the improvement created by each alternative or combinations of alternatives, allow for a sound decision-making process by the City of Vallejo and the SCRT and result in a long-term sustainable outcome.

6. Monitoring and Adaptive Management Strategy

This task would provide quantitative measurements of sediment, channel form, water quality and water temperature at the stations and study reaches used in the watershed assessment as well as complete a more extensive morphological survey of

Suisun Creek. This monitoring information should be used to revise projects in the watershed program and direct additional actions to address limiting factors for aquatic and riparian habitats and steelhead trout survival.

I. INTRODUCTION

Suisun Creek watershed encompasses 53 square-miles of land in Napa and Solano County. The watershed has no incorporated cities; Fairfield is the closest urban area (see Figure 1). Located in the southeastern corner of Napa County and western edge of Solano County, the watershed has two major creeks – Wooden Valley and Suisun Creek (see Figure 2). These creeks drain a watershed of steep mountainous terrain and several large valleys into the Suisun Marsh, a major habitat area for waterfowl and other wildlife. Steelhead trout, a federally-listed threatened species have been found in both Wooden Valley and Suisun Creeks.

This plan was prepared by Laurel Marcus & Associates (LMA), a natural resources planning and restoration firm, under contract to the California Sportfishing Protection Alliance (CSPA). The Save the Suisun Creek Alliance, a group of landowners in the watershed interested in habitat restoration, requested the involvement of CSPA and LMA to assist them in their restoration efforts.

The Save the Suisun Creek Alliance also began meeting with the City of Vallejo, the owner of Lake Curry, the largest reservoir in the watershed. The City was seeking federal legislation in 2000 to allow water from Lake Curry to be moved in the federal Putah South Canal to a water treatment plant in the City. Previously, the City had a water treatment facility at Lake Curry, but changes in drinking water standards rendered this facility obsolete. Congressman George Miller, who sponsored the legislation, was also concerned with environmental issues such as the restoration of Suisun Creek and its anadromous fishery. Congressman Miller's staff, along with the staff of Congressman Mike Thompson's and State Senator Wes Chesbro began meeting with the City of Vallejo, the Save the Suisun Creek Alliance and the California Sportfishing Protection Alliance. These groups formed the Suisun Creek Restoration Team (SCRT) and agreed to work together to evaluate the feasibility of restoring the Suisun Creek and its watershed, while the City endeavored to resume use of Lake Curry for water supply. The groups adopted a "Statement of Intent to Provide Instream Flows to Suisun Creek" that established interim flows for the creek from Lake Curry to protect steelhead trout populations and wildlife that utilize the creek while studies were performed to assess the condition of the creek and the steps needed to restore its aquatic and riparian habitats. Bylaws to govern SCRT's operation were adopted on March 15, 2001. Additional members included the National Marine Fisheries Service, California Department of Fish and Game, Gordon Valley residents, Napa County Farm Bureau, Solano County Farm Bureau, Solano County Water Agency, Solano County Community College, and others (see Table 1). As the SCRT was becoming organized, LMA became involved in pursuing funds on behalf of the Save the Suisun Creek Alliance and CSPA to prepare an enhancement plan for the Suisun and Wooden Valley Creek watersheds.

LMA prepared a detailed scope of work for a watershed enhancement plan that was reviewed by the SCRT and submitted for funding to the San Francisco Bay Program of the California State Coastal Conservancy. Funding was approved in 2001 with the

Figure 1. Regional Location

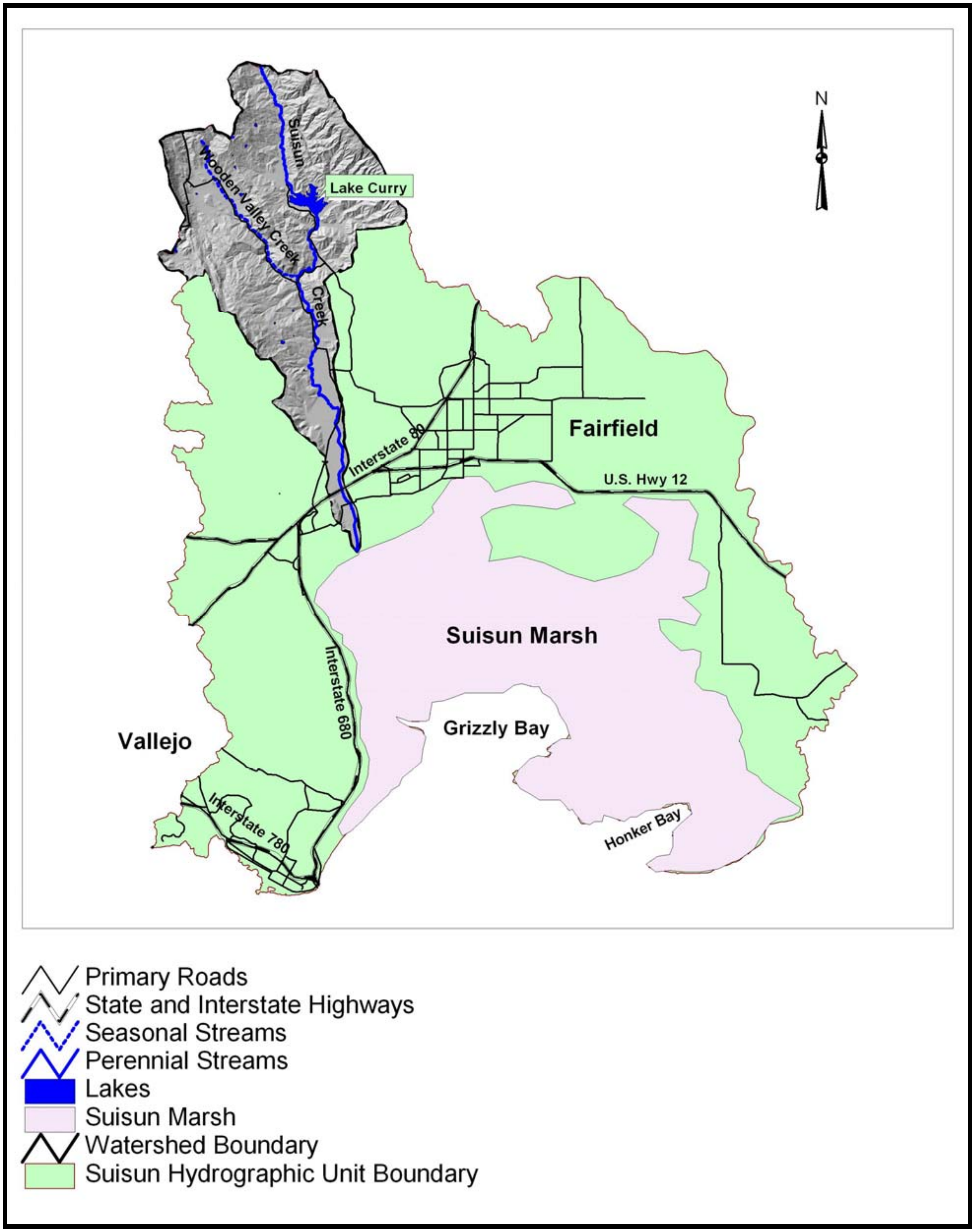


Figure 2. Suisun Creek Watershed

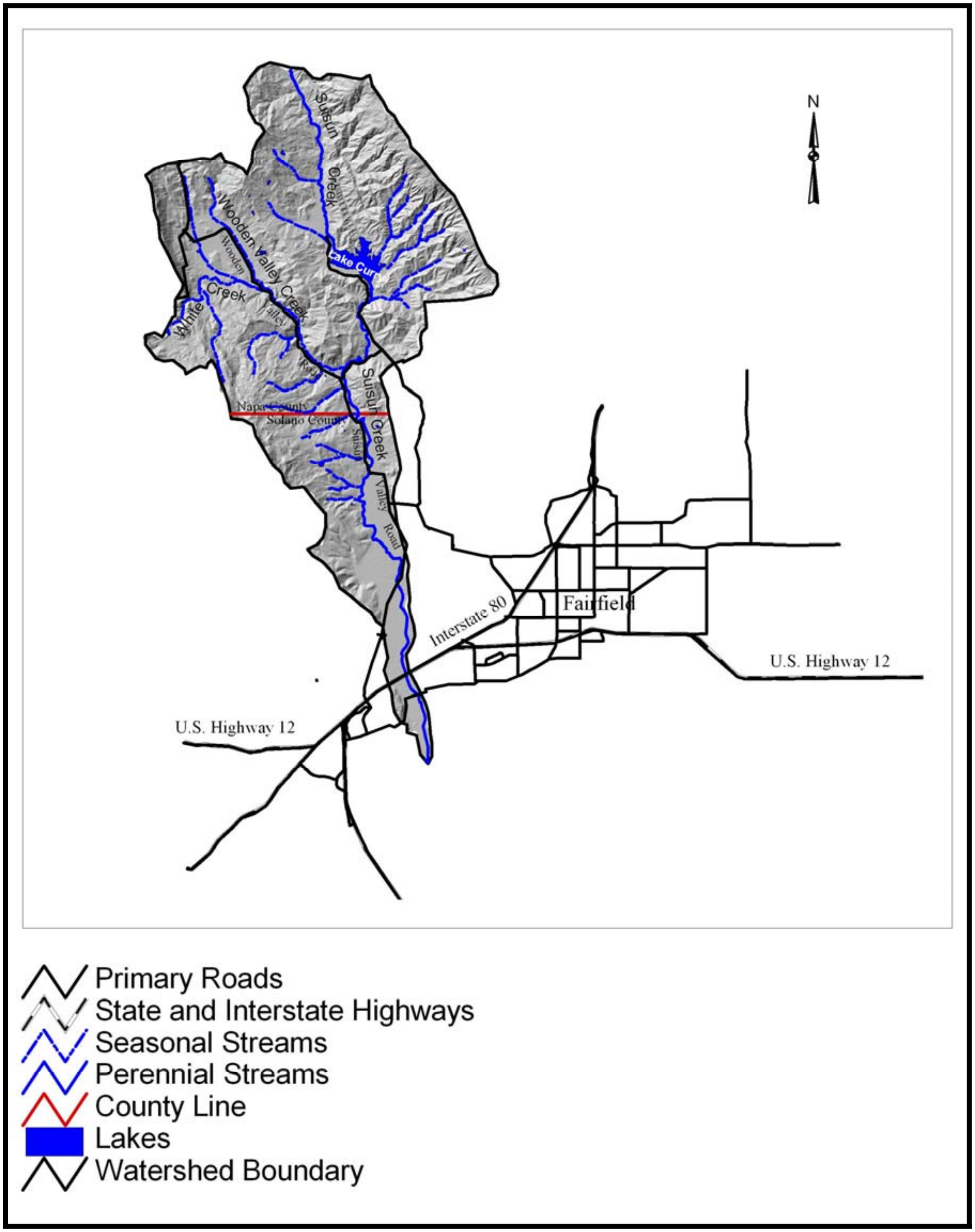


Table 1. The Suisun Creek Restoration Team (SCRT)	
George Ambrose	Solano County Farm Bureau
John Beuttler	California Sportfishing Protection Alliance
Dan & Marguerite Capp	Suisun Creek Alliance, landowners
Bill Cox	California Department of Fish & Game
Cheryl Diehm	Congressman Thompson
Ex Ganding, Mark Akaba	City of Vallejo
Anthony Grandison	Suisun Creek Watershed resident
Kathy Hoffman	Congressman Miller
Jim Leddy	Senator Chesbro
John Nogue	Solano Community College, Suisun Creek Alliance
Tom Pate	Solano County Water Agency
Rob Schroeder	US Bureau of Reclamation
Leigh Sharpe	Napa County Resource Conservation District
Gary Stern	National Marine Fisheries Service
Pat Ticher	Suisun Watershed resident
Bill Wolf	Napa County Farm Bureau
Roxanne Wolf	Suisun Creek Alliance, landowner

support of the SCRT members. LMA provided regular updates and information on the monitoring, data collection, community involvement and plan preparation.

As part of the overall SCRT effort, the City of Vallejo hired Hanson Environmental, Inc. in 2000 to complete a stream habitat survey for Suisun Creek only, stream water temperature monitoring and monitoring of Lake Curry water temperatures. These studies are summarized for this plan.

Scope of Watershed Plan

This plan includes various studies of the factors that affect and limit steelhead trout habitats and water quality in Suisun Creek watershed. Data was collected on in-stream habitat conditions, water flows, the size, extent and species diversity of the riparian corridor, water temperatures, water quality, siltation in the stream channel, sediment sources in the watershed, bank erosion, fish passage barriers and other features. In addition, the watershed was assessed for erosion sites, roads, vegetative cover, land use, soils, geology and other features. This assessment and data collection were used to formulate recommendations for restoring and sustaining conditions that support steelhead trout habitats. The methods used and results of the data collection and assessment are discussed in sections II and III.

The scope of the watershed plan includes the following tasks:

Task 1 Gather Existing Sources of Information
Task 2 Community and Landowner Involvement
Task 3 Evaluate Watershed Features and Determine Locations for Monitoring Sites and Surveys
Task 4 Watershed Assessment and Data Gathering
Task 5 Evaluate Monitoring and Survey Information, Identify Enhancement Needs and Activities and Prepare Enhancement Plan

The focus of the enhancement plan is restoration of steelhead trout habitat including the improvement of water quality. The enhancement plan does not address all issues in the watershed. Specifically, flood control issues and water rights issues are not evaluated.

Goals

The following set of goals were distributed in public meetings for the plan and discussed by SCRT. The recommendations of this plan incorporate and would implement these goals.

- Work cooperatively to enhance the Suisun Creek watershed to protect, enhance and sustain steelhead trout and other native wildlife, improve water quality, protect water supplies and protect and enhance current land uses;

- Provide a process to directly involve landowners, elected officials, environmental groups, government agencies, and local community interests in the enhancement of the Suisun Creek watershed;

- Respect private property rights by requesting access in writing for studies and by working with willing landowners on project implementation;

- The study and enhancement of Suisun Creek Watershed represents a pro-active approach to create incentives to restore and sustain endangered steelhead trout habitat and avoid the need for regulatory actions while fulfilling the purpose of regulatory mandates;

- Use the full range of watershed assessment and monitoring techniques to provide a science-based approach to long-term resource enhancement and revisions to land and water management practices.

II. ASSESSMENT AND MONITORING METHODS

A number of tasks were completed to collect information, measure and monitor features of the Suisun Creek watershed. A literature and internet search was completed for information on stream flows, rainfall, geology, soils, vegetation, land use and fish and wildlife specific to the Suisun Creek watershed.

Geographic Information System (GIS)

A Geographic Information System (GIS) was created for the Suisun Creek watershed. Digital ortho-photo quarter quadrangles (DOQQs) were acquired from the United States Geological Survey (USGS). Additional data layers depicting perennial and seasonal streams, major roads, major reservoirs and canals were imported from the California River Assessment of the UC Davis Information Center for the Environment (ICE), CalWater, a project of the California Department of Forestry and Fire Protection, and the State Water Resources Control Board.

A number of additional layers were created through evaluation of the aerial photographs, field data collection using global positioning system (GPS) coordinates and mapped features in other studies. These layers include:

- Major erosion sites and eroded soil areas
- Dirt roads
- Stream miles for the three major creeks
- Extent of riparian corridor

- Areas with little or no riparian corridor
- Seasonally dry streams
- Fish passage barriers recorded in stream surveys
- Location of monitoring and survey sites used in this plan
- Location of monitoring sites used by the Regional Water Quality Control Board
- Confined and unconfined channel reaches in Suisun and Wooden Valley Creeks
- Slope classes of Suisun and Wooden Valley Creeks

These layers were used to analyze and illustrate conditions and features in the watershed. The GIS evaluates the physical features of the watershed and drainage network and their effects on water temperature, fine sediment levels and riparian and in-stream habitats measured or monitored in the field.

Establishing Study Reaches

Monitoring and surveying were carried out in a number of locations. Two types of monitoring locations were established – point locations distributed over the creek system for water temperature and water quality monitoring and one study reach on each major tributary.

Locations for potential study reaches were determined from an analysis of channel slope, channel confinement, location and size of significant tributaries, a field check of channel conditions and requests for landowner access.

Channel conditions provide a practical way of assessing overall watershed conditions. The study reach serves as a location to complete monitoring of changes in channel form to evaluate trends in the creek that affect aquatic habitats. It would be too labor-intensive and difficult to acquire landowner access to monitor changes in the composition and form of the entire length of each of the two creeks frequently. Therefore, only short sections of the channel are defined as study reaches and monitored (Harrelson et al 1994, Washington Forest Practice Board 1997).

Wooden Valley and Suisun Creek were evaluated in detail for potential study reach locations. A stream reach is defined as a segment of channel that demonstrates similar features throughout its length. For the study reach to provide information on changes in sediment levels in the watershed, the stream reach must be a type of channel that readily responds to changes in sediment load. Potential study reaches must be low slope, unconfined creek channels without excessive alteration or significant tributaries in locations where landowners will grant long-term access.

USGS topographic maps of the watershed (Capell Valley Quadrangle – 1968, Mt. Vaca Quadrangle – 1968, Mt. George Quadrangle – 1973, Fairfield North Quadrangle – 1980, and Fairfield South Quadrangle – 1980) were used to evaluate channel slope. Channel slope is a measure of how the channel drops over a horizontal distance. Contour lines on the topographic map are lines of constant elevation; each point along a single contour line has the same elevation. The distance between contour lines was measured along each creek to document the approximate slope of the stream channel. The stream segments were then separated into slope classes of >20%, 8-20%, 4-8%, 2-4% 1-2%, 1% and <1% (Figures 16-19).

The two creeks were also evaluated for confinement. Three types of confinement were used. The creek was indicated as confined if the valley width, including the channel, is less than two channel widths. It is partially confined if the valley width is two to four channel widths. A channel is unconfined if the valley width is greater than four channel widths. Channel confinement can only be approximated from a topographic map and must be confirmed in the field (see Figure 20).

Significant tributaries to Suisun Creek and Wooden Valley Creek were also identified. A tributary is significant if the watershed area of the tributary is greater than or equal to ten percent of the watershed area on the main creek upstream of the tributary. Areas of the creek that are low slope and unconfined, but immediately downstream or upstream of the confluence with a significant tributary are removed from consideration as study reaches. Figures 3-6 illustrate potential study reaches as determined by slope class, confinement and location of significant tributaries. While there are a number of potential study reaches on Suisun Creek, Wooden Valley Creek has only two areas – in Wooden Valley or in the lower mile of Wooden Valley Creek.

Following this analysis, the potential study reaches were field checked. The field visit confirmed the analyses and reviewed the level of alteration or disturbance. Highly disturbed channel areas would not accurately reflect watershed conditions, but more likely reflect local disturbance.

After the field check, the number of potential study reaches (PSR) was narrowed down based on their suitability. Landowners along the remaining reaches were identified from assessor parcel maps. Letters and access requests were then mailed out in order to gain permission to access the creek for data collection. Two study reaches were established – Wooden Valley PSR 1 and Suisun Creek PSR 6 (see Figure 5 and 6) with ten year access agreements with the owners.

Channel Surveys

Each study reach was evaluated to determine the bankfull channel width and then the length of the study reach was established at ten bankfull widths. The bankfull channel was identified using methods described in Leopold and Miller 1964 and Harrelson et al 1994. Detailed surveys were completed in each study reach. A series of six channel cross sections were monumented and marked in the field with rebar. GPS coordinates were recorded for the locations of each cross section and detailed descriptions completed in field notebooks to allow for identification by future researchers. Cross sections are established in the study reach separated at distances of approximately two bankfull channel widths. The cross sections are

Figure 3. Potential Study Reaches (PSR) of Lower Suisun Creek

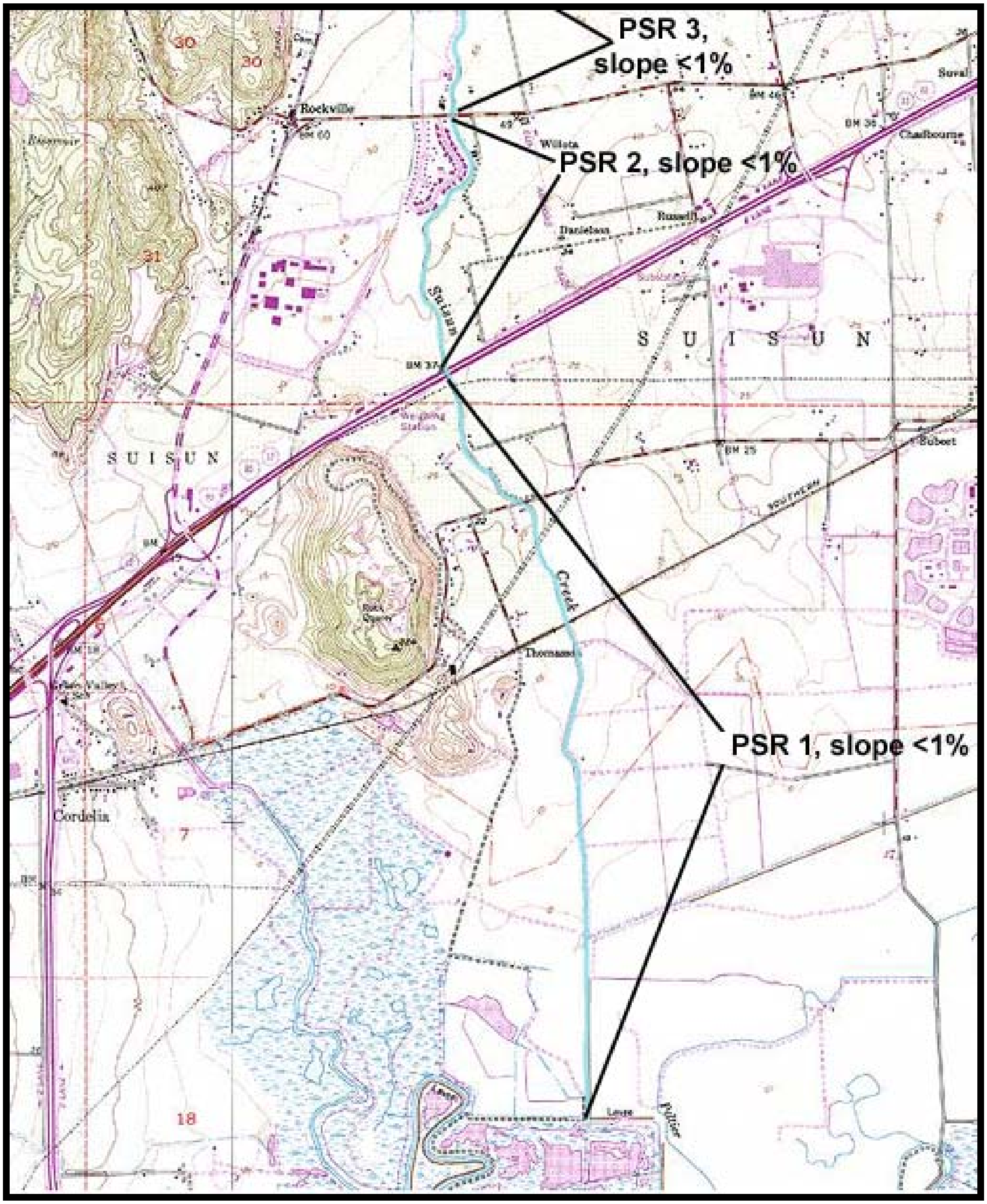


Figure 4. Potential Study Reaches (PSR) of Middle Suisun Creek

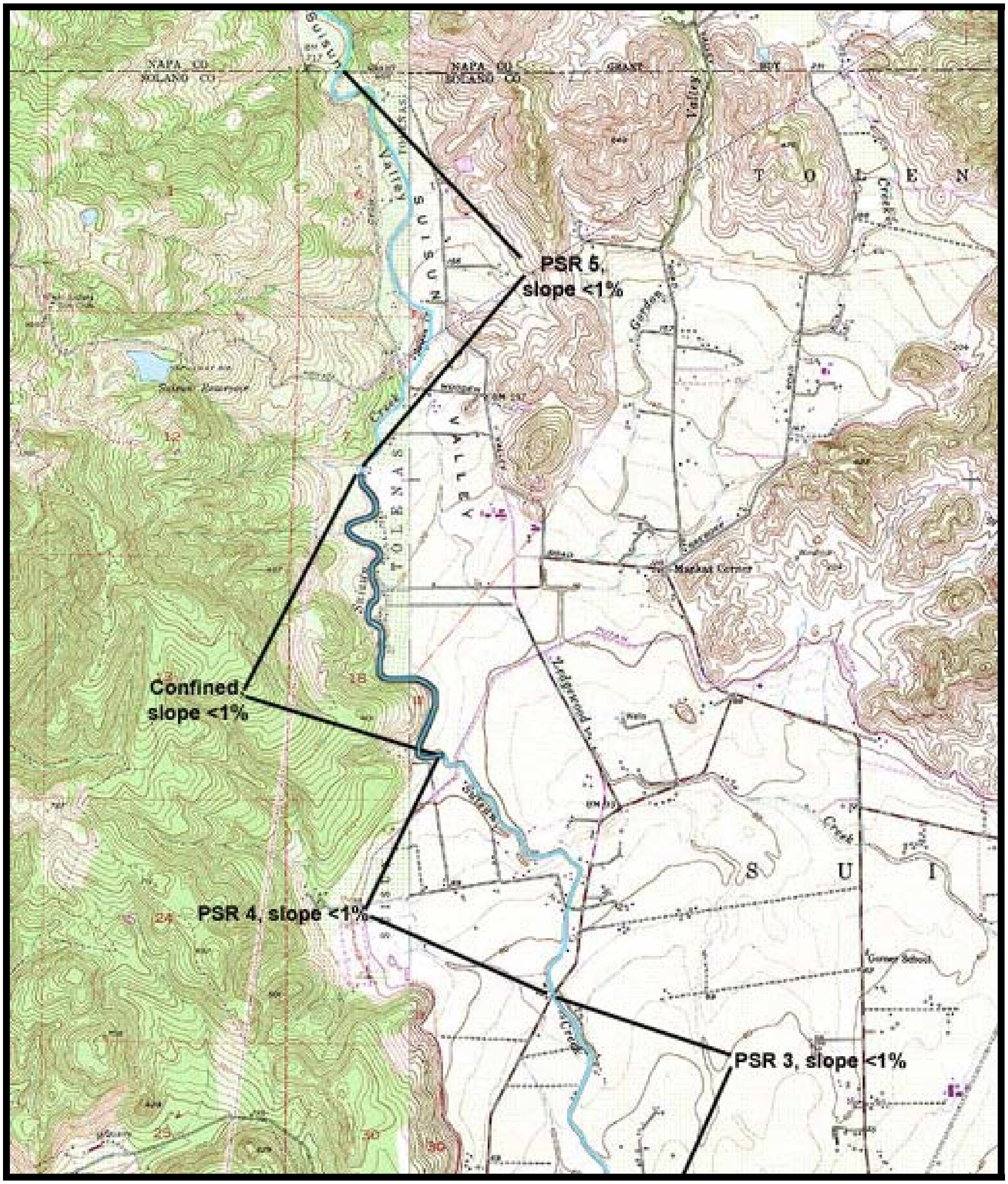


Figure 5. Potential Study Reaches (PSR) of Upper Suisun Creek

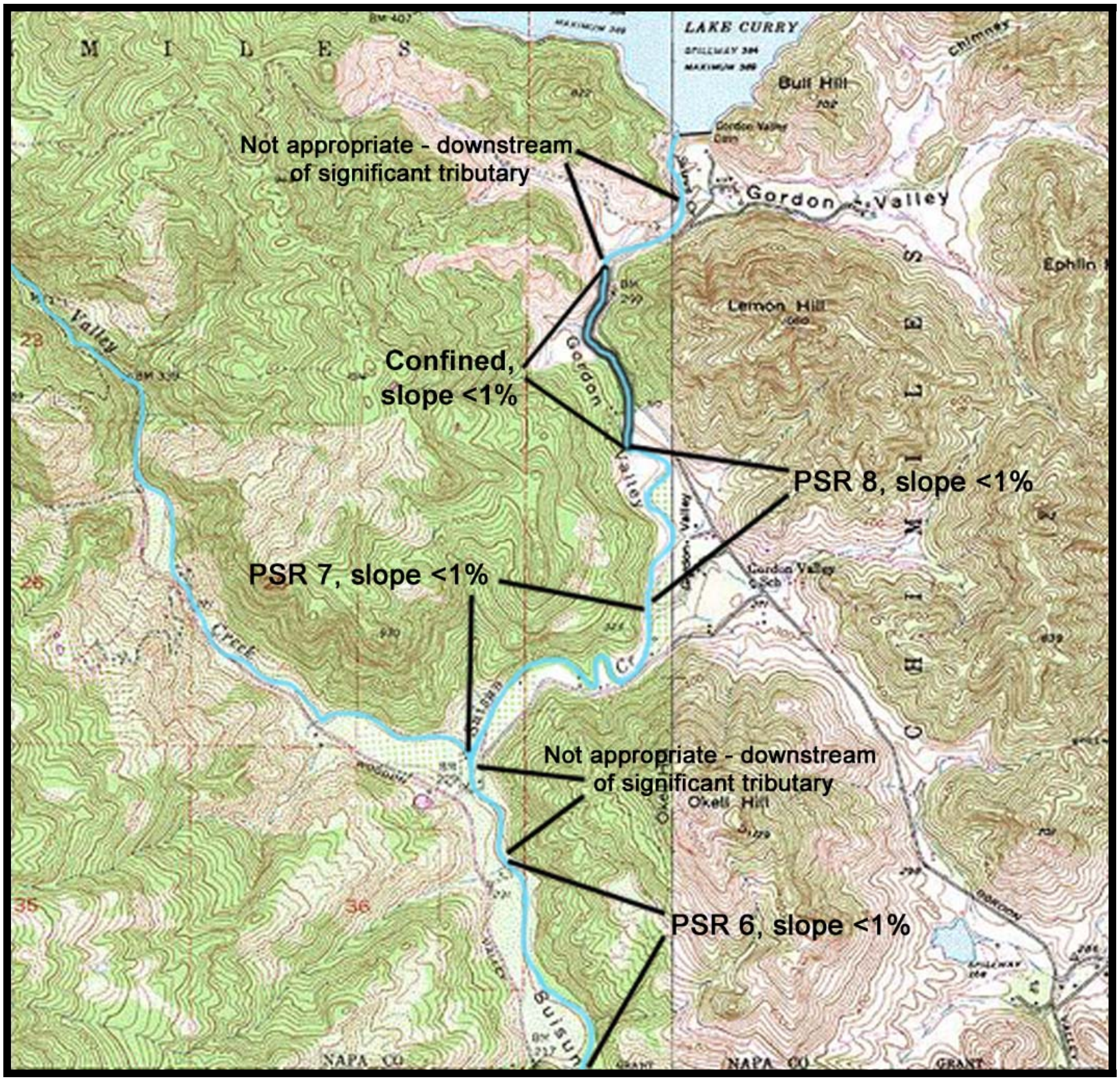
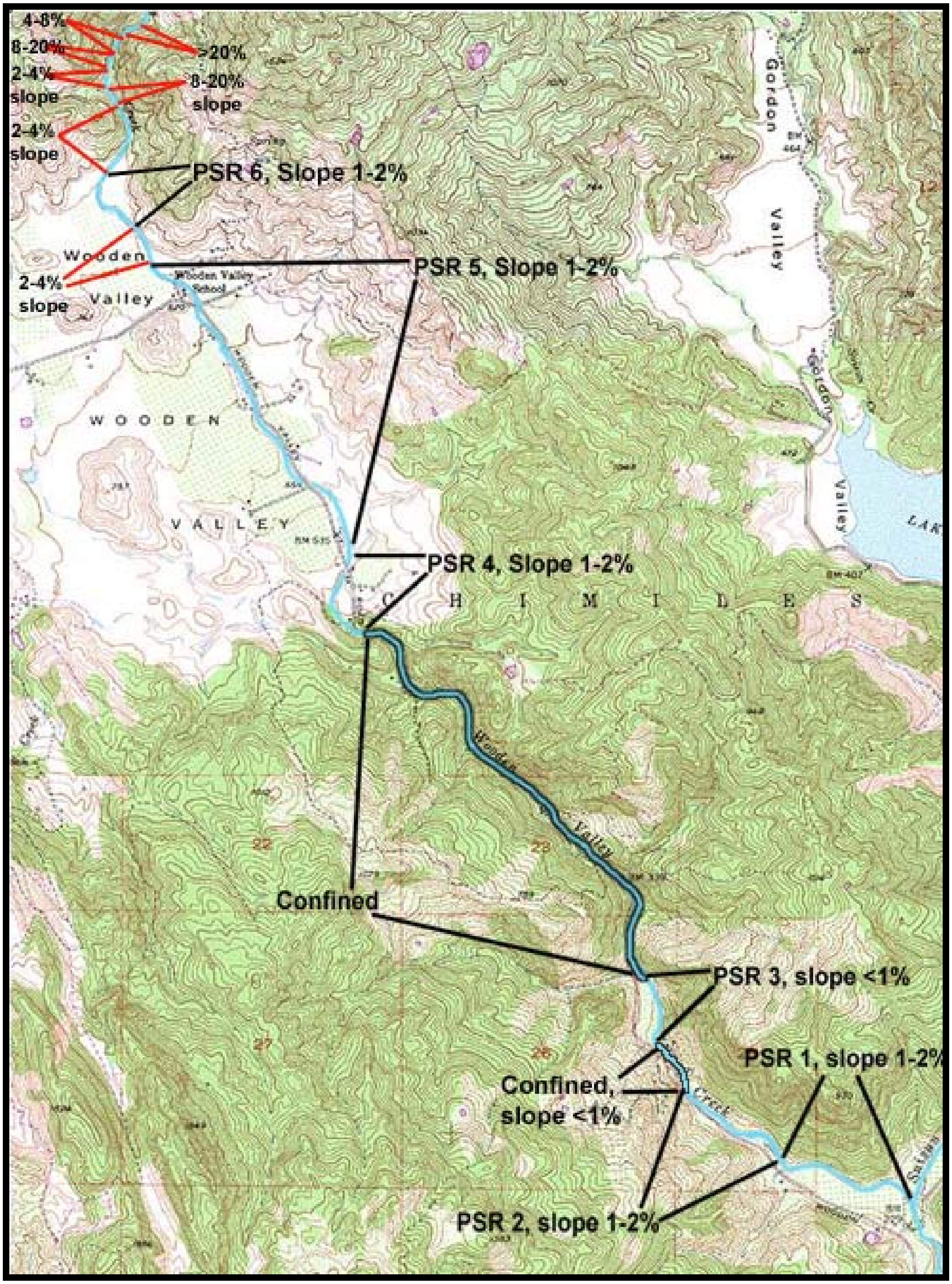


Figure 6. Potential Study Reaches (PSR) of Wooden Valley Creek



surveyed to document small topographical changes in the stream bed. A longitudinal profile of the study reach was also surveyed.

Surveys were completed in 2001 and 2002 on the Wooden Valley Creek study reach and in 2001, 2002 and 2003 on the Suisun Creek study reach. These surveys were completed to a standard of no greater error than 0.05 feet in elevation and 0.2 feet in horizontal distance.

Water Quality and Water Temperature

Point location stations used in previous (2000-2001) monitoring studies and a number of new sites were established and reflect a broad geographic distribution of locations in Suisun, Wooden Valley and White Creeks. Landowner access agreements were completed for these sites. A total of twenty–one stations were established for water temperature monitoring. Ten stations were on Wooden Valley and White Creeks and eleven were on Suisun Creek downstream of Lake Curry. Twelve stations on Suisun, Wooden Valley and White Creeks were used for water quality monitoring (see Figure 7).

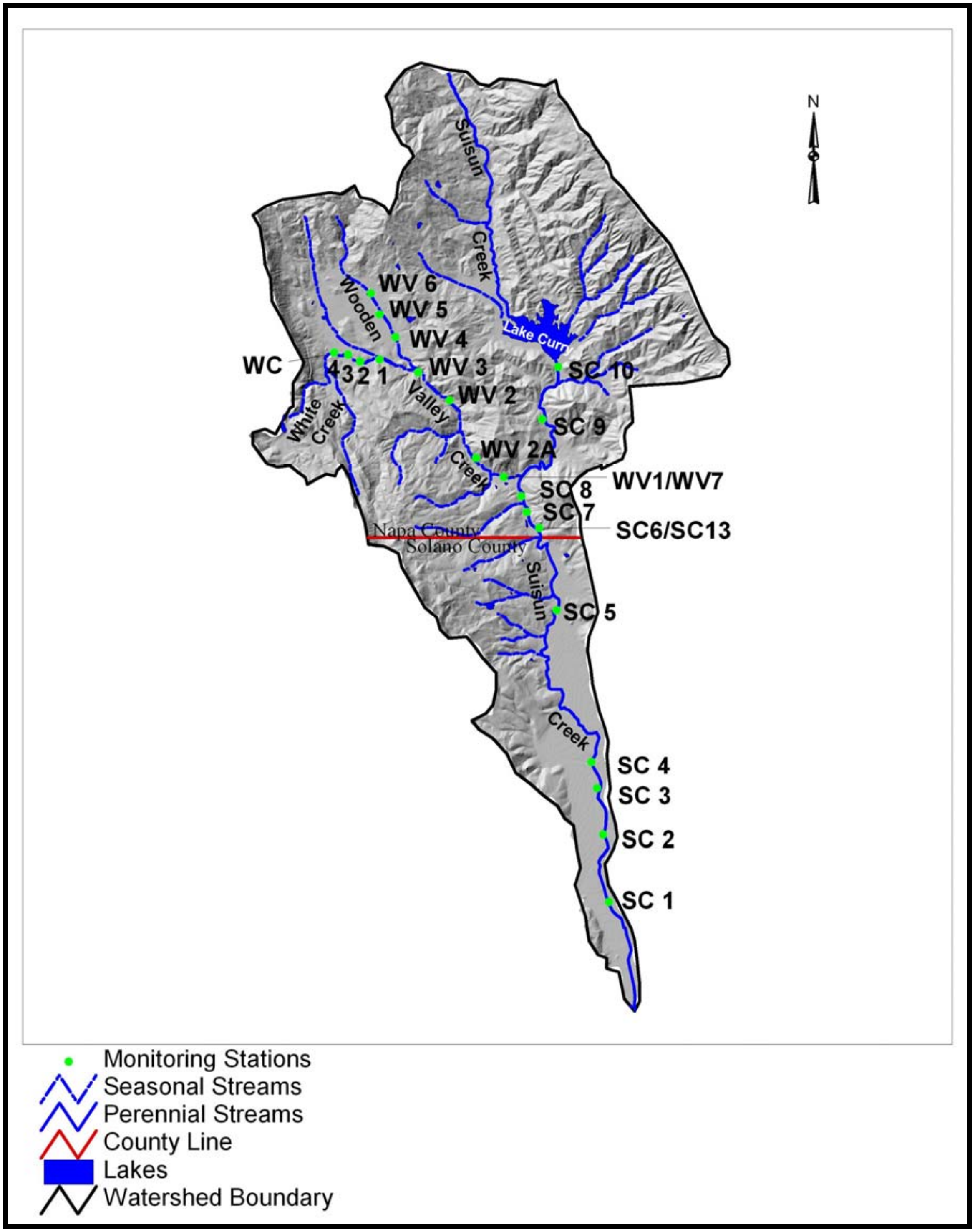
From September 2000 – August 2001, Hanson Environmental, Inc. conducted water temperature monitoring at ten sites on Suisun Creek and one site on Wooden Valley Creek. Many of these stations were also used in 2002 and 2003 along with three additional sites on Suisun Creek and eleven stations on Wooden Valley and White Creeks. Water temperatures were monitored from May/June to the end of October/beginning of November to collect data on the period of stressful conditions for aquatic life.

Temperature monitoring was completed following the Stream Temperature Protocol of the Forest Science Project, Humboldt State University. Each data logger (Hobo temp H-08, manufactured by Onset Computer Corporation) was calibrated prior to use, in accordance with this protocol, using a NIST traceable thermometer in both a room temperature bath and an ice water bath. All data loggers performed within the manufacturer's specified accuracy range and protocol requirements.

Deployment of the data loggers was completed in June in 2002 and May in 2003. The data loggers were placed in the stream at locations representative of summer conditions. In most cases, the data logger was placed at a deep point in the channel to assure submersion as water levels decline over the summer months. Field notes were kept of instrument number, station, a map and description of conditions.

Instruments were downloaded and re-launched using a Hobo shuttle several times during the monitoring period. Field notes on the condition of each station and any changes in instrument location or other features were recorded. Photographs of each station were taken at initial launch, every download and end of season removal to document conditions. Vandalism, such as removal of the instrument from the water, was noted and indicated on data readouts.

Figure 7. Temperature and Water Quality Monitoring Stations used in 2002 and 2003



Canopy cover was measured at each station using a spherical densiometer. Four measurements facing opposite directions in a circle were made every three feet on a transect across the creek where the instrument was deployed. Canopy conditions upstream and downstream were also documented. The width and depth of the wetted channel at each station was recorded.

Summer flow measurements were not done in Wooden Valley or White Creek as most stations have isolated pool areas rather than measurable streamflow. The amount of the reservoir release in Suisun Creek was documented.

Water temperature data, once downloaded into the Hobo shuttle, were transferred into the BoxCar 4.0 program and then Excel program for analysis. Water temperatures at all sites were recorded in 30-minute intervals continuously. Water quality data were collected at twelve stations on a monthly basis for the June to October period. Dissolved oxygen, temperature, ammonia, nitrate, phosphate and pH were monitored in the year 2002. Dissolved oxygen and temperature were also monitored using a YSI 550a meter in 2003. Water quality data for Suisun Creek and Wooden Valley Creek were requested from the San Francisco Regional Water Quality Control Board Surface Water Ambient Monitoring Program. Water quality data collected by Hanson Environmental, Inc. for Suisun Creek was collected and summarized.

Sediment Measurement

Pebble count and embeddedness measurements were completed in the two study reaches in 2002. A pebble count was performed at three different cross sections in each study reach. A modified-Wolman technique was used (Wolman 1954). These measurements indicate the amount of fine sediment surrounding the gravel and cobble of the streambed. The dominant size of material on the streambed in the study reach is also evaluated.

The V-star protocol (Lisle 1992) was used to measure residual pool volume at two locations in Suisun Creek. The portions of Wooden Valley and White Creeks where access was available were not appropriate for use of this protocol. V-star is a method for measuring the percentage of fine sediment filling pools. Additional and more widespread monitoring using V-star is recommended for Suisun Creek in Section IV.

Stream Habitats

A stream habitat survey was completed for Wooden Valley and White Creeks following the methodology established by the California Department of Fish and Game (1998). The stream survey of Suisun Creek completed by Hanson Environmental, Inc. in 2001 using a modified version of the Fish and Game protocol was reviewed and summarized. This methodology involves walking along the creek channel from downstream to upstream during the summer and recording the length and type of habitat unit including frequency of pools, riffles, glides, and other stream morphology features, water flow, canopy cover, presence of large wood, undercut banks, boulders or other elements of fish habitat (shelter). Qualitative estimates of sediment levels on the stream bottom are made and the location of potential passage barriers, bank conditions, water temperatures at the time of the survey and other features are recorded. The stream survey ends when the dry point in the channel is reached. Landowner access is required to complete the stream survey and those areas where access was not received were not evaluated. In addition to the stream surveys, a literature search for records and reports of steelhead trout presence in Suisun Creek and its tributaries was completed.

Riparian plant transects and habitat evaluations were completed in several locations. The extent of invasive *Arundo* in the riparian corridor could not be digitized from the available digital aerials. The extent of riparian forest was digitized from 2001 aerial photographs at a 1" = 2000' scale into the GIS and was field checked in as many locations as access allowed. The extent of the riparian forest along the main creeks and on the floodplain and areas of both high and medium density vegetation were mapped. Only areas with no vegetation were indicated separately.

In addition, at each temperature monitoring station, riparian vegetation, the presence of invasive plant species, bank heights and channel conditions were noted over the 2001-2003 period.

III. ASSESSMENT OF THE SUISUN CREEK WATERSHED

Watershed Processes and Aquatic and Steelhead Trout Habitats

Steelhead trout (*Oncorhynchus mykiss*) are anadromous cold water fish. The species uses two very different environments – the ocean and freshwater rivers and creeks. Unlike most fish species that live in either salt or freshwater throughout their life, salmon and steelhead use both. During the freshwater component of their lifecycle, the fish require gravel bed streams with low levels of fine sediment, cold water (less than 60-65°F) and very good water quality. As adults migrate to find spawning areas, they need adequate flows of cold water for the large fish to swim upstream, and cover and complexity in the stream, such as large wood as resting areas and waiting areas during floods. The adult fish also need to be able to gain access to spawning areas and not be blocked by barriers. Steelhead use the streambed as a nest for their eggs to develop. The conditions in the creek must support the growth and development of the eggs with cold clean water and moderate-sized gravel with little to no fines (less than 20% is optimal). The eggs stay in the spaces between the gravel rocks nurtured by cold, oxygen-filled water. As the young emerge, they seek shelter and protection behind logs and stumps, undercut banks, rocks and tree roots. The small fish eat aquatic insects and bits of food and dead insects carried on the current. Over the summer, the creek must retain a pool of cold water with enough oxygen and food to support the fish until the next rainy season. Steelhead trout juveniles will spend 1-4 years in the freshwater system. The species gains an advantage by having their young emerge and develop in an environment with fewer predators than the ocean. But the freshwater creek also has fewer food resources. When the young steelhead leave the creek on their journey to the ocean, they turn silver and their body's physiology will shift from a freshwater to a saltwater adapted system. When they reach the ocean, the fish are one to several years old and six or more inches long. Their larger size gives them an advantage and the ocean provides abundant food sources for the steelhead juveniles to reach adult size.

For this anadromous life cycle to be fulfilled successfully, the freshwater environment must support all steps in their lifecycle - in-migration and spawning of adults, egg incubation and emergence of young, juvenile rearing over the hot summer months and out-migration by juveniles.

The freshwater environment, particularly aquatic and riparian (streamside) habitats are created and sustained by watershed processes. For example, spawning habitat requires deposits of gravel within the creek. Gravel is deposited, moved and sifted by flood events and changes in the natural form of the creek, its meanders and banks. The gravel needs air and water spaces and to be relatively free of fine silt, often a product of excessive erosion in the watershed. If the creek receives few flood events due to reservoirs, or has been straightened and managed as an urban creek, the spawning habitat is compromised or non-existent. Similarly, if erosion from roads and gullies is too great, spawning may occur, but the eggs are smothered with silt.

Similarly, rearing habitat requires adequate cold groundwater to support the small fish. The shade of dense riparian tree cover, deep pools, and cold groundwater help to keep the water below 65ºF when summer air temperatures exceed 100ºF. Groundwater availability is a function of the watershed's ability to infiltrate and store rainfall, the geology of the drainage, the condition of the creek, and the extent and timing of water diversion and storage.

Each watershed and its network of creeks is a complex system that moves water and sediment from hilltop to ocean or bay. Each watershed is a unique combination of features such as geology, vegetation, topography, soil types, climate, the stream network, land development and management and historic land uses. The condition of a creek at any one time is the result of the interaction of these features over both the short-term period such as the last winter flood, as well as the long-term period, such as the last ice age or geologic epoch. The ability of a creek to support aquatic life results from natural and man-made watershed conditions and processes, as well as whatever direct management is practiced on the creek, its vegetation and floodplain.

This section describes many of the features of the Suisun Creek watershed and data collected on creek conditions, habitats and water quality.

Figure 8. Coho Salmon and Steelhead Trout Life Cycle

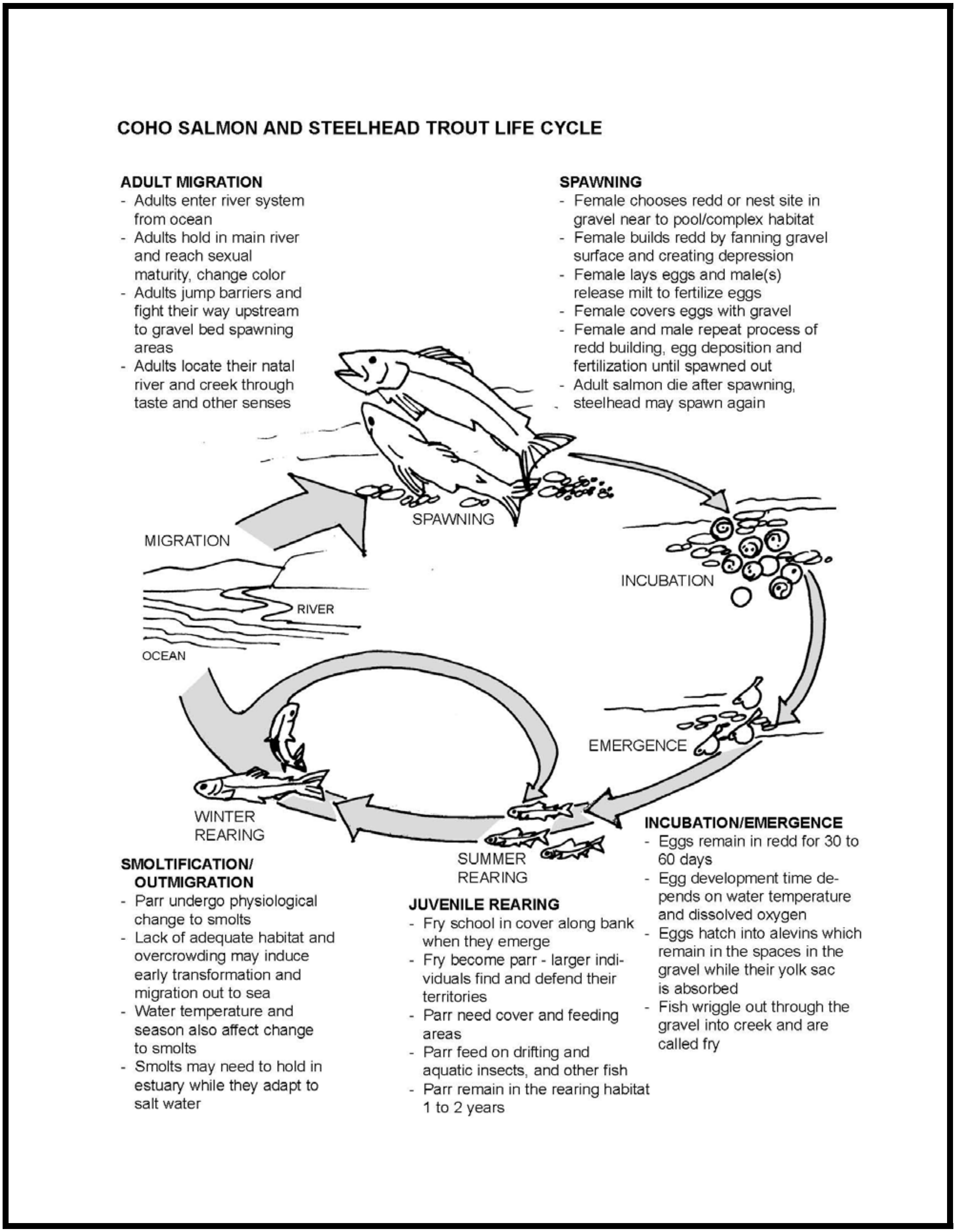
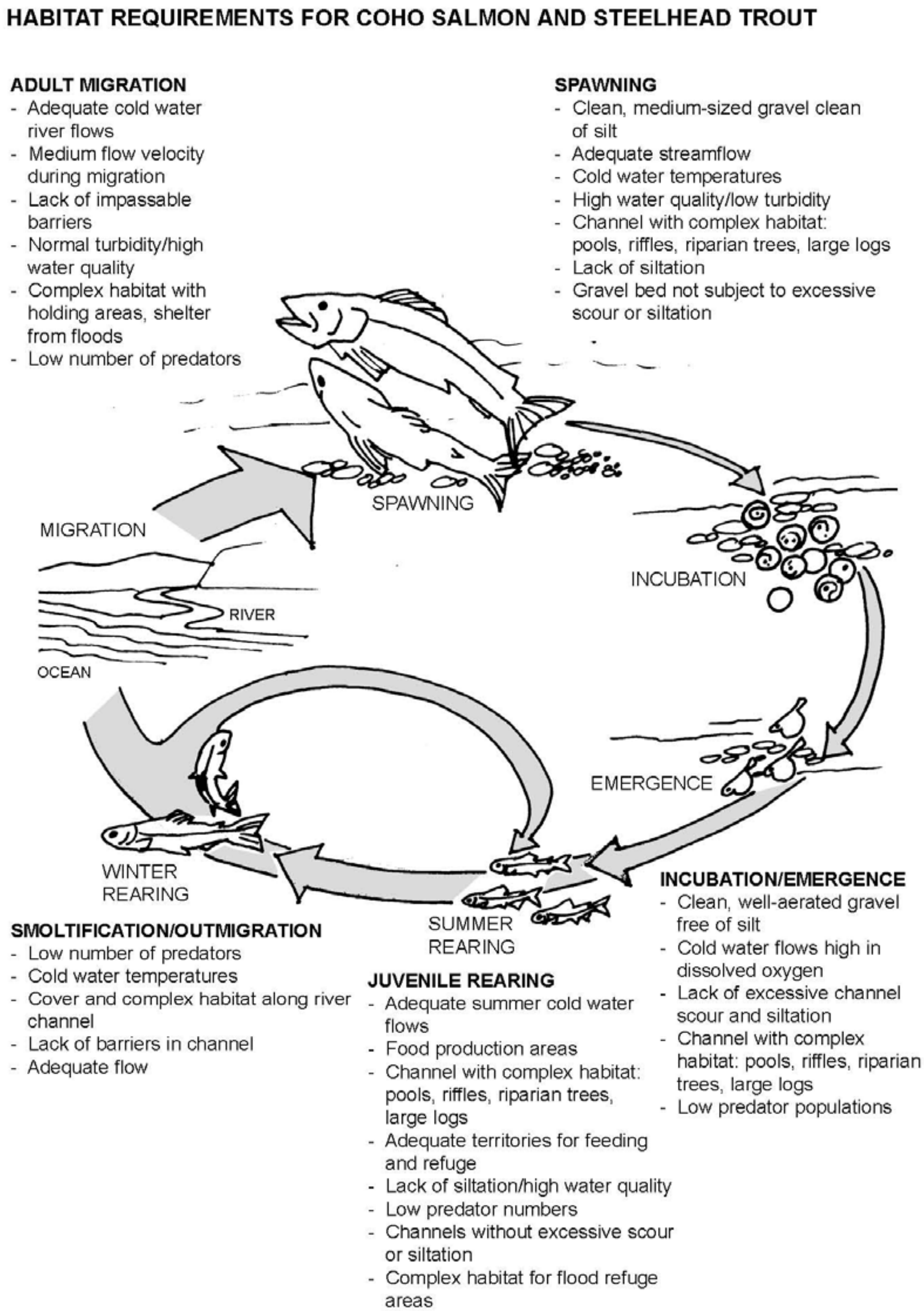


Figure 9. Habitat Requirements for Coho Salmon and Steelhead Trout



Geology

Geologic studies and maps were collected from the California Department of Mines and Geology (renamed California Geologic Survey in 2003) and the USGS. The primary source of information is the 1 to 100,000 scale Santa Rosa geologic map. No focused geologic studies or maps were found for the watershed. While the 1 to 100,000 scale map is general, it does provide information about geologic formations and faults in the Suisun Creek watershed (see Figure 10).

Three major geologic formations occur in the Suisun Creek watershed: the Sonoma Volcanics, the Great Valley Sequence and serpentinized ultramatic rock (see Figure 10). The Sonoma Volcanic formation dominates the Wooden Valley Creek subbasin and the western portion of the Suisun Creek subbasin. The Sonoma Volcanic formation includes andesite, rhyolite, tuff and basalt and dates from the Pliocene 5 before present when a volcanic field 350 square miles stretched from Fairfield to Novato to Santa Rosa.

Two types of Great Valley Sequence formation (Lower Cretaceous, 135 million before present and Lower Cretaceous - Upper Jurassic, 150 million before present) make up much of the Suisun Creek Subbasin. Great Valley Sequence is made up of marine mudstone, sandstone, siltstone and conglomerate formed through deposition on the bottom of a shallow sea and subsequent uplift through tectonic processes. Great Valley Sequence often appears as a series of distinct layers of material tilted sideways.

A third formation, serpentized ultramatic rock, or serpentine, occurs in a small outcrop in the northern portion of the Wooden Valley Creek subbasin. Serpentine occurs in much larger amounts north of the Suisun Creek watershed and is typically found along faults in the California Coastal Ranges.

In addition to these three rock formations, there are extensive landslide deposits that dominate the western hills of Suisun Valley and Wooden Valley and some areas upstream of Lake Curry. Alluvium (unconsolidated sand, gravel and silt) fills the valley floor of Wooden Valley and Suisun Valley. The most downstream area of the watershed in Suisun Marsh has intertidal deposits of mud and sand.

The Green Valley Fault extends along the western side of the watershed and the Wragg Canyon Fault extends along the eastern side of the watershed. These faults are part of the Cordelia Fault Zone, a portion of the San Andreas Fault system of the northern California Coastal Ranges.

Figure 10. Outline of the Suisun Creek Watershed on California Division of Mines and Geology 1:100,000 Santa Rosa Geologic Map

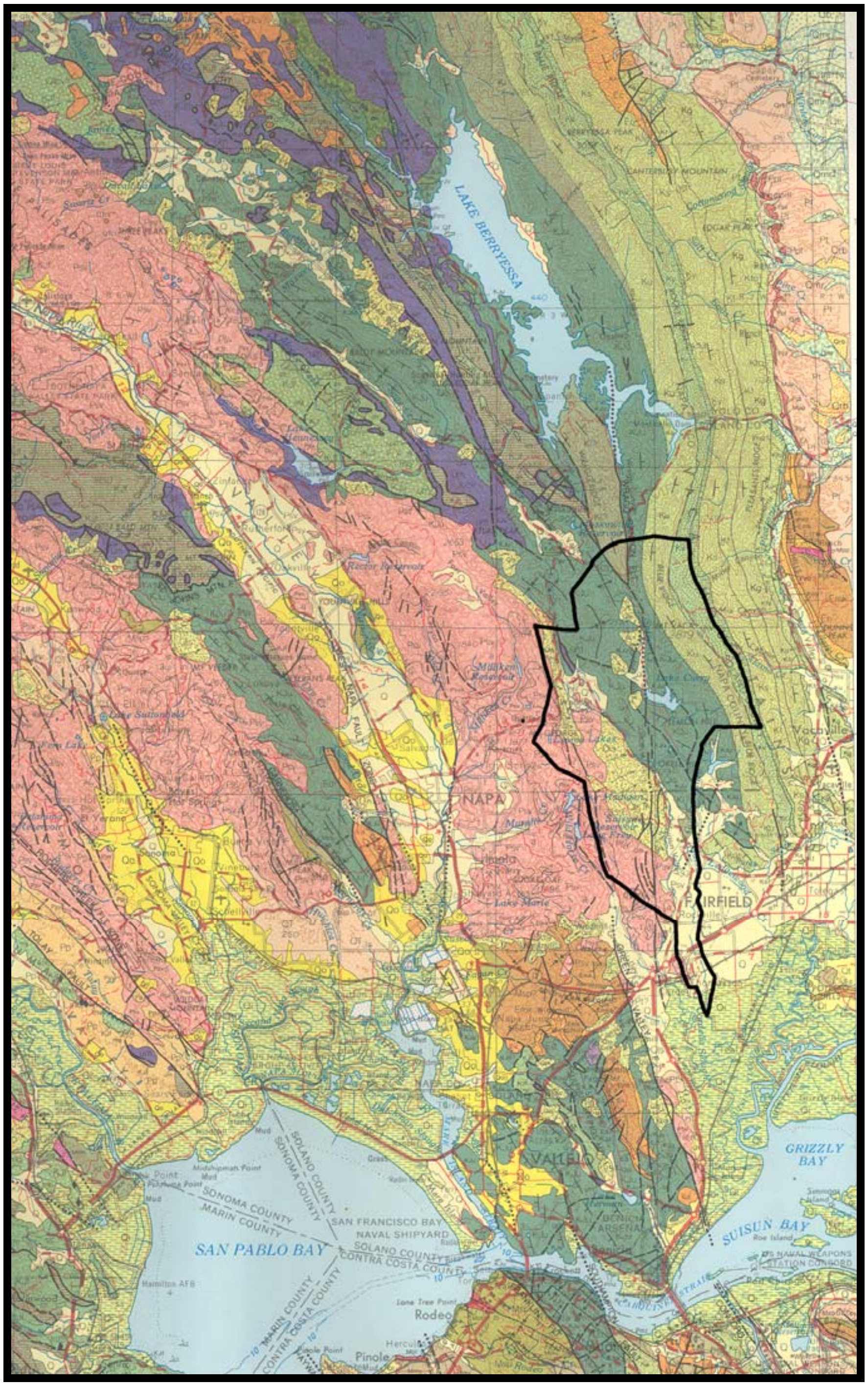
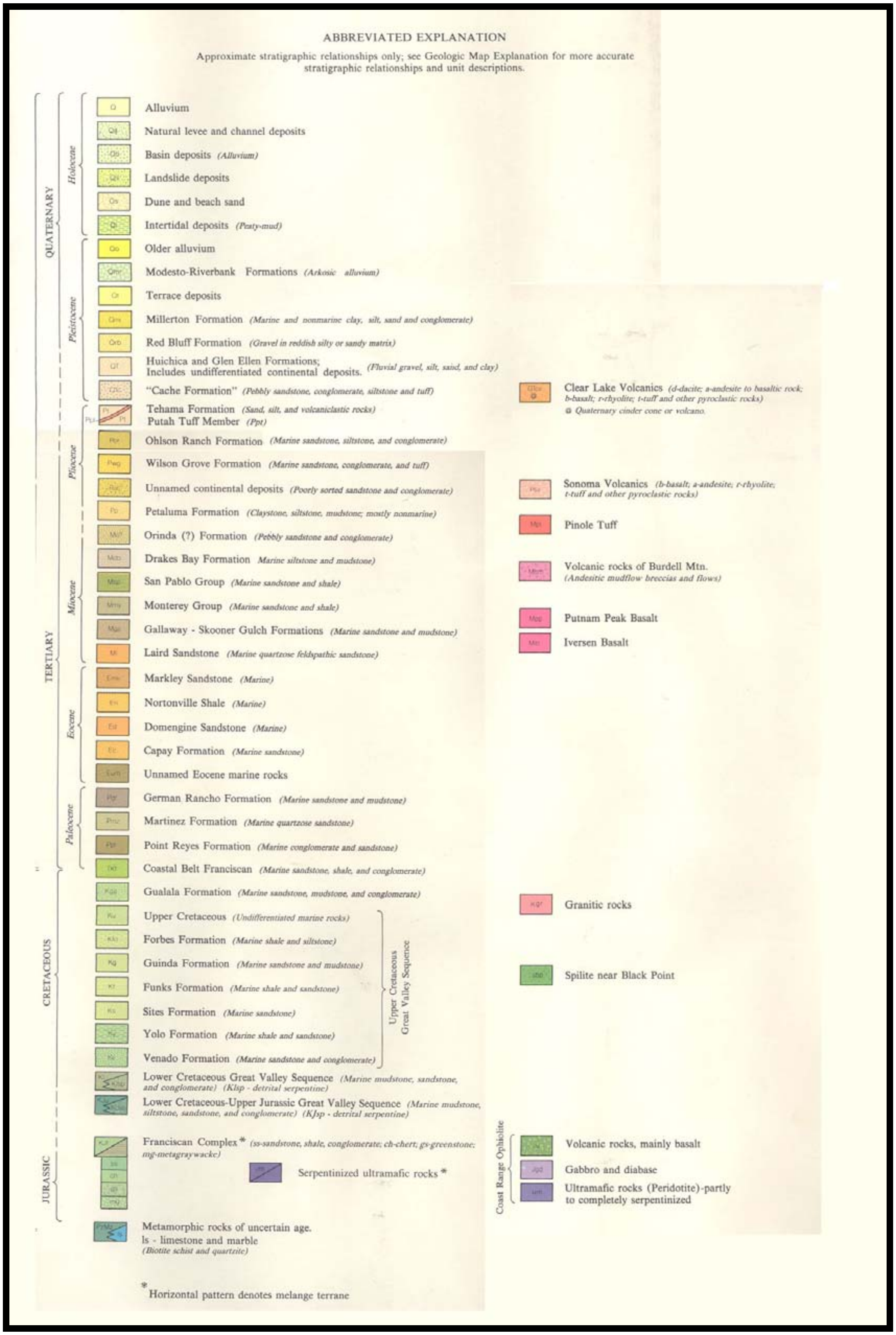


Figure 10. Legend for Geologic Map



Assessment: Geology

The geologic make up of the watershed gives an indication of the particular features occurring in each subbasin. The Sonoma Volcanic formation is likely to have springs and more abundant summer groundwater than the denser sedimentary Great Valley Sequence formation. Wooden Valley Creek and its tributary, White Creek, likely have cold groundwater in the summer months for salmonid rearing. Suisun Creek may also have springs, but this subbasin overall is likely to have less summer groundwater than the Wooden Valley subbasin under natural conditions. Additionally, alluvial valleys are often groundwater basins and the alluvial sections of Wooden Valley Creek and Suisun Creek may have cold summer rearing habitat for salmonids. Another general observation is the large area of landslide deposits dissected with faults along the western side of Suisun Creek watershed and upstream of Lake Curry. This area is likely to be erosion prone and a source of fine sediment.

Soils

Information on soil types in the Suisun Creek watershed was collected from the Napa County Soil Survey (1978) and Solano County Soil Survey (1977), prepared by the US Department of Agriculture. Both soil surveys depict soil types on 1:20,000 scale aerial photographs. Table 2 lists the soil types found in the Suisun Creek watershed. Many soils have only a minor occurrence, but several soil types are dominant in the hilly areas of the watershed. The soil classifications also include general slope classes and therefore indicate the predominant slope classes of the watershed. The majority of the northern portion of the Suisun Creek subbasin and Wooden Valley Creek subbasin consists of Bressa-Dibble complex of the 15 to 30% slope class and 30 to 50% slope class. These soils are formed from weathered sandstone and shale and have a severe erosion hazard in areas over 30% slope. Oak woodland or oak savannah grows on Bressa soils

Maymen-Los Gatos complex soils in the 50-75% slope class make up a significant portion of the eastern side of the Suisun Creek subbasin. This soil also formed from weathered sandstone and shale and typically supports chaparral scrub vegetation.

The south and eastern portion of the Wooden Valley Creek subbasin is dominated by Sobrante loam in the 30-50% slope class. These areas are typically used for livestock grazing.

Hambright loam in the 15-40% slope class dominates the western hills of the Suisun Creek subbasin. This soil is underlain by volcanic rock and is found in mountainous areas.

Areas of “eroded soil” indicated in the soil surveys were digitized as a layer in the GIS. Hillslope areas on the aerial photographs with obvious erosion features such as gullies were digitized on the GIS.

Table 2. Soil Types Found in the Suisun Creek Watershed.						
Upper Watershed – Napa County						
Degree of Occurrence	**Soil Code**	**Soil Type**	**Slope Class (%)**	**Runoff**	**Erosion Hazard**	**Land Use**
Minor	104	Bale clay loam	0-2 %	Slow	Slight	Vineyards
Minor	105	Bale clay loam	2-5 %	Slow	Slight	Vineyards
Minor	107	Boomer loam	2-15%	Medium	Slight	Timber, recreation, and watershed
Minor	108	Boomer gravelly loam	15-30%	Rapid	Moderate	Timber and watershed
Minor	112	Bressa-Dibble complex	5-15%	Medium	Slight	Range and vineyards
Minor	113	Bressa-Dibble complex	15-30%	Medium	Slight-Moderate	Grazing, homesites and recreation
Major	114	Bressa-Dibble complex	30-50%	Rapid	Moderate-Severe	Grazing
Minor	116	Clear Lake clay, drained	0-2%	Slow-Very slow	Little to None	Pasture and vineyards
Minor	117	Clear Lake clay, overwashed	0-2%	Slow-Very slow	Little to None	Irrigated pasture and vineyards
Minor	118	Cole silt loam	0-2%	Very slow	Little to None	Vineyards, orchards and irrigated pasture
Minor	119	Cole silt loam	2-5%	Slow-Very slow	Little to None	Vineyards, orchards and irrigated pasture
Minor	127	Diablo clay	9-15%	Medium	Moderate	Range and pasture
Minor	132	Fagan clay loam	15-30%	Rapid	Moderate	Range, pasture and dryland grain
Minor	133	Fagan clay loam	30-50%	Rapid	High	Range and watershed
Minor	138	Forward gravelly loam	2-9%	Medium	Slight	Timber production, vineyards, orchards, wildlife habitat and watershed
Minor	139	Forward gravelly loam	9-30%	Medium	Slight-Moderate	limited timber production, wildlife habitat, and watershed
Minor	140	Forward gravelly loam	30-75%	Rapid	High-Very High	Timber, recreation, wildlife habitat and watershed
Minor	146	Haire loam	2-9%	Slow-Medium	Slight	Grazing and vineyard
Minor	151	Hambright-Rock outcrop complex	2-30%	Medium-Rapid	Slight-Moderate	Wildlife habitat, watershed and grazing
Minor	152	Hambright-Rock outcrop complex	30-75%	Rapid-Very rapid	High	Wildlife habitat, recreation, watershed and grazing
Minor	154	Henneke gravelly loam	30-75%	Rapid-Very rapid	Moderate-High	Wildlife habitat, recreation, watershed and grazing
Minor	156	Kidd loam	30-75%	Rapid-Very rapid	High-Very high	Wildlife habitat, recreation and watershed
Minor	161	Maxwell clay	2-9%	Slow	Slight	Range and pasture
Major	162	Maymen-Los Gatos complex	50-75%	Rapid-very rapid	High-Very high	Range, wildlife habitat, watershed and recreation
Minor	166	Montara clay loam	5-30	Rapid	Moderate	Range, wildlife habitat and watershed
Minor	169	Perkins gravelly loam	5-9%	Medium	Slight	Vineyards and orchards

Table 2. Soil Types Found in the Suisun Creek Watershed (cont.)						
Upper Watershed – Napa County (cont.)						
Degree of Occurrence	**Soil Code**	**Soil Type**	**Slope Class (%)**	**Runoff**	**Erosion Hazard**	**Land Use**
Minor	171	Pleasanton loam	2-5%	Slow	Slight	Pasture and vineyards
Minor	175	Rock outcrop	N/A	Rapid	High	Watershed, wildlife habitat and recreation
Minor	178	Sobrante loam	5-30	Medium	Slight-Moderate	Range and orchards
Major	179	Sobrante loam	30-50%	Rapid	Moderate-High	Range and watershed
Minor	181	Yolo loam	0-2%	Slow	Slight	Vineyards, orchards and pasture
Minor	182	Yolo loam	2-5%	Slow	Slight	Vineyards, orchards and pasture
Lower Watershed – Solano County						
Degree of Occurrence	**Soil Code**	**Soil Type**	**Slope Class (%)**	**Runoff**	**Erosion Hazard**	**Land Use**
Minor	An	Alviso silty clay loam	Nearly level	Very slow	Slight	Saltgrass pasture, irrigated pasture, and dryfarmed barley
Minor	AoA	Antioch-SanYsidro complex	0-2%	Very slow	Slight	Sugar beets, irrigated pasture, grain sorghum, dryfarmed small grain, pasture, wildlife habitat, and recreation
Minor	BrA	Brentwood clay loam	0-2%	Very slow	Slight	Irrigated orchard, row crops, forage crops, dryfarmed grain, wildlife habitat, recreation, and urban development
Minor	CeA	Clear Lake Clay	0-2%	Very slow	None	Irrigated row crops, field crops, irrigated pasture, dryfarmed grain, wildlife habitat, and recreation
Minor	Cn	Conejo loam	Nearly level	Slow	None	Orchards, vineyards, urban development, wildlife habitat, and recreation
Minor	Co	Conejo gravelly loam	Nearly level	Slow	Slight	Orchards, vineyards, urban development, wildlife habitat, and recreation
Minor	DbE	Dibble-Los Osos loams	9-30%	Medium	Moderate	Dryfarmed small grain, dryland pasture, range, wildlife habitat, recreation
Minor	DlE	Dibble-Los Osos clay loams	9-30%	Medium	Moderate	Dryfarmed small grain, dryfarmed pasture, range, wildlife habitat, recreation
Minor	DlF2	Dibble-Los Osos clay loams, eroded	30-50%	Rapid	High	Range, wildlife habitat, recreation, and watershed
Minor	GlE	Gilroy Loam	9-30%	Medium	Moderate	Pasture, range, wildlife habitat, and recreation
Major	HaF	Hambright loam	15-40%	Medium to rapid	High	Range, wildlife habitat, and recreation
Minor	HtE	Hambright-Toomes stoney loam	9-30%	Medium	High	Range, wildlife habitat, recreation, and watershed

Table 2. Soil Types Found in the Suisun Creek Watershed (cont.)						
Lower Watershed – Solano County (cont.)						
Degree of Occurrence	**Soil Code**	**Soil Type**	**Slope Class (%)**	**Runoff**	**Erosion Hazard**	**Land Use**
Minor	Pc	Pescadero clay loam	Nearly level	Very slow	Slight	Native pasture, irrigated pasture, wildlife habitat, and recreation
Minor	Ra	Reiff fine sandy loam	Nearly level	Very slow to slow	Slight	Orchards, irrigated row crops, forage crops, dryfarmed small grain, wildlife habitat, and recreation
Minor	Re	Reyes silty clay	Nearly level	Ponded	Slight	Wildlife habitat, recreation, pastured
Minor	Sr	Sycamore silty clay loam	Nearly level	Slow	Slight	Irrigated orchards, row crops, dryfarmed small grain, wildlife habitat, and recreation
Minor	Ss	Sycamore silty clay loam, drained	Nearly level	Slow	Slight	Irrigated orchards, row crops, dryfarmed small grain, wildlife habitat, and recreation
Minor	St	Sycamore silty clay loam, saline	Nearly level	Slow	Slight	Dryfarmed small grain, irrigated and dryfarmed pasture, wildlife habitat, and recreation
Minor	ToG2	Toomes stoney loam, eroded	30-75%	Rapid to very rapid	Very high	Wildlife habitat, recreation, and watershed
Minor	TrE	Trimmer loam	9-30%	Medium	Moderate	Pasture, range, wildlife habitat, recreation, and watershed
Minor	Ys	Yolo silty clay loam	Nearly level	Slow	Slight	Orchards, irrigated row crops, forage crops, dryfarmed small grains, urban development, wildlife habitat, and recreation

Assessment: Soils:

The soil surveys for the watershed indicate that the predominant soil types are Bressa-Dibble complex in the 15 to 30% and 30 to 50% slope classes, Maymen-Los Gatos complex in the 50-75% slope classes, Sobrante loam in the 30-50% slope classes and Hambright loam in the 15-40% slope class. These soil types are generally high slope, have erosion ratings of high or greater and have runoff rates of rapid to very rapid. These soil types in the mountainous areas of the watershed create conditions for excessive erosion in disturbed areas or along road cuts. The dominant soil types of the mountainous areas of the drainage also have limited agricultural uses. The fertile soils of the valley floor and creek floodplains are relatively flat, highly variable in type with low erosion hazard ratings. The valley supports a variety of agricultural uses.

Hydrology and Geomorphology

Background

Hydrology and geomorphology are a critical part of a watershed assessment. Hydrology includes the study of water from rainfall to moving through the watershed and the stream network to the drainage outlet. Flood size and frequency are often the focus of hydrologic studies. For aquatic habitat evaluations both hydrology and fluvial geomorphology are needed. Fluvial geomorphology includes how water movement through the watershed's stream network changes the form of the network through the erosion, transport and deposition of sediment. Aquatic habitat and many other features of creeks are highly affected by both the volume and frequency of flood flows and the volume and type of sediment load.

Different parts of the watershed play different roles in the generation, movement and storage of stormflow and sediment. Storms tend to release more rainfall in the taller mountains of the drainage. These steep mountains are also the main sites for the generation of sediment into the stream system through erosion and landslides. The creeks in these mountainous areas will be steep and prone to debris flows and other rapid movements of water and sediment. Steep creek channels often have very large rocks and boulders with cascades or small, closely spaced pools. Sediment may consist of large boulders, cobbles, gravel, as well as fine material such as silt and clay particles and transport processes dominate depositional processes.

In the valley, streams have a low slope. This area of the watershed has streams that both store sediment and transport it and have a well-defined floodplain. Stormflows slow down and spread out on the floodplain. Stream channels are likely to have glides, bars, pools and riffles. Rather than being dominated by large rock and boulders as in the steeper channels, cobble and gravel armour the stream bed of the valley streams. The meandering stream in the valley is typical of this area. When low slope streams receive large inputs of sediment from the watershed, it may take many years for transport processes to move it out. These processes as well as land use and management of the various types of creek channels has a large effect on their condition and ability to support aquatic habitat.

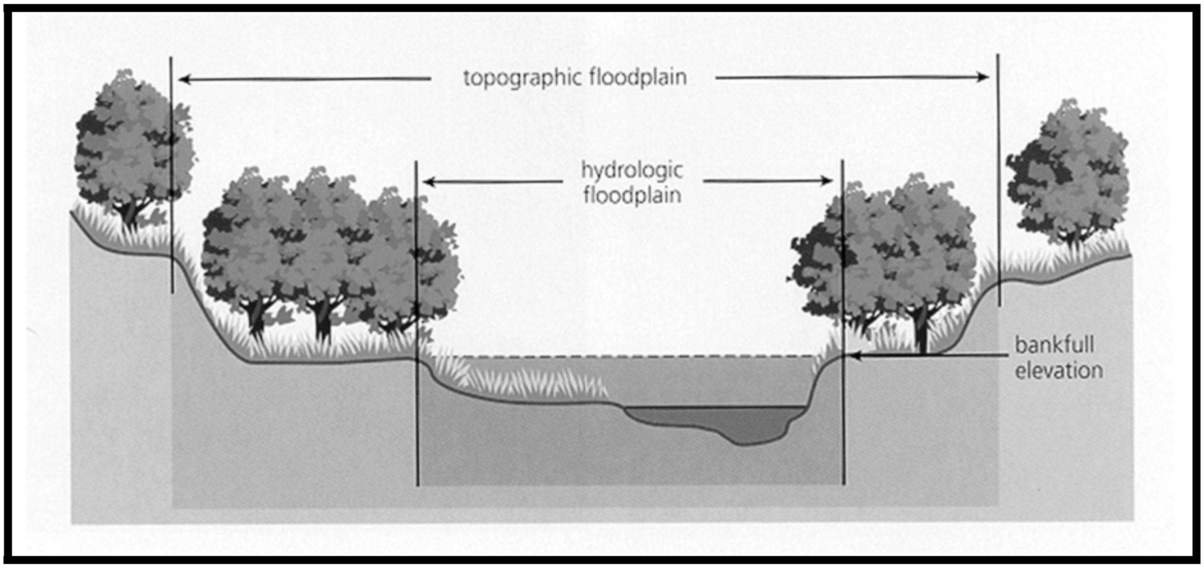
In the study of stream channels, certain concepts have been established that are particularly relevant to aquatic and riparian habitats. Creek channels tend to be much smaller then the largest flood. This is because the large 100-year frequency flood is relatively uncommon and the small two-year frequency flood is very common. The two-year flood has enough power to scour and deposit sediment in the creek channel and occurs often (Leopold 1994). In general, the two-year flood, also termed the dominant discharge, has the greatest effect on the size of the creek's scour or active channel, also called the bankfull channel (see Figure 11). Adjacent to and slightly above the creek channel is the floodplain where larger floodflows spill out and slow down. The floodplain is an important part of the stream system and is where larger floods are accommodated. It is also the location where streamside or riparian vegetation grows and provides shade to the creek.

The network of streams in the watershed moves both water and sediment. The processes involved are complex and dynamic. Stream channels change and adjust during floods to balance out the discharge, or volume of floodwater, with the sediment load. These adjustments include changes in the width and depth of the flow, the velocity or speed of the water, the roughness of the channel (amount of sediment or vegetation in the channel), and the slope of the water surface. These adjustments occur during floods and are largely unobservable until the flood is over and the changes are apparent. In some cases, measurements of various features of the creek or watershed are needed to document changes in the system and can be used as a tool to predict how a certain creek may adjust and change and what habitats it may have. In the bankfull channel, the adjustments that occur during floods form pools, riffles, bars and undercut the large wood needed for salmonid habitat.

Another important concept of stream morphology is dynamic equilibrium (Leopold 1994). As floods and sediment loads of various sizes are delivered into the stream, the size and shape of the channel adjusts through the processes of erosion and deposition. A large flood may cause great changes to the creek channel, but through subsequent smaller floods and adjustments, these changes are diminished. The creek's size and shape will vary over time within a range of conditions termed dynamic equilibrium (see Figure 12). Because every creek is constantly adjusting its form, improvements to "fix" its form are often short-lived.

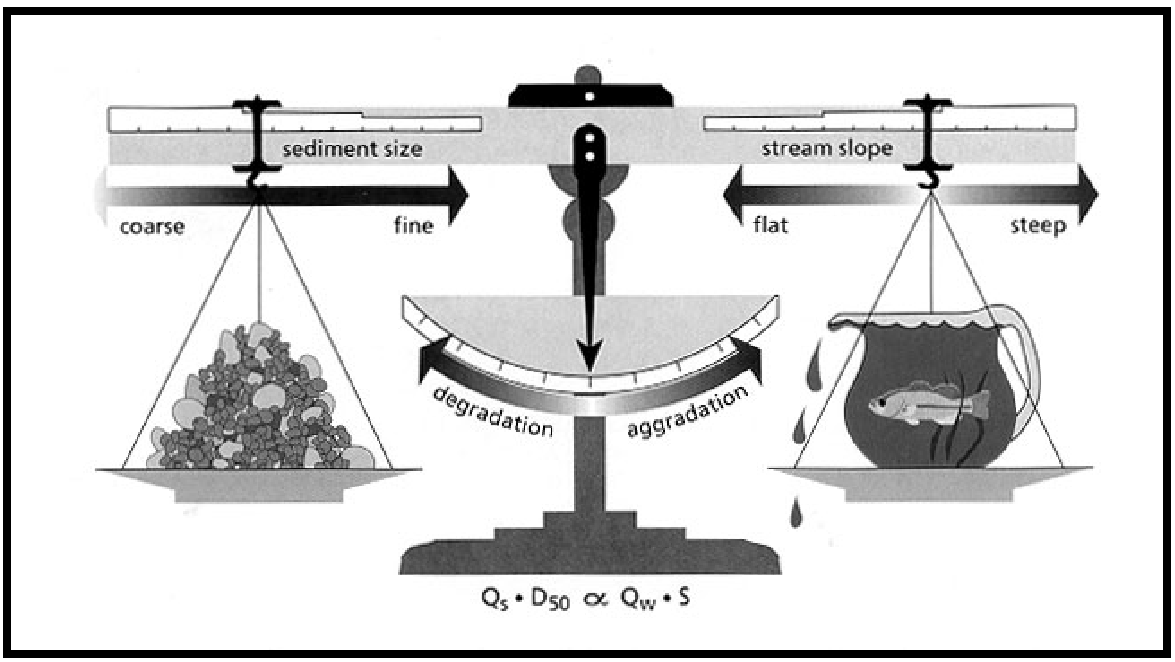
For this plan, information on rainfall, streamflow and floods was collected; the GIS was used to measure and evaluate a variety of features of the stream system; a variety of observations on the stream channel were collected during the field work, and two study reaches and several stations were established for channel surveys, v-star and pebble counts/embeddedness measurements.

Figure 11. Diagram of Bankfull Channel and Floodplain



From US Department of Agriculture, 1998.

Figure 12. Diagram of Dynamic Equilibrium Concept for Streams



From US Department of Agriculture, 1998

Rainfall

Located on the edge of the San Francisco Bay Area and the Central Valley, the Suisun Creek watershed has a Mediterranean climate with rainfall concentrated from October to April and little to no rainfall from May to September. Rainfall data are collected at Lake Curry. Regional rainfall data are also available from the National Oceanic and Atmospheric Administration's (NOAA) National Climatic Data Center website.

The Lake Curry records show the mean annual precipitation as 28 inches. NOAA rainfall maps indicate the 100-year frequency, 24-hour duration rainfall event is 7.5 to 8.0 inches and the 100-year frequency, 6-hour duration rainfall event is 3.5 to 4.0 inches.

Stream Network

The Suisun Creek watershed has two distinct tributaries – Wooden Valley Creek and Suisun Creek. Wooden Valley Creek extends approximately 7.0 miles from its origins 1.5 miles north of Wooden Valley to its confluence with Suisun Creek. The Wooden Valley subbasin encompasses 14 square miles. There are a number of tributary creeks that drain the steep mountain surrounding Wooden Valley and conduct flow into Wooden Valley Creek. White Creek, the longest of these tributaries, drains the largely undeveloped Wild Horse Valley Ranch on the southwestern side of Wooden Valley.

The headwaters of Suisun Creek are located to the north of Lake Curry in the mountainous northeastern portion of the watershed. Lake Curry is the only large reservoir in the watershed and covers 377 acres. Suisun Creek stretches 4.9 miles from its headwaters to its confluence with Lake Curry. From the Lake Curry outlet, Suisun Creek stretches 11.5 miles to Interstate 80, and a total of 14.5 miles to Suisun Marsh. Figure 13 delineates stream miles for each creek.

One way of evaluating the stream system is the period of time a creek carries water. On a topographic map, only the intermittent and year round creeks are indicated. This delineation is based on the conditions when the map was made and may not reflect the current conditions in the creek. Figure 14 illustrates the "blue line" creeks for a portion of the Wooden Valley subbasin along with the network of ephemeral creeks that only carry stormflow in storms. This entire network of creeks conducts water and sediment during large storms. Ephemeral creeks often drain steep hillsides and disturbance of the hillside or the creek can result in slides and erosion.

Channel Slope

Another aspect of stream channels is the channel slope. Channel slope is a measure of how far the channel drops over a horizontal distance. Streams with approximately

Figure 13. Suisun Creek Watershed with Stream Miles Indicated

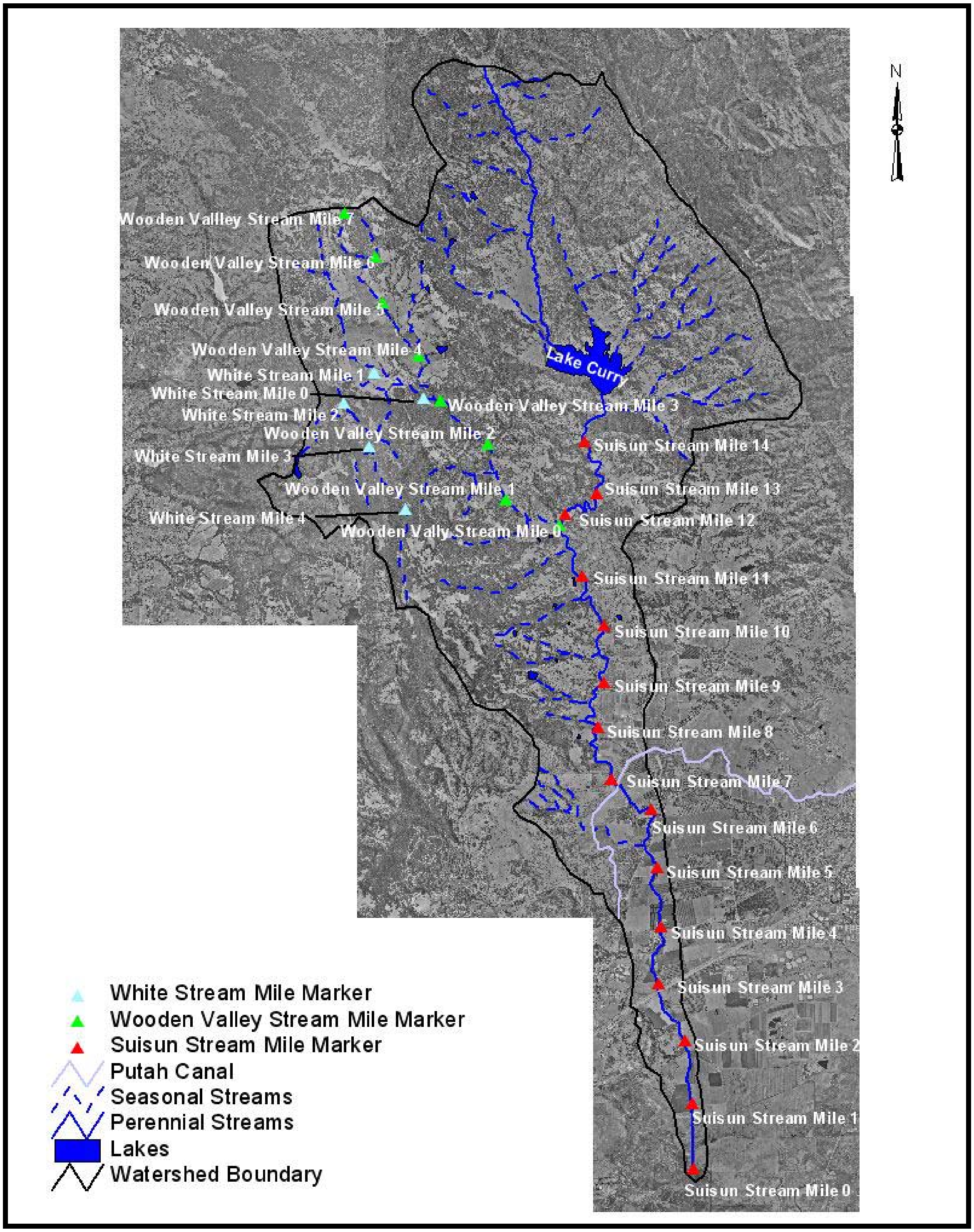
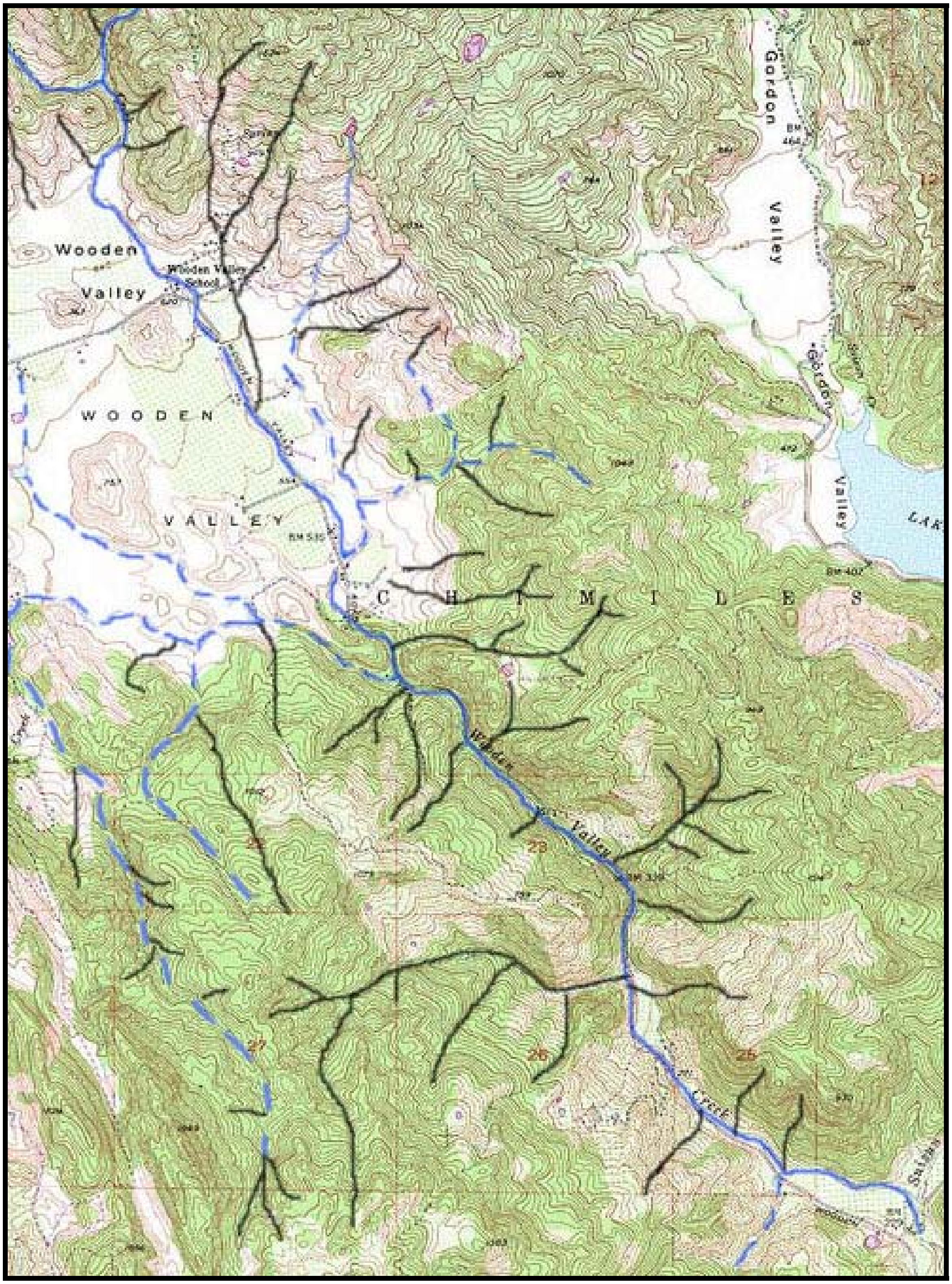


Figure 14. A Portion of Wooden Valley Creek Subbasin Illustrating Year-Round and Seasonal Creeks in Blue and Ephemeral Creeks in Black



the same slope respond similarly to changes in flow (discharge) or sediment load. Scientists have identified six slope classes that exhibit distinct channel patterns. A slope class is a small range of slope values. Table 3 lists these slope classes and their associated channel pattern. Figure 15 illustrates additional information on the processes associated with these channel patterns.

Table 3. Relationship between Slope Class and Channel Pattern

Slope Class	**<1%**	**1-2%**	**2-4%**	**4-8%**	**8-20%**	**>20%**
Channel Pattern	Pool-Riffle or Regime	Pool-Riffle Or Plane-Bed	Plane-Bed or Forced Pool-Riffle	Step-Pool	Cascade	Colluvial

From Montgomery and Buffington, 1993

Figure 15 shows how the steep slope class channels are the locations of debris flows and a source of sediment. In Figure 14 of the Wooden Valley subbasin, the headwaters, ephemeral creeks and portions of the intermittent creeks are steep and relatively steep slope channels (>20%, 8-20% and 4-8%). Figure 15 also demonstrates the processes that occur in lower slope channels of the <1%, 1-2% and 2-4% slope classes including sediment deposition and response to erosion and deposition.

Figures 16-19 show the slope classes of Suisun Creek and Wooden Valley Creek. Suisun Creek from Lake Curry to Suisun Marsh has a very flat slope of <1% with a pool-riffle channel pattern. Wooden Valley Creek, in its northern area, has slope classes of >20%, 8-20%, 4-8% and is low slope at 1-2 % through Wooden Valley and in its most downstream area. Between Wooden Valley and the low slope downstream area, Wooden Valley Creek goes through a confined canyon with a gentle slope class of 2-4%. These lower slope channels (less than 4%) under natural conditions probably had a meandering form with pools and riffles and riparian forest on the adjacent floodplain. Both the steeper channels in the 4-8% slope class, as well as the lower slope classes of 2-4%, 1-2% and <1% of Suisun and Wooden Valley Creeks support fish habitats.

Figure 15. Channel Types. This illustration of an idealized stream shows the general distribution of channel types from the hilltop down through the channel network. From Montgomery and Buffington, 1993.

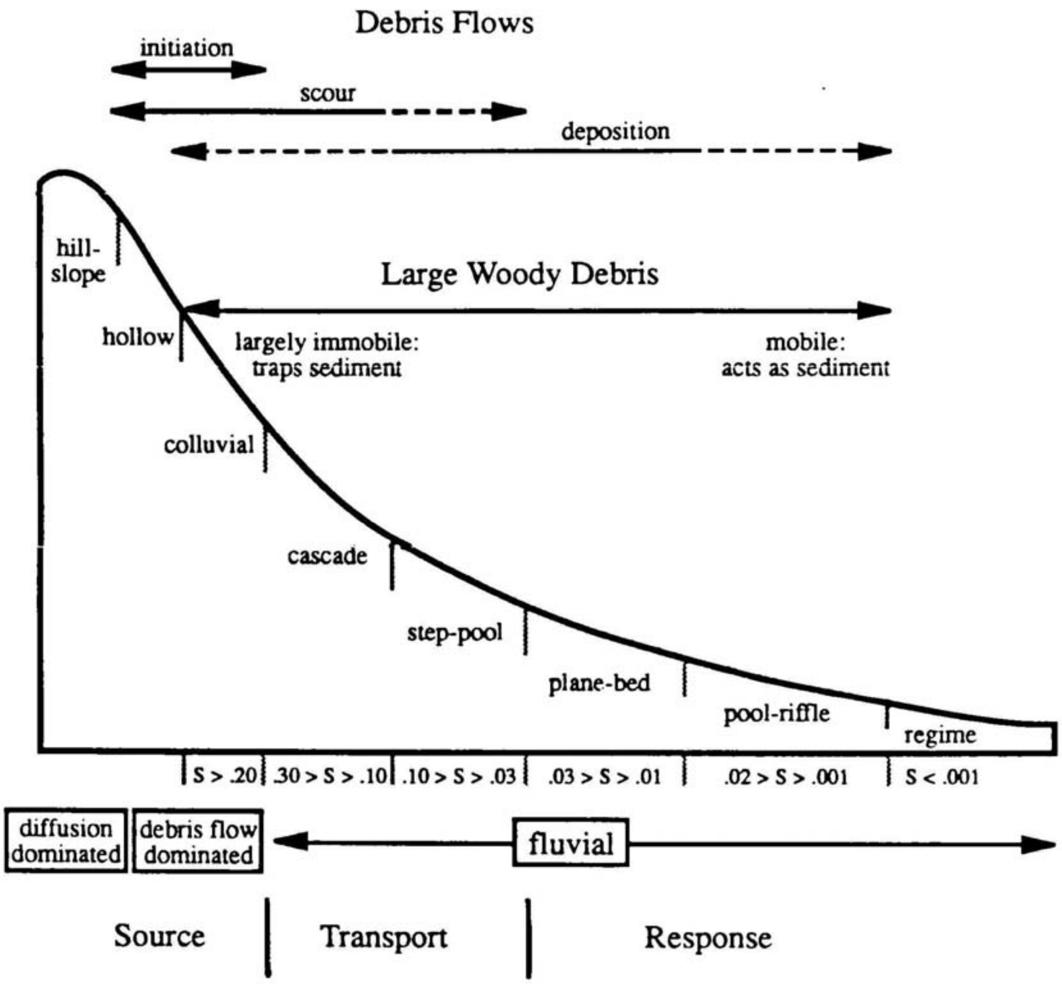


Figure 16. Slope Classes of Lower Suisun Creek

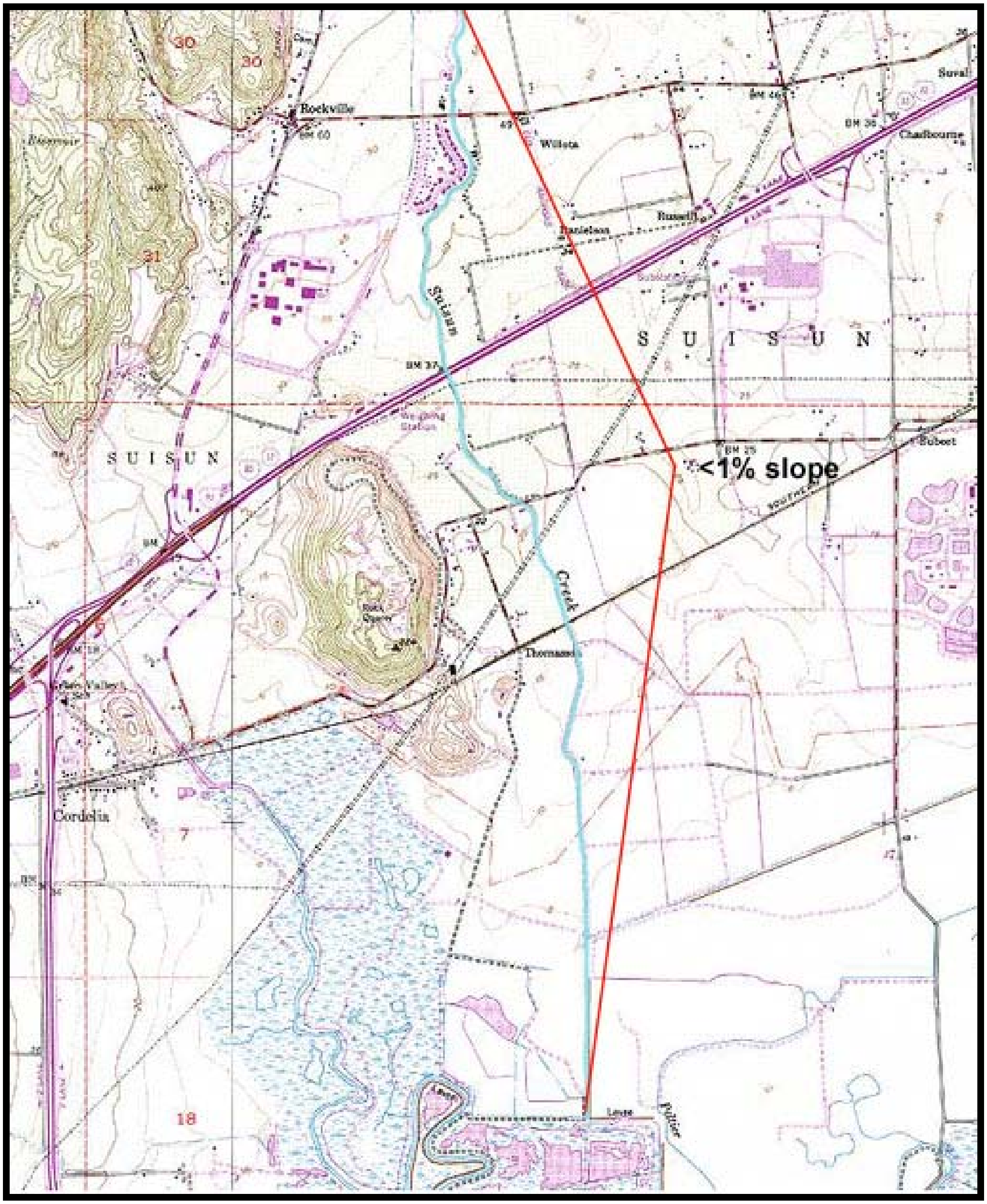


Figure 17. Slope Classes of Middle Suisun Creek

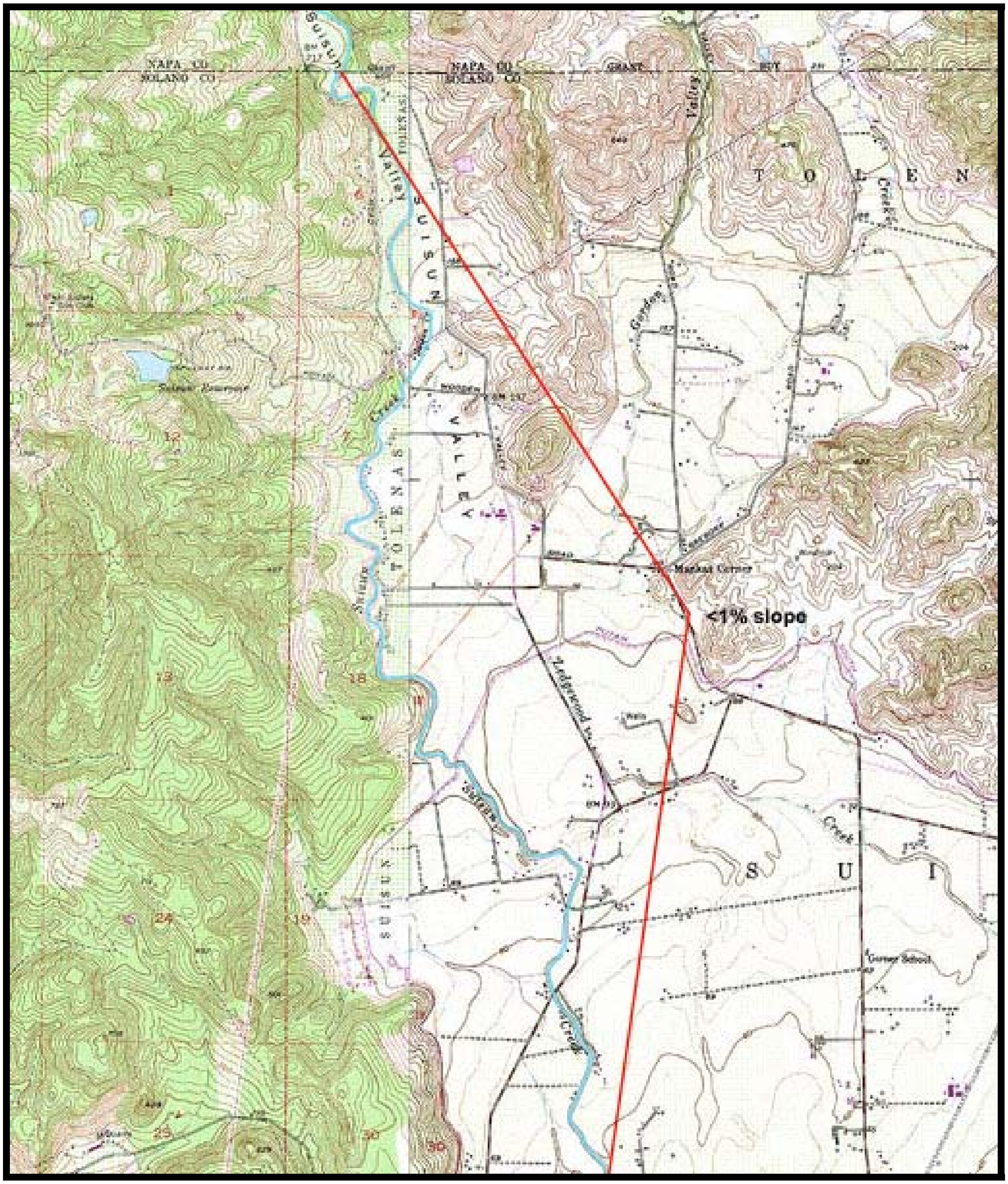


Figure 18. Slope Classes of Upper Suisun Creek

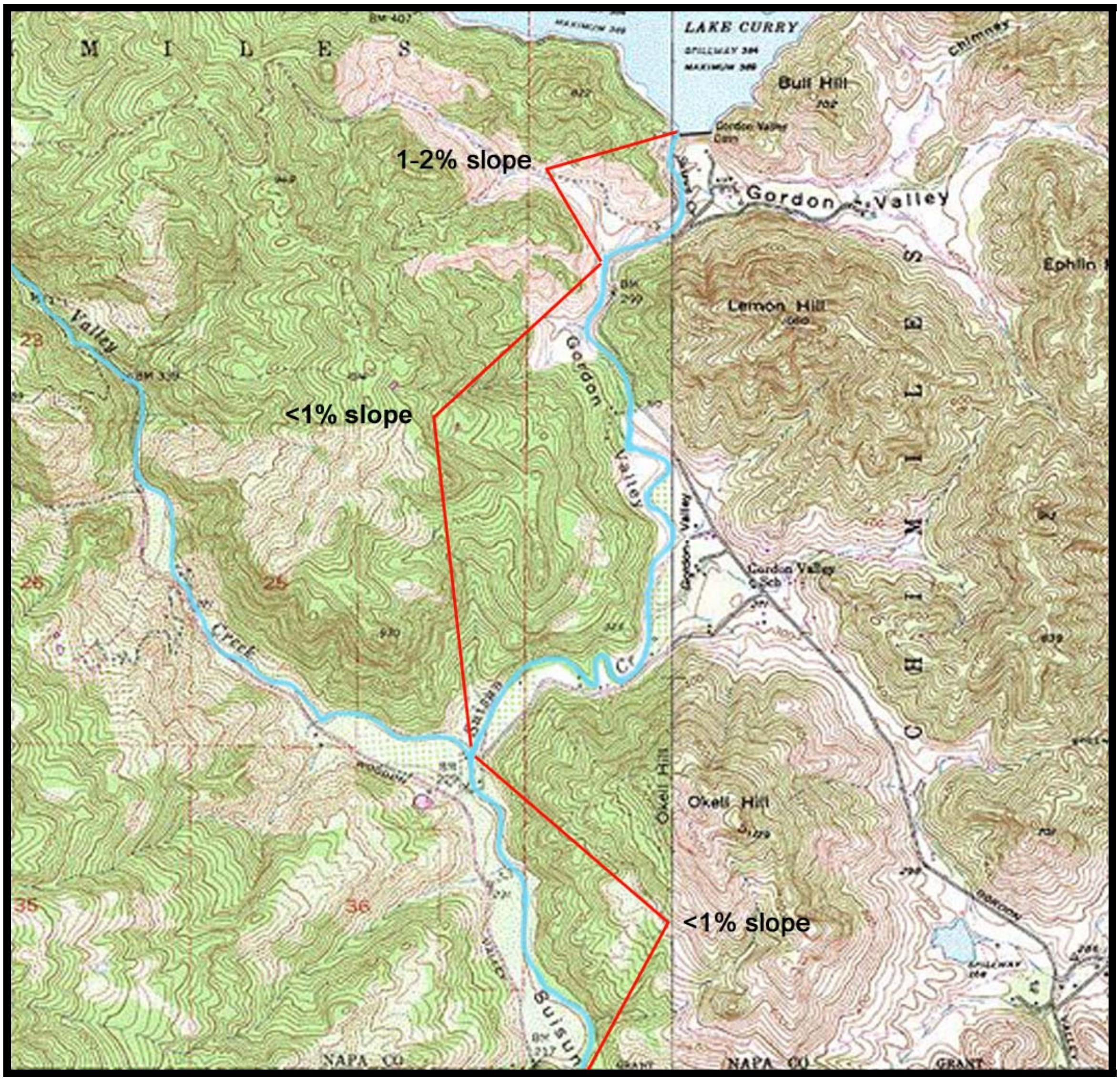
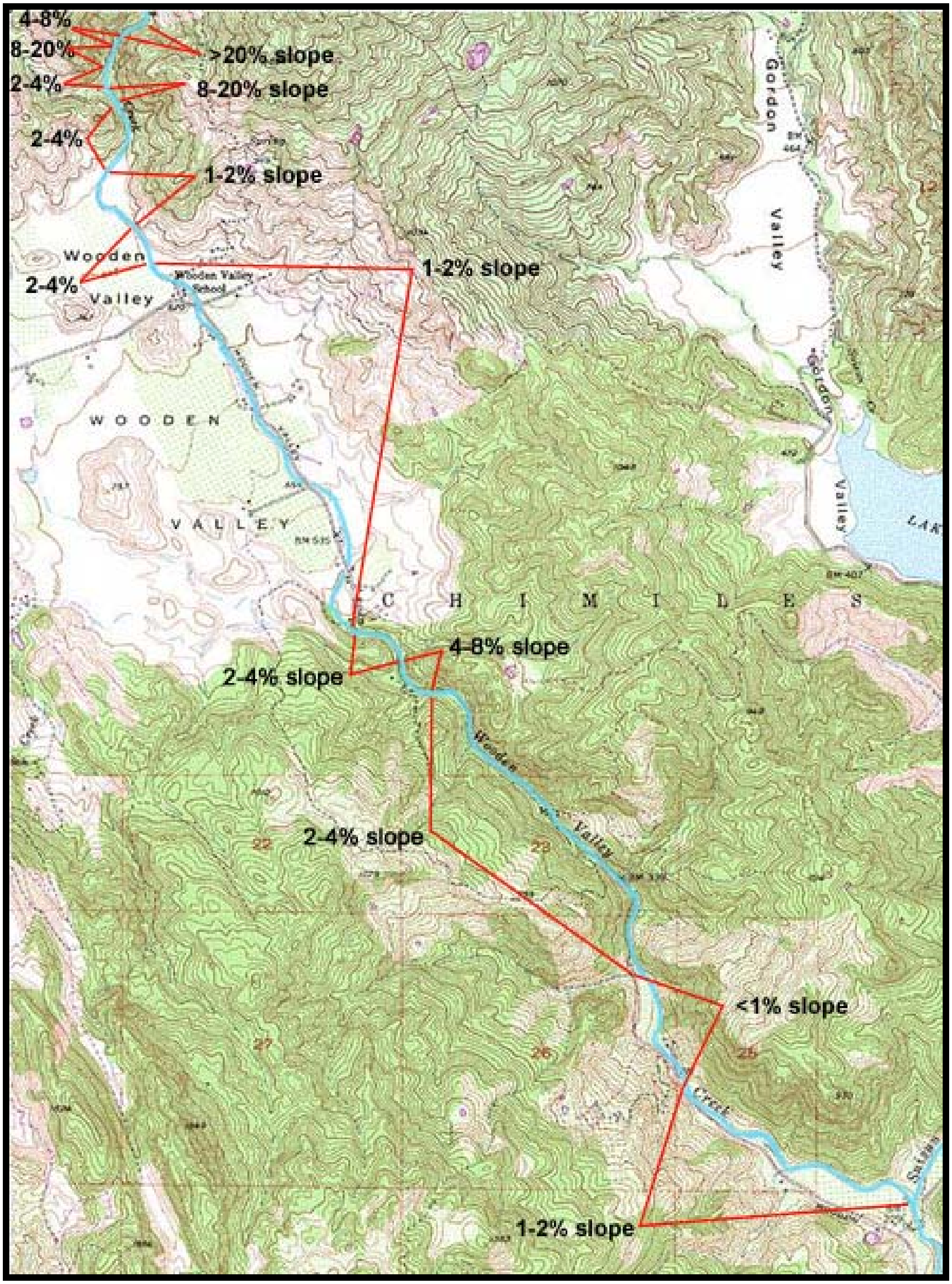


Figure 19. Slope Classes of Wooden Valley Creek



Channel Confinement

Another aspect of the stream system that affects the types of aquatic and riparian habitats is the level of natural confinement. Figures 21-24 show the confined and unconfined sections of Wooden Valley and Suisun Creek along with the slope class.

Unconfined channels are not tightly bound by the walls of a canyon or a bedrock channel bed. Instead, the unconfined channel typically meanders, can change location in a flood and has a floodplain adjacent to the channel. Unconfined channels typically have banks made of alluvial material and have modest bank heights. Unconfined channels are usually low in slope. Unconfined channels can support fish habitats in pools and riffles with riparian forest on their floodplains and banks.

Confined channels typically are dominated by bedrock in the bed and banks. They have little to no floodplain so floodwater does not spread out and slow down, but instead becomes deeper and fast moving. In general, confined channels transport, but do not store sediment, whereas unconfined channels and their floodplains both transport and store sediment. Confined channels may support fish habitats and a limited area of riparian forest along the channel edge. Trees on the slopes of the canyon may serve to shade the confined channel.

Confinement was determined from measurement of the topographic maps and channel. Confined channels have a bankfull channel width less than two valley widths and unconfined channels have a valley width of greater than four bankfull channel widths as depicted in Figure 20 (Montgomery and Buffington 1993). Confined channel sections were field-checked to confirm the map determination.

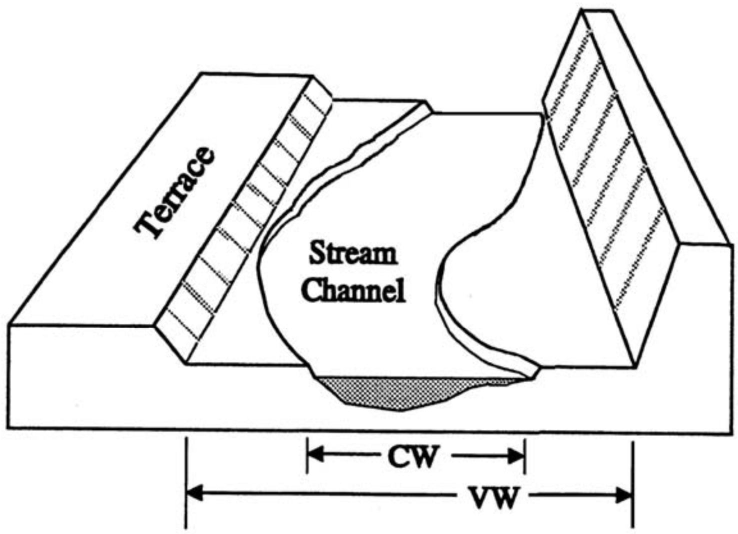
Suisun Creek is primarily an unconfined low slope channel. Wooden Valley Creek varies between unconfined and confined from its open valley area through a relatively low slope bedrock gorge to an open valley at the confluence with Suisun Creek.

Streamflow

There are no long-term stream flow station records for Suisun or Wooden Valley Creek. The Department of Water Resources operated a streamflow gage on Suisun Creek near Cordelia Road from 1991 to 1997. A flood destroyed the gage in 1997.

Although this plan does not address flood problems, information on streamflow and floods was reviewed. As previously described, Suisun Creek is an unconfined channel for most of its length and as such has a broad floodplain. Wooden Valley Creek has a wide floodplain in Wooden Valley (stream miles 4-6) and in its lower one mile. In these areas, floodwaters naturally fill up the relatively small channel and overflow onto the adjacent floodplain. In very large floods, this process may inundate the entire floodplain. As the stormwater flows over the floodplain, it slows down and

Figure 20. Confined and Unconfined Channels. The upper illustration shows a confined channel. The valley width (VW) in the upper illustration is less than twice the channel width (CW). The lower illustration shows an unconfined channel. The valley width, in the lower illustration, is greater than four times the channel width. A terrace is a former floodplain that is too high above the channel to flood.



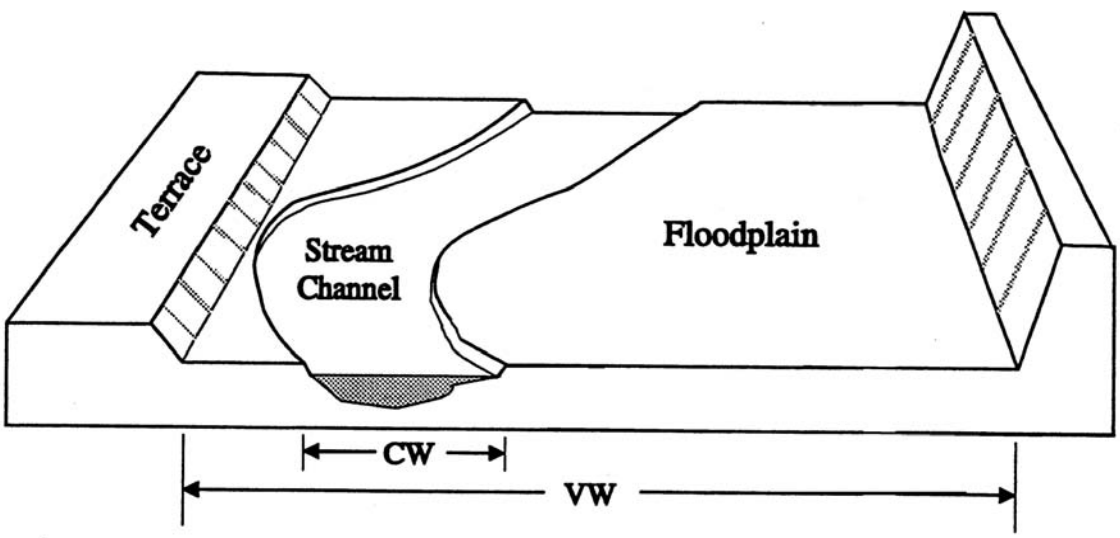


Figure 21. Confined and Unconfined Sections of Lower Suisun Creek

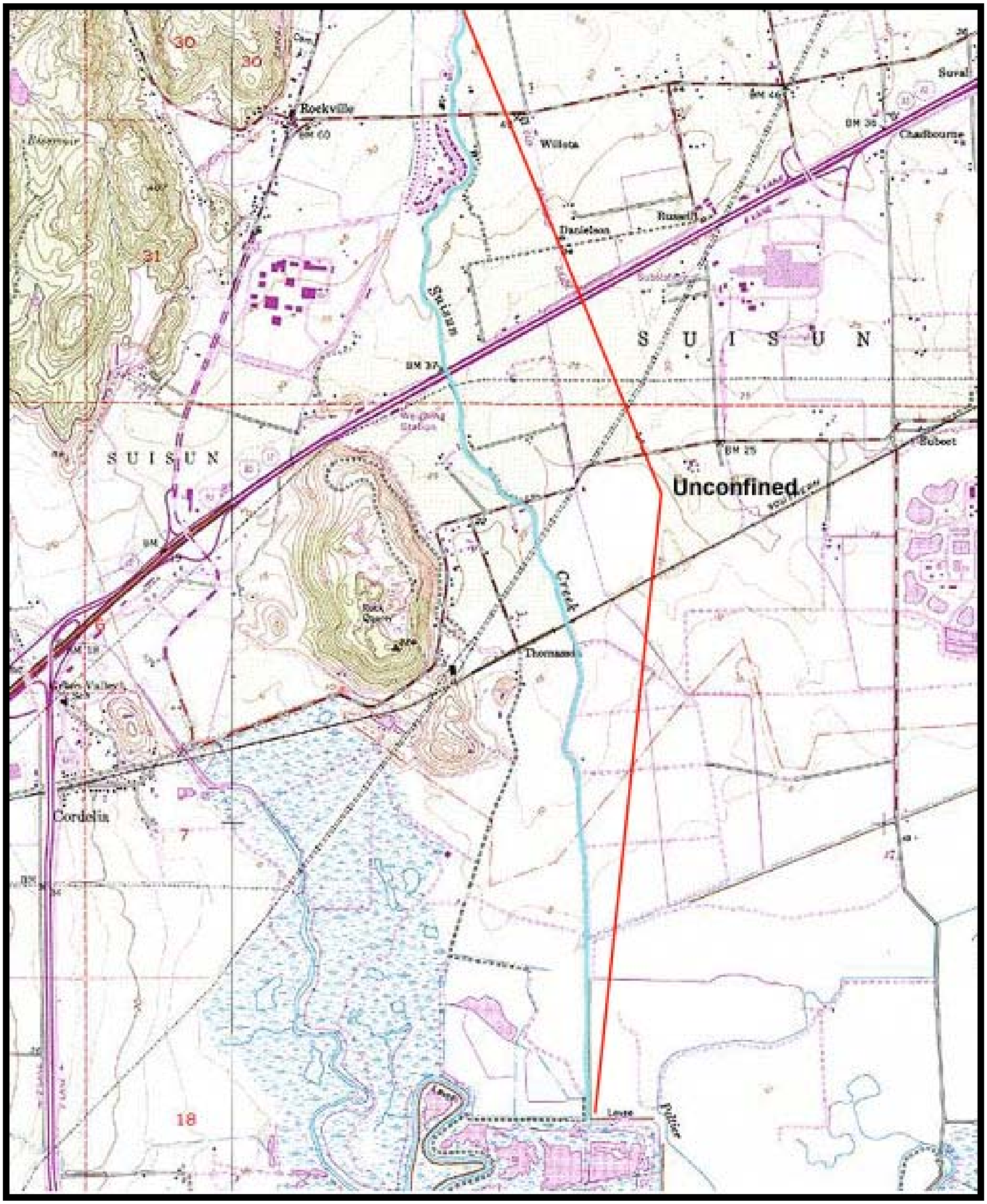


Figure 22. Confined and Unconfined Sections of Middle Suisun Creek

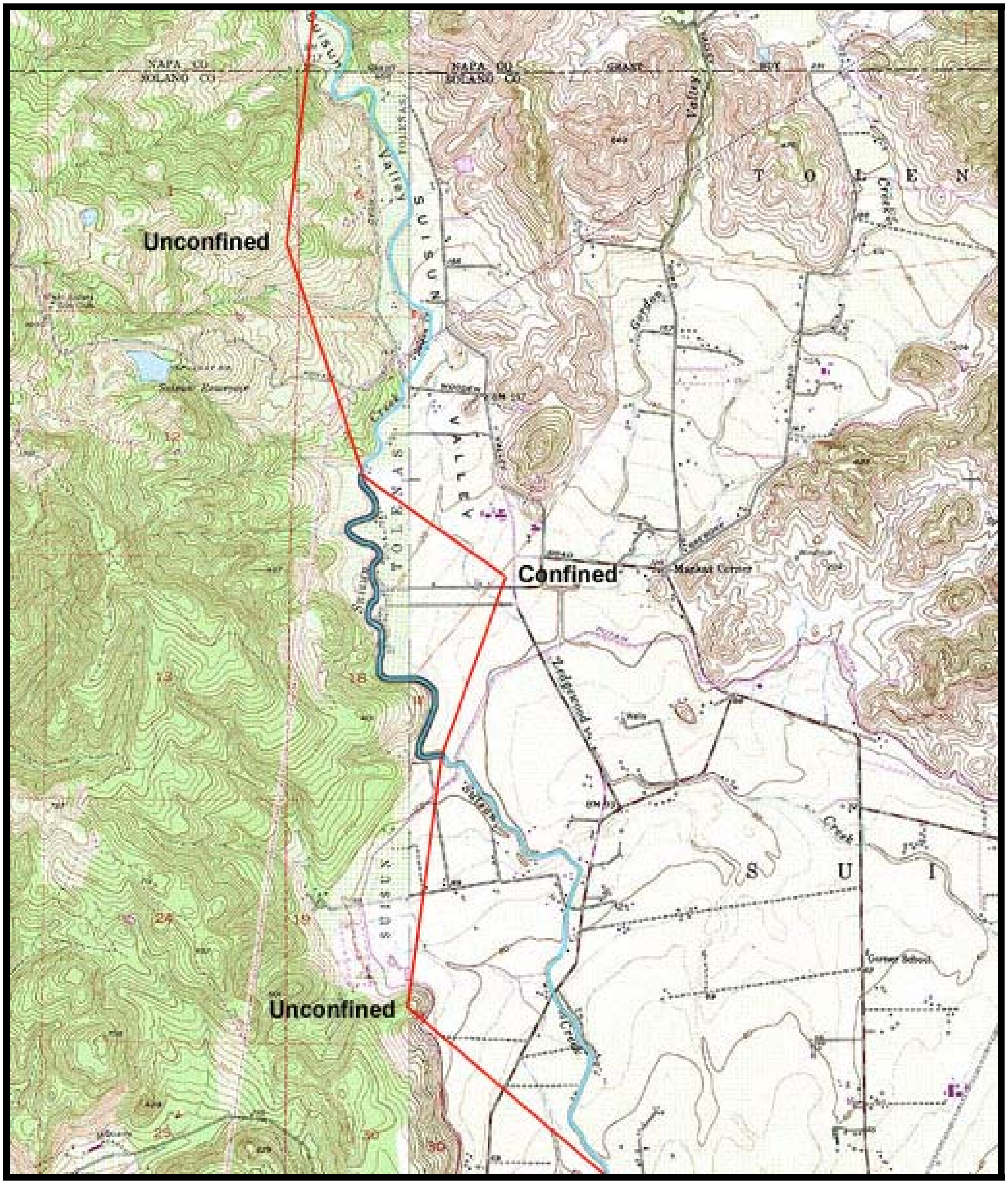


Figure 23. Confined and Unconfined Sections of Upper Suisun Creek

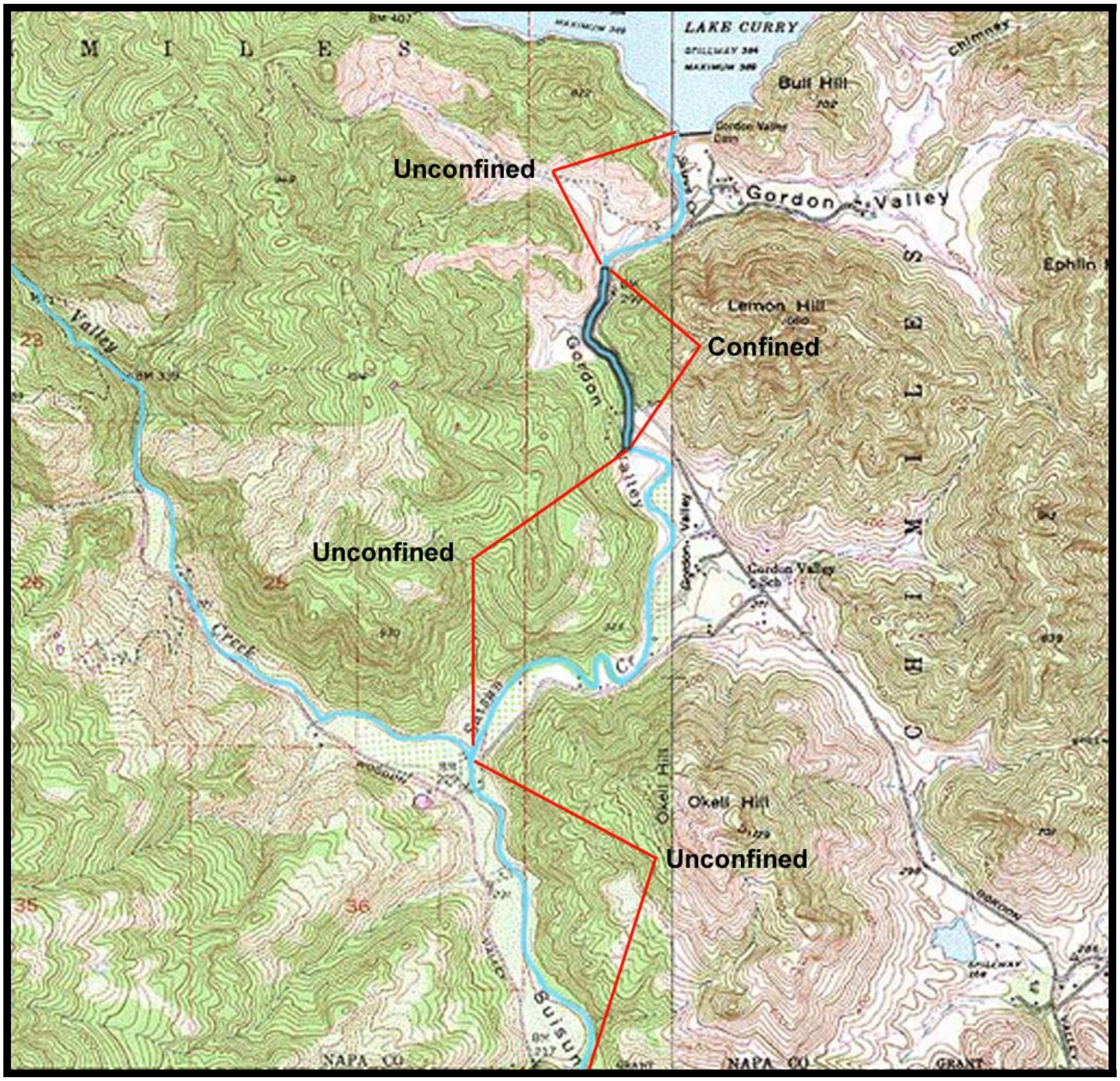
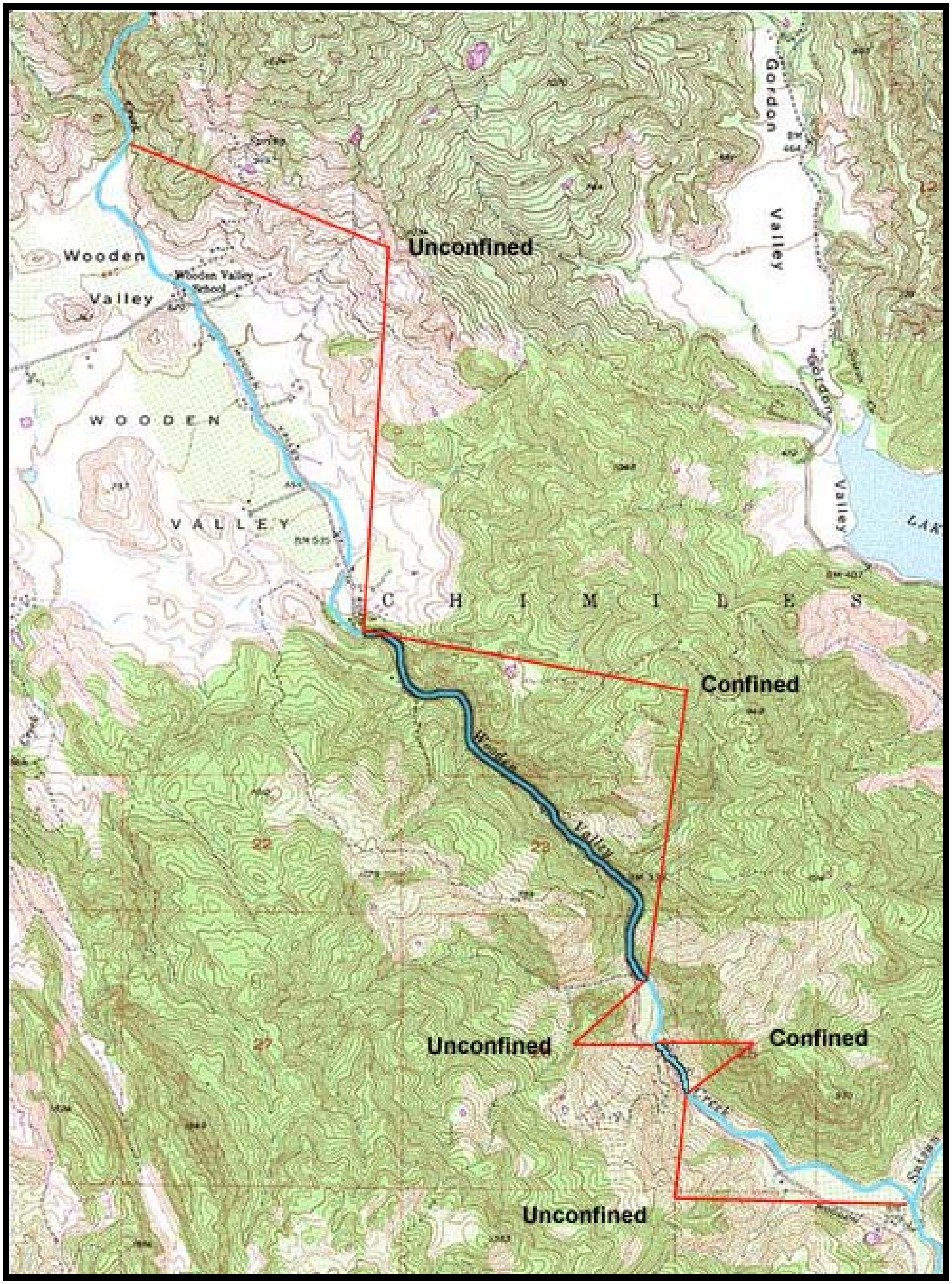


Figure 24. Confined and Unconfined Sections of Wooden Valley Creek



takes longer to move to the lower portion of the watershed. The stormwater in the channel moves faster and reaches the lower watershed sooner. The floodplain serves to temporarily store or detain floodwater.

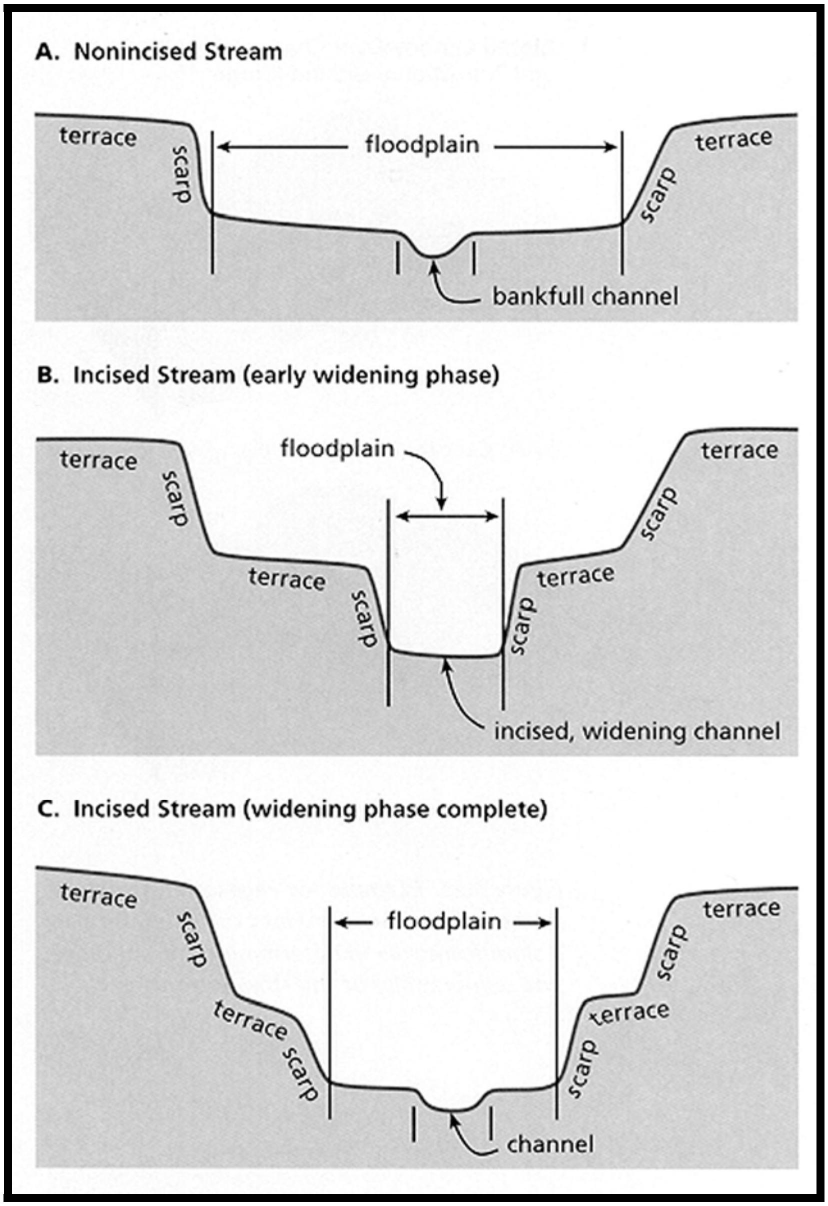
With the increase in floodplain development for agricultural and residential use over the past 40-50 years, landowners have completed actions to confine floodwaters into the Wooden Valley and Suisun Creek channels and reduce or eliminate overbank flow and floodplain inundation. There are several effects that typically occur from a reduction in floodplain inundation (Schumm 1997, Dunne and Leopold 1978). The increase in floodwater in the channel causes more erosion of the bed and banks of the channel often causing entrenchment or downcutting of the creek into the floodplain. As the channel entrenches and stormflows are confined to the channel, flood reaches the lower portion of the watershed faster. Overtime, erosion in the channel will increase and stream banks will become very steep and unstable and will slump and fail. This process results in formation of a new floodplain within the entrenched channel (see Figure 25).

There are several areas of Suisun Creek that demonstrate this process of entrenchment and bank slumping. Near stream mile 4.5 on Suisun Creek as of 2003, the channel bed was 20-25 feet deeper than the floodplain and entrenched. The banks are actively eroding and slumping, undercutting mature oak trees. Just downstream, the banks are completely lined with riprap, which is also being undercut. Just upstream, the Suisun Valley Road bridge also shows signs of previous undercutting and has been retrofitted with a cement drop structure across the channel at the base of the bridge piers. There may be additional areas of Suisun Creek upstream and downstream of this section that are entrenched and adjusting through bank erosion and slumping. We did not visit these areas due to a lack of access.

Several areas of the southern portion of Suisun Creek have perennial flood problems. These problems were evaluated in an October 2000 study, *Preliminary Evaluation of Suisun Valley Creek* prepared by West Yost and Associates for the Solano County Water Agency. Several areas – the Willotta Oaks Subdivision, an area near the Cordelia Road Bridge, several levees downstream of the railroad bridge and Suisun Valley Road bridge #1, were found to flood in large storms. These flood prone areas are immediately adjacent to the creek in the downstream portion of the watershed and are near to the tidal area of Suisun Creek. Tidal flows back up flood water and can increase flood problems. The downstream area may also be receiving floodflows at a quicker rate than it did historically, due to the development of floodplain areas throughout the watershed and the faster delivery of floodwater to downstream areas due to reduction of floodplain inundation.

The West Yost report looks at a number of features of the Suisun Creek watershed including rainfall data, subbasins, tidal heights and rainfall event frequency. A hydrologic model is used to simulate land conditions in the watershed, floods and the effectiveness of various alternatives to reduce floods in the identified problem areas. Lake Curry was evaluated for reducing flooding, but deemed ineffective because of

Figure 25. Entrenchment and the Formation of a New Floodplain. This illustration shows channel change during the processes of incision (entrenchment) and establishment of new flood plain through bank slumping.



From US Department of Agriculture, 1998

its small capacity in relationship to the size of the 100-year flood and distance from the flood prone area. The only alternatives evaluated are channel clearing and off-channel detention basins in the downstream area. Clearing vegetation requires federal and state permits and an evaluation of effects on the listed steelhead trout. Enhancement Action #6 includes an in-depth survey of Suisun Creek which could be used to identify environmentally beneficial and more permittable flood control options.

Stream Channel Form and Bed Composition

Channel Surveys

As described in Section II, two study reaches were established - one on Wooden Valley Creek and one on Suisun Creek. Cross sections were surveyed in 2001 and 2002 on the Wooden Valley Creek study reach and 2001, 2002 and 2003 on the Suisun Creek study reach. Measurements of change in stream channel form require a longer record than 2-3 years to demonstrate trends in the system. These study reaches have long-term access agreements and continued monitoring is recommended in Section IV.

Repeated surveys of cross sections of the stream channel document erosion and deposition within the channel. Measurements of this type over ten or more years can demonstrate overall trends in the watershed. Trends may be downcutting or a deepening and entrenchment of the channel, or filling in and widening or aggradation of the channel.

The stream channel changes in response to conditions in the watershed. Monitoring trends in the channel gives an indication of the watershed conditions that are having the greatest effect on aquatic habitats and should be addressed. Monitoring data for stream channels is also used in revegetation and restoration designs to assure that projects are based on a thorough understanding of stream channel processes and morphology.

Appendix 2 contains cross sections 1-6 as surveyed in the summer of 2001 and summer of 2002 for the Wooden Valley Creek study reach. The cross sections show a small amount of channel change as would be expected over a relatively dry year. The longitudinal profile of the Wooden Valley Creek study reach in 2001 and 2002 is contained in Appendix 2. There is less than a half-foot of change in the thalweg or the lowest point in the channel.

Appendix 2 contains cross sections 1-6 as surveyed in 2001, 2002 and 2003 for the Suisun Creek study reach. The cross sections show a relatively small amount of change between 2001 and 2003 despite a wet winter in 2002/2003 that caused water to flow over the Lake Curry spillway for several months. This lack of change in the channel during a wet winter further illustrates the effect of Lake Curry in reducing flood flows for a significant distance downstream (see page 49). This lack of scour and rejuvenation of the streambed is likely to increase embeddedness with fine sediment and reduce spawning habitat. The longitudinal profile of the Suisun Creek study reach in 2001, 2002, and 2003 is contained in Appendix 2. There is about a half-foot of change in the thalweg.

Bankfull channel width was measured for each channel cross section. The bankfull channel width for the study reach in Suisun Creek averaged 41.5 feet. The bankfull channel width for the Wooden Valley study reach averaged 56.8 feet.

Channel Bed Composition

Excessive fine sediment can degrade aquatic habitats, particularly steelhead trout habitat. Fine sediment clogs air spaces in the gravel, reducing oxygen and smothering fish eggs. Aquatic insects living in riffles are also smothered by fine sediment. Pool habitats become shallower and warmer. There are a number of ways to evaluate fine sediment levels in aquatic habitats. During floods, sediment moves in water flows with heavier rocks termed bedload, moving along the bottom of the stream and lighter sediment such as silt and clay particles suspended in the flowing water. Stormflows erode and deposit material on the streambed and transport the sediment load provided by the watershed. If measurements of fine sediment on the streambed are high, then improvements in land management and development practices are needed.

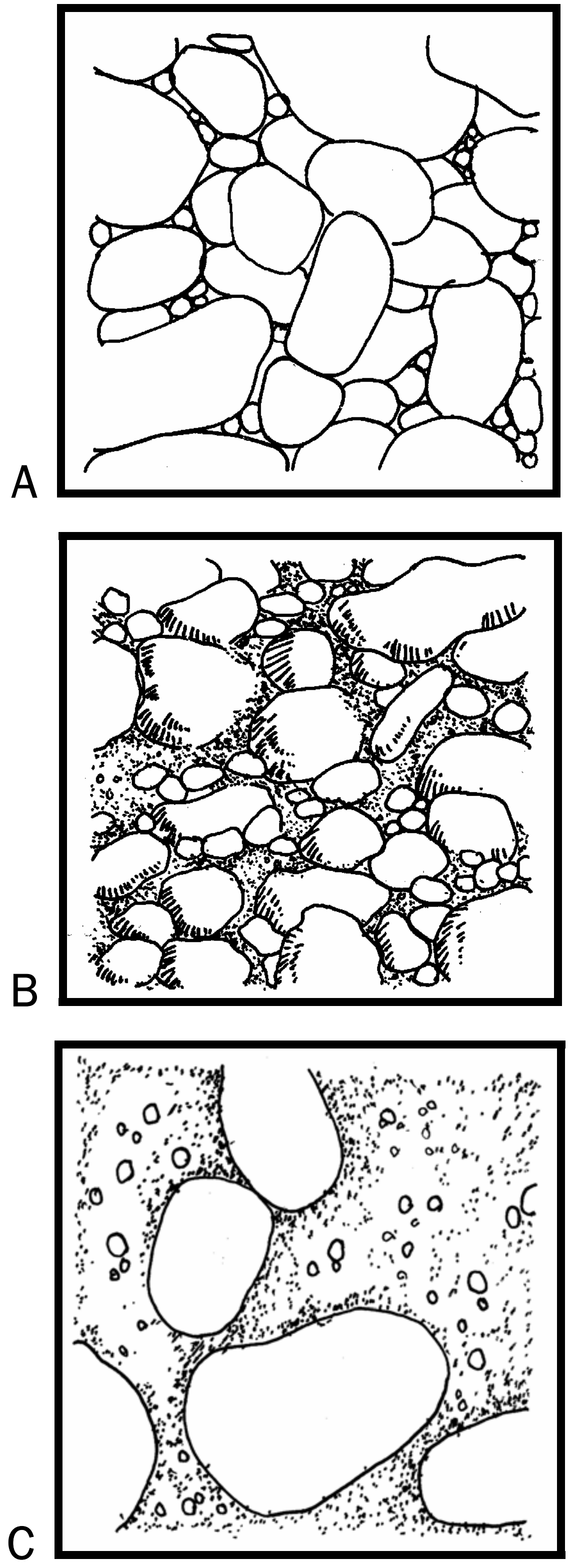
Pebble counts and measurements of embeddedness were completed in both study reaches in 2002. Both study reaches are in locations where sediment would be expected to deposit – low slope, unconfined channel areas.

The pebble count for the Wooden Valley study reach showed sand and silt (<4mm) as the largest percentage (34%) of the surface bed material. Coarse gravel (16-33mm) was the second most common size bed material at less than 10%. Embeddedness of rocks larger than 64mm totaled 60%. Just upstream of the Wooden Valley Creek study reach is a section of creek with excessive bank erosion that is likely generating fine sediment since both sections, the eroding area and the study reach, are very low slope (<1%).

The pebble count for the Suisun Creek study reach showed coarse gravel (22-32mm) to very coarse gravel (32-64mm) as the dominant bed material with a high percentage (26%) of sand and silt (<4mm). Embeddedness of rocks larger than 64mm totaled 51%.

These measurements give an overall indication of conditions for aquatic habitats in both creeks. Fine sediment levels at both study reaches are very high. For spawning habitat to support salmonid egg incubation, fine sediment levels need to be less than 20%. The Wooden Valley study reach lies downstream of a creek section with significant bank erosion and a watershed with road erosion and areas of hillslope instability. Measurements indicate very high fine sediment levels but within the fines, gravel of suitable size for spawning (11-45mm)

Figure 26. Substrate Embeddedness and Composition. Drawing of three different levels of embeddedness. Frame A is composed of 80% small cobble, 20% gravel and embeddedness is rated as 0%. Frame B consists of 40% small cobble, 30% gravel and embeddedness is rated at 30%. Frame C is 40% large cobble, 10 % gravel, 50% sand and embeddedness is rated at 50%.



were recorded. The Suisun Creek study reach lies midway on the length of this creek and represents an area affected by Lake Curry, as well as surrounding land uses. The Suisun Creek study reach also showed a very high level of sediment, but had a greater percentage of spawning-size gravel than the Wooden Valley Creek study reach.

V-star or Residual Pool Volume

Two areas of Suisun Creek were monitored using the V-star protocol in 2002. The V-star value measured in the Suisun Creek study reach was 0.605. This indicates a high fine sediment supply to the site. The V-star value measured at stream mile 4.5 (SC 3) on Suisun Creek was 0.588. This indicates a high fine sediment supply to the site. Wooden Valley Creek has very few areas where this protocol is applicable and access was gained.

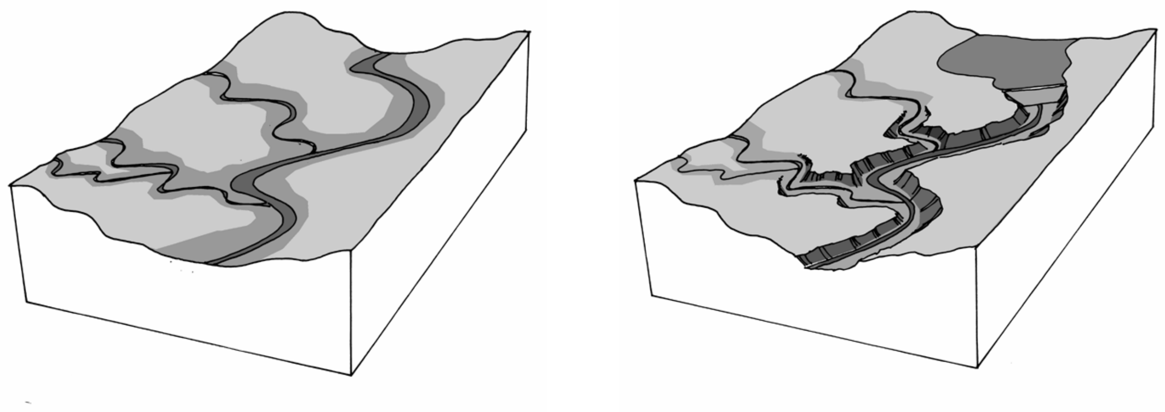
Lake Curry – Effect of Reservoir on Aquatic Habitat and Suisun Creek

Background

Lake Curry is the largest reservoir in the Suisun Creek watershed and is used for municipal water supply. The reservoir was created by the City of Vallejo in 1926 with construction of the Gordon Valley Dam, an earth embankment dam approximately 107 feet high. Lake Curry drains a 17 square-mile watershed of upper Suisun Creek and has a surface area of 377 acres. Lake Curry has an antiquated outlet works that can release a maximum of 7 cubic feet per second (cfs) flow. In previous years, Lake Curry water was treated on-site, transported to the City and sold to rural residential neighborhoods in the nearby area. The majority of the water was transported by pipeline to the City and sold to City customers. Since 1992, the City has not been able to use Lake Curry water as the on-site water treatment works was not adequate to meet federal drinking water requirements. The City is currently preparing an EIR/EIS with the Bureau of Reclamation to evaluate alternatives for moving Lake Curry water into the Putah South Canal.

An on-channel reservoir such as Lake Curry, has a number of effects on the hydrology of the downstream creek. A reservoir interrupts the movement of bedload along the creek and can induce changes in the downstream creek. For alluvial streams to make up for the lack of bedload, the stream erodes its own bed and banks. Over time, this process causes downcutting and incision of the channel into the floodplain (see Figure 27).

Figure 27. Illustration of Effects of Reservoir on Stream System



River and Tributaries Without Reservoir

Channel Incision Following Dam Construction

Reservoirs interrupt sediment transport to downstream areas. Rivers and creeks compensate by eroding sediment from their bed and banks resulting in channel incision or entrenchment. Reservoirs also change the size of flood events in the downstream creek. Because the reservoir holds stormwater until filled and then stormflows flow over the spillway, the reservoir reduces the frequency of small floods. It is these small floods (two-year frequency) that shape the bankfull channel, replace and rejuvenate the gravel in riffles and spawning areas and clear fine sediment from pools and other habitat areas. The stormflows, diminished by the effect of the reservoir, have less power to shape the channel and move coarse bed material. As a result, the percentage of fine material in the streambed may increase.

A reservoir can affect a stream by interrupting the movement of coarse sediment along the bed and a reservoir may also decrease the magnitude of flood flows generated by the watershed draining into the reservoir. Therefore, to assess the effect of a reservoir on the stream channel downstream, an estimate of the decrease in magnitude of flood flows and an estimate of the length of channel affected by the decrease in flood magnitude are both needed.

<u>Zone of Influence</u>

A reservoir tends to decrease the magnitude of floods downstream. Watershed area increases in the downstream direction. As a flood moves downstream below the reservoir, a greater amount of runoff from the additional watershed area is added as floodflows from unregulated or natural areas of the watershed move into the creek. Consequently, at some point the effect of a reservoir on flood flows will diminish to a level of insignificance. Insignificance is defined as the level of measurement error, which for flood flows is about five to ten percent.

A 1962 study by Benson found that when usable (available) reservoir storage in a watershed exceeded 103 acre-feet per square mile, the reservoir decreased downstream peak stormflows by more than 10 percent (Hunrichs, Pratt and Meyer 1998). So, when a watershed contains less than 103 acre-feet per square mile of available storage, the effect of the reservoir is judged to be insignificant. Equation 1 shows Benson's threshold for significance for a reservoir to impact flood discharges.

$$\left(\text{Storage} \big/ \text{Watershed Area} \right) = 103 \text{ acre-feet per square-mile} \qquad (1)$$

The zone of influence of a reservoir is calculated by solving Equation 1 for the watershed area required to limit the available storage to 103 acre-feet per square mile. Equation 2 shows the result of solving Equation 1 for watershed area.

$$\text{Zone of Influence} = \text{Watershed Area} = \left(\text{Storage} \big/ 103 \text{ acre-feet per square mile} \right) \qquad (2)$$

The zone of influence of a reservoir is measured in square-miles. The downstream end of the zone of influence is the point along the stream channel which has a watershed area equal to that calculated by Equation 2. For each year, the zone of influence of the annual maximum flood can be estimated by dividing the available storage in the reservoir by Benson's threshold of 103 acre-feet per square-mile. For example, suppose that a reservoir has 2,060 acre-feet of available storage, then the zone of influence would be 20 square-miles (=2,060 acre-feet/103 acre-feet per square-mile). The zone of influence of a reservoir includes the watershed area above the reservoir. So, the reservoir would affect the channel downstream only in years when the zone of influence is greater than the watershed area above the dam.

Decrease in Flood Magnitude

The affect of a reservoir on decreasing the magnitude of flood events can also be assessed by estimating the magnitude of the unimpaired floods that would occur at the outlet of the reservoir if the reservoir was not there.

One method to estimate the magnitude of floods from an ungaged watershed is called the *index-flood* method. The index-flood method assumes that the statistical distribution of floods at different sites in a region is the same, except for a scale parameter (index flood) (Rao and Hamed 2000). The mean annual flood is usually used as the index flood. Flood records from several gaging stations are combined and used to estimate the magnitude of floods with selected return periods.

Before the flood records from the various gages are combined, each recorded annual maximum flood discharge is divided by the mean annual maximum flood (mean annual flood) for the station. The annual maximum flood and the mean annual flood both are measured in cubic-feet per second (cfs). The units or dimension of flood discharge is cfs. Thus, the ratio of an annual maximum flood to the mean annual flood produces a dimensionless number; cfs/cfs has no dimension.

The relationship between the mean annual flood and watershed area of all the gaging stations used to create a regional flood frequency model can be quantified by ordinary linear regression. Therefore, the mean annual flood for an ungaged watershed can be estimated based on its watershed area. After the mean annual flood has been estimated for an ungaged watershed, the return period of any discharge can then be estimated by scaling the regional flood frequency model by the estimated mean annual flood for the ungaged watershed.

Lake Curry

Figure 28 shows the location of Lake Curry. Lake Curry occupies a portion of Gordon Valley on upper Suisun Creek. According to the storage-capacity table provided by the City of Vallejo (the City), the storage capacity of the lake at the spillway elevation is 9,848 acre-feet. According to City staff, the mean annual precipitation for Lake Curry is about 28 inches.

A year-round flow of about three cfs is released from the lake through the outlet works. This flow is low enough that its effect on flood flows from the spillway is negligible.

Only low to moderate floods will be affected by the presence of Lake Curry. Once the storage in the reservoir has been filled and the lake begins to spill, Lake Curry is no longer able to moderate the magnitude of the floods generated by its watershed. Large floods rapidly fill the available storage in Lake Curry. Large magnitude floods occur in very wet years. The annual maximum flood is rarely the first flood of the season. Typically, it takes a few storms to satisfy the soil moisture deficit that accumulated over the previous dry period. The storms prior to the annual maximum flood decrease the available storage in Lake Curry. So, when the annual maximum flood occurs, the available storage in the lake is less than it was at the start of the flood season. Table 4 shows that the 31-year average of available storage, on or about January 1, is 4,271 acre-feet. At a constant discharge from the upper Suisun Creek watershed of 1,000 cfs, it would take 2.15 days to deliver 4,271 acre-feet to the reservoir.

An estimate of Lake Curry's downstream zone of influence can be made for 31 of the 44 water-years from 1957 through 2000. In the data provided by the City, data for 1971 through 1983 is missing. The City provided a spreadsheet showing the water surface elevation of Lake Curry on various dates from October 1956 through December 1999 (see Table 4). The City also provided a storage capacity table that

Figure 28. Lake Curry. Seventeen USGS gauging stations, listed in Table 3, with more than 5 years of flood records that lie within 30 miles of Lake Curry are shown above. These stations were used to develop a regional flood frequency curve for the Lake Curry region. Map scale: 1 inch to 5.34 miles.

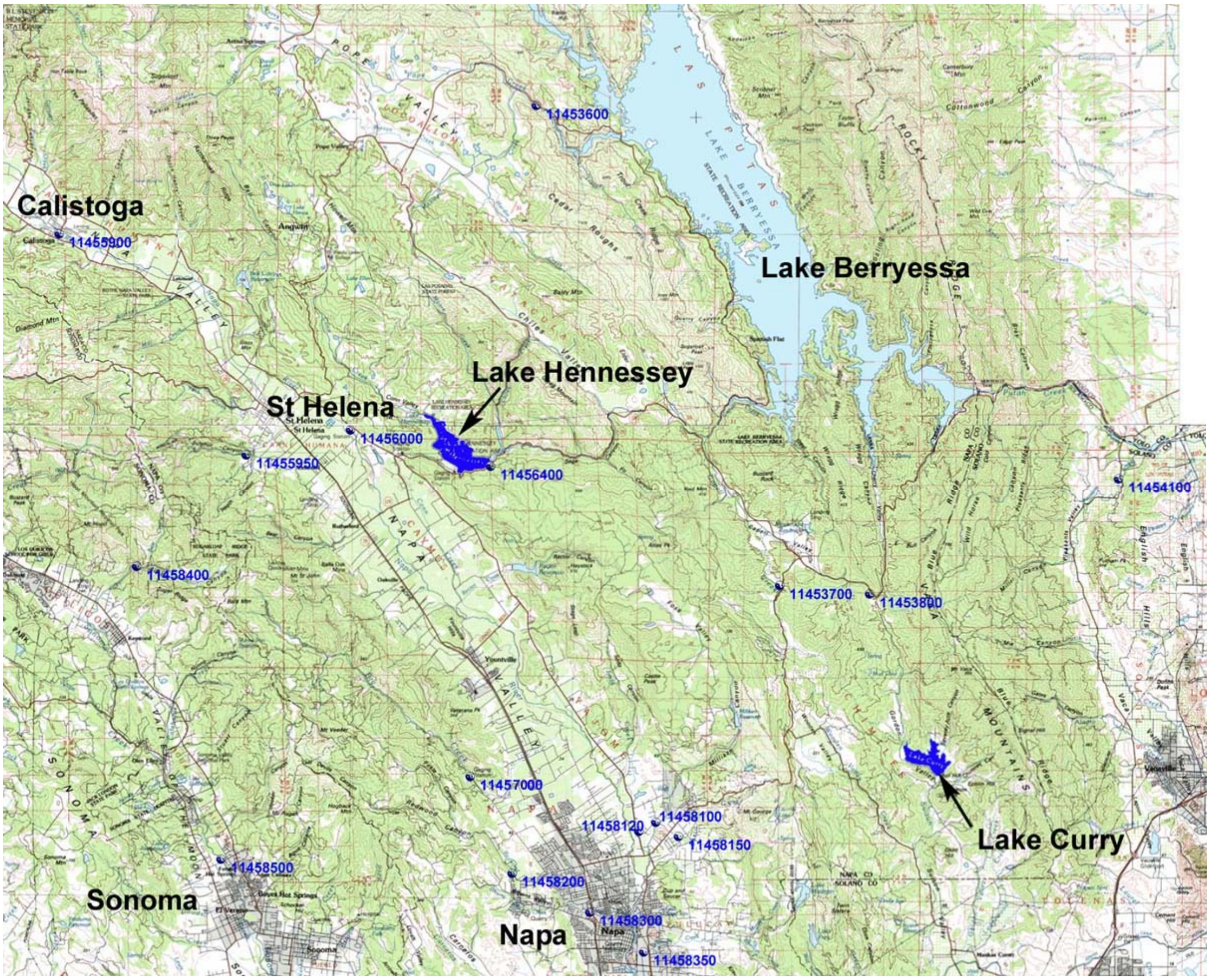


Table 4. The estimated watershed area required to reduce the ratio of storage to watershed area to Benson's threshold of 103 acre-feet per square-mile is shown in the last column, for the 1957 through 2000 water-years. The watershed area required to reach Benson's threshold is a measure of the zone of influence of a reservoir. The available storage was estimated around January 1 each year. See Figure 29 for a histogram of the zone of influence.

Date	Lake Level[1] (ft.)	Storage[1] (mg)	Storage[1] (ac-ft.)	Available Storage (ac-ft.)	Ratio of Available Storage to Watershed Area (ac-ft./sq-mi)	Watershed Area of the Approximate Zone of Influence of Lake Curry (sq-mi.)
1/1/1957	377.19	2,614.9	8,023.6	2,676	157	26
1/1/1958	374.22	2,265.4	6,951.2	3,749	221	36
1/1/1959	377.49	1696.9	5,206.8	5,493	323	53
1/4/1960	372.49	2,067.4	6,343.6	4,356	256	42
1/1/1961	372.84	2,102.3	6,450.7	4,249	250	41
1/1/1962	366.15	1,432.9	4,396.7	6,303	371	61
1/1/1963	363.18	1,177.7	3,613.7	7,086	417	69
1/1/1964	356.57	714.8	2,193.3	8,507	500	83
1/1/1965	359.77	909.5	2,790.6	7,909	465	77
1/1/1966	377.10	2,603.3	7,988.0	2,712	160	26
1/4/1967	375.60	2,428.5	7,451.6	3,248	191	32
1/4/1968	377.50	2,649.9	8,131.0	2,569	151	25
1/1/1969	368.36	1892.6	5,807.3	4,893	288	48
1/1/1970	378.85	3,222.7	9,888.5	811	48	8
1/1/1984	374.14	2,253.8	6,915.6	3,784	223	37
1/1/1985	371.91	1,997.5	6,129.1	4,571	269	44
1/1/1986	366.06	1,432.9	4,396.7	6,303	371	61
1/1/1987	370.91	1,881.0	5,771.7	4,928	290	48
1/1/1988	379.95	2,929.5	8,988.9	1,711	101	17
1/1/1989	372.00	2009.1	6,164.7	4,535	267	44
1/1/1990	375.41	2591.6	7,952.1	2,748	162	27
1/1/1991	372.46	2,067.4	6,343.6	4,356	256	42
1/1/1992	379.66	3,249.6	9,971.1	729	43	7
1/1/1993	370.72	1,857.7	5,700.2	5,000	294	49
1/1/1994	366.37	1,459.3	4,477.7	6,222	366	60
1/1/1995	378.66	2,789.7	8,559.9	2,140	126	21
1/7/1996	372.54	2,067.4	6,343.6	4,356	256	42
1/1/1997	370.52	1,834.4	5,628.7	5,071	298	49
1/2/1998	377.88	2,696.5	8,273.9	2,426	143	24
1/4/1999	374.50	2,300.4	7,058.5	3,641	214	35
12/20/1999	369.77	1,758.5	5,395.8	5,304	312	51
			Maximum	**8,507**	**500**	**82.6**
			Median	**4,356**	**256**	**42.3**
			Average	**4,271**	**251**	**41.5**
			Minimum	**729**	**43**	**7.1**

[1] Source: City of Vallejo Water Division

gives the volume stored in the reservoir for any given water surface elevation. The usable (available) storage in the reservoir is the difference between the maximum capacity and the amount of water in storage on the selected date.

The USGS has operated a stream gaging station on the Napa River near St. Helena for 62 years. A review of the flood data for the Napa River near St. Helena shows that 79% of the annual maximum floods occurred in January, February or March. Only 19% of the annual maximum floods occurred before January. So, using the available storage in Lake Curry around the beginning of January would give a reasonable estimate of the potential for Lake Curry to affect flood discharges.

Table 4 shows the estimated zone of influence of Lake Curry on Suisun Creek as calculated by Equation 2. Figure 29 shows a histogram of Lake Curry's zone of influence by ten square-mile size classes. The median zone of influence, for the 30 year period of record, is 42.3 square-miles. As a comparison, the watershed area above the point where the Napa-Solano County line crosses Suisun Creek is 41 square-miles. Table 5 shows the watershed area above selected points along Suisun Creek.

Table 4 shows that the ratio of available storage to watershed area was less than Benson's threshold of 103 acre-feet per square mile in only three out of 31 years. That is, for three out 31 years of records, Lake Curry did not affect the creek downstream of the dam. In six out of 31 years, the estimated zone of influence is larger than the entire Suisun Creek watershed. In 17 of 31 years, Lake Curry affects Suisun Creek downstream of the Napa-Solano County line. So, in most years, Lake Curry significantly affects the magnitude of the annual maximum flood on Suisun Creek. The analysis also gives an indication of the approximate size of Lake Curry's zone of influence on the annual maximum flood.

<u>Flood Regionalization</u>

Flood frequency information from 17 USGS gaging stations was used to create a regional flood frequency curve for the region around Lake Curry. Gaging stations within 30 miles of Lake Curry with no significant upstream regulation (reservoirs) and at least five years of record were incorporated into the regionalization. The watersheds above these 17 stations tend to have similar topography and are rural. The watershed above Lake Curry has similar topography and land use. Table 6 lists the 17 stations used in this study.

The maximum annual flood discharge for each year of record (annual flood series) was transformed into a dimensionless (cfs/cfs) series by dividing each annual maximum flood by the mean annual flood for that gaging station. The 17 dimensionless annual flood series were then lumped into a single data set with a total of 272 observations. A Kruskal-Wallis non-parametric test showed that there was a 95% chance that the 17 dimensionless flood series all had the same statistical distribution. Therefore, it is reasonable to group the observations from the 17

Figure 29. This histogram shows the number of years that the zone of influence of Lake Curry, measured as the watershed area required to reduce the ratio of available storage to watershed area to 103 acre-feet per square-mile. The available storage was estimated on or about January 1 each year. The data for the histogram are in the last column of Table 4.

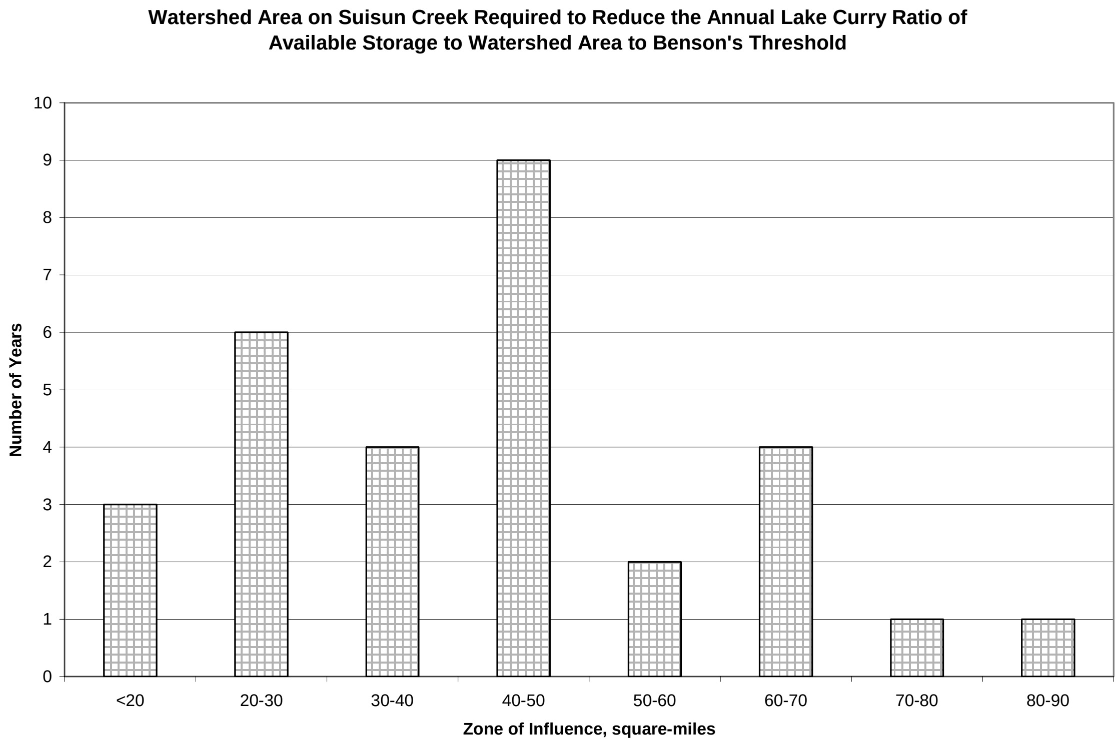


Table 5. The watershed areas for selected locations along Suisun Creek are given below.

Location on Suisun Creek	Watershed Area Upstream of Location (in square-miles)
Lake Curry Dam	17.0
Suisun Creek upstream of confluence with Wooden Valley Creek	22.4
Suisun Creek downstream of confluence with Wooden Valley Creek	36.4
Suisun Creek at Napa-Solano County Line	41.0
Suisun Creek at Suisun Marsh	53.0

Table 6. The 17 USGS gaging stations used in this study are listed below. The Napa River near St Helena has 62 years of record between 1929 and 2001. The other stations were in operation for various portion of the period 1956 to 1983.

Station	Station Number	Number of Years of Record	Drainage Area (in sq-mi.)	Latitude	Longitude	Distance (in miles)	Azimuth	Median Annual Flood (in cfs)	Mean Annual Flood (in cfs)
Capell Creek trib near Wooden Valley	11453700	15	0.87	38.43	122.21	7.03	321.20	142	145
Dry Creek near Napa Ca	11457000	15	17.40	38.36	122.36	12.98	269.63	1,400	1,614
Lake Hennessey trib near Rutherford	11456400	14	1.04	38.48	122.36	15.38	305.53	51	65
Milliken Creek trib near Napa	11458120	5	2.54	38.34	122.28	8.57	259.20	237	219
Milliken Creek near Napa	11458100	13	17.30	38.34	122.27	7.99	260.24	1,920	1,858
Napa at Calistoga	11455900	8	21.9	38.58	122.58	29.14	302.39	2,345	2,310
Napa Creek near Napa	11458300	13	14.90	38.30	122.30	10.51	247.86	2,100	1,652
Napa River near St. Helena	11456000	62	81.40	38.50	122.43	19.23	301.20	6,290	6,417
Pleasants Creek near Winters	11454100	8	15.90	38.48	122.03	9.94	59.22	1,890	1,784
Pope Creek near Pope Valley	11453600	20	78.30	38.63	122.33	22.41	329.80	7,040	7,416
Redwood Creek near Napa	11458200	15	9.79	38.32	122.34	12.25	256.61	1,160	1,069
Sarco Creek near Napa	11458150	6	3.56	38.33	122.25	7.15	255.39	416	441
Sonoma Creek at Agua Caliente	11458500	27	58.40	38.32	122.49	20.19	263.06	5,900	5,415
Sonoma Creek at Kenwood	11458400	16	6.07	38.44	122.54	23.22	285.01	1,170	1,232
Sulphur Creek near St. Helena	11455950	14	4.50	38.49	122.48	21.45	295.55	512	565
Tulacay Creek near Napa	11458350	12	12.60	38.29	122.28	9.68	238.15	948	1,044
Wragg Creek near Winters	11453800	9	0.74	38.43	122.16	5.56	340.04	169	149

Table 7. The descriptive statistics for the combined dimensionless annual maximum flood observations at 17 USGS gaging stations are shown in the table below. The ratio of skew to its standard error and the ratio of kurtosis to its standard error are both within the range of +/-2.0, indicating that the data has a normal distribution.

Grouped Dimensionless Flood Series Annual Maximum Discharge/Mean Annual Flood for the Station	
N	272
Mean	1.000
Standard Error of Mean	0.036
Median	0.997
Mode	0.450
Standard Deviation	0.601
Variance	0.361
Skewness	0.253
Standard Error of Skewness	0.148
Kurtosis	-0.446
Standard Error of Kurtosis	0.294
Range	2.833
Minimum	0.007
Maximum	2.840
Ratio of Skew to Standard Error of Skewness	**1.71**
Ratio of Kurtosis to Standard Error of Kurtosis	**-1.52**

stations. Table 7 shows the descriptive statistics for the group dimensionless flood series. The ratio of the skew to its standard error and the ratio of kurtosis to its standard error are both within the range of +/-2.0, indicating that the data has a normal distribution. Consequently, a normal distribution was fit to the grouped dimensionless flood series to obtain the return period for various magnitude floods.

Table 8 shows the recurrence intervals for various values of the grouped dimensionless flood series for the Lake Curry region. The mean annual flood (ratio = 1.0) has a recurrence interval of 2.0 years.

The bankfull discharge is considered to be the discharge that is most responsible for shaping the stream channel. Leopold (1994) suggests that the 1.5 year return period (recurrence interval) discharge, on the annual flood series, can be taken as a good approximation of the bankfull discharge. Table 8 shows that the 1.5-year return period dimensionless discharge is 0.7411 times the mean annual flood for the station.

Table 8. The recurrence intervals for various values of the grouped dimensionless flood series for the Lake Curry region are shown below. The dimensionless flood series is formed by dividing each annual flood by the mean annual flood for the station. The mean annual flood (ratio = 1.0) has a recurrence interval of 2.0 years.

Recurrence Interval (in years)	Probability of Exceedence	Ratio of Annual Maximum Flood to Mean Annual Flood
1.05	95.00%	0.0112
1.10	90.91%	0.1974
1.19	**84.12%**	**0.3991**
1.30	76.92%	0.5574
1.50	66.67%	0.7411
2.00	**50.00%**	**1.0000**
2.33	42.92%	1.1073
5.00	20.00%	1.5059
6.30	**15.87%**	**1.6010**
10.00	10.00%	1.7704
25.00	4.00%	2.0524
50.00	2.00%	2.2346
100.00	**1.00%**	**2.3985**

Applying the Regional Flood Frequency Curve

The regional flood frequency curve shown in Figure 30 can be applied to any ungaged location. However, to convert the ratio of annual flood to mean annual flood to a discharge measured in cubic feet per second it is necessary to relate the mean annual flood to some characteristic(s) of the watershed above the point of interest. The selected watershed characteristic(s) should be available for the ungaged location and for each of the 17 USGS gaging stations used to develop the regional frequency curve. The watershed area above the point of interest was selected as the watershed characteristic to convert the dimensionless frequency curve to a standard frequency curve.

Figure 30. The Lake Curry regional dimensionless flood frequency curve is shown above. A normal distribution was fitted to the grouped dimensionless flood series from 17 USGS gaging stations within 30 miles of Lake Curry. The mean annual flood (ratio = 1.0) has a return period of 2 years.

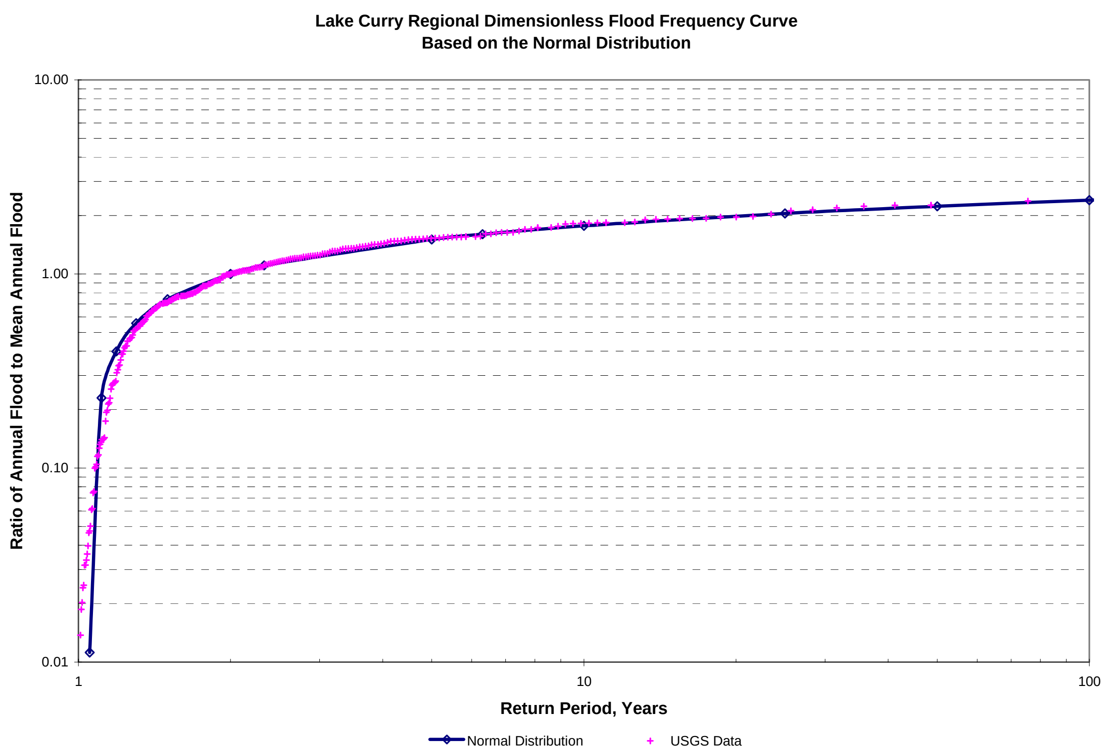


Figure 31 shows the relationship between the mean annual flood and watershed area for the 17 USGS gaging stations. The power function that was fit to the data by linear regression has a R^2 value of 0.956, indicating that watershed area explains about 95% of the variability in the mean annual flood. The four labeled stations indicate stations that were outside the 95% confidence interval for the regression.

Difference in rainfall patterns between the watersheds above the 17 USGS gaging stations probably account for most of the remaining variability in the mean annual flood.

Lake Curry has a watershed area of 17 square-miles. Applying the relationship between mean annual flood and watershed area shown in Figure 31 produces an estimate of 1,758 cfs for the unimpaired mean annual flood at the site of the Lake Curry dam. Applying the estimate of the mean annual flood to the regional dimensionless flood frequency curve produces the table of values shown in Table 9. Discharge estimates have been rounded to the nearest 10 cfs. The 1.5-year return period discharge is considered a reasonable estimate of the bankfull discharge. So, the bankfull discharge at the dam is about 1,300 cfs.

Estimating the Spillway Discharge

The City maintains a chart recorder to track the water surface elevation of Lake Curry. The charts are only made when the elevation in the lake is close to the level of the spillway. So, charts are only produced in years when the reservoir spills.

Water level charts were obtained for 1993 through 2000, excluding 1994 when the reservoir did not spill. The City verified that the lake did not spill in 1991, 1992, and 2001. So, Lake Curry did not spill in four of the 12 years between 1991 and 2002.

The available charts were digitized so that a spreadsheet could determine the maximum elevation of the lake and the number of days the lake was spilling.

The discharge over the spillway can be estimated by considering the spillway to be a broadcrested weir. The discharge of a broadcrested weir, Q, is given by

$$Q = CLH^{(3/2)} \qquad (3)$$

Where H is the depth of the water (head), L in the length of the weir, C is an empirically determined coefficient. The values of C from Table 47 of *The Handbook of Hydraulics*, 4th edition by Horace Williams King were used in the formula. The value of C depends on the head and the breadth of the weir. The breadth of the Lake Curry spillway is almost 30 feet. The values of C in Table 47 for a weir with a breadth of 15 feet are almost independent of head and tend to a constant value of 2.63. The

Figure 31. The relationship between the mean annual flood and watershed area for the 17 USGS gaging stations is shown above. The power function that was fit to the data by linear regression has a R^2 value of 0.956, indicating that watershed area explains about 95% of the variability in the mean annual flood. The four labeled stations indicate stations that were outside the 95% confidence interval for the regression. Difference in rainfall patterns between the watersheds above the 17 USGS gaging stations probably account for most of the remaining variability in the mean annual flood.

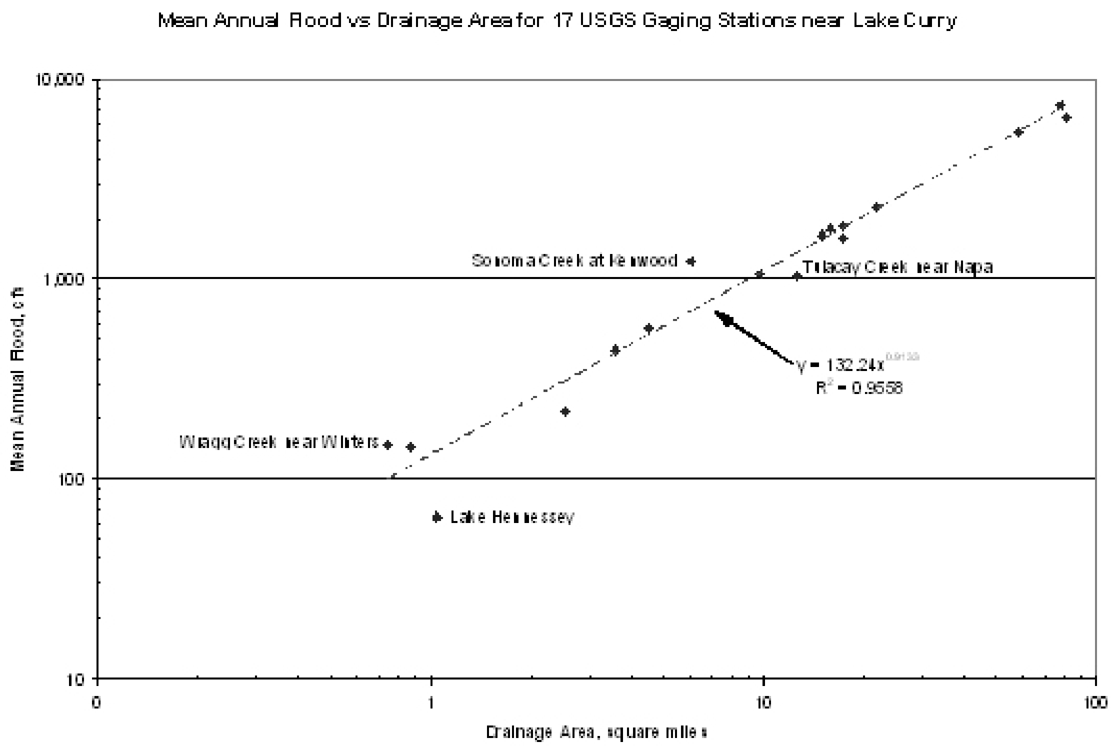


Table 9. The regression equation expressing the relationship between the mean annual flood and the watershed area estimates the unimpaired mean annual flood at the site of the Lake Curry dam to be 1,758 cfs. Applying the estimate of the mean annual flood to the regional dimensionless flood frequency curve produces the following table of values. Discharge estimates have been rounded to the nearest 10 cfs. The 1.5-year return period discharge is considered a reasonable estimate of the bankfull discharge. So, the bankfull discharge at the dam is about 1,300 cfs.

Recurrence Interval (in years)	Probability of Exceedence	Ratio of Annual Maximum Flood to Mean Annual Flood	Expected Unimpaired Lake Curry Watershed Flood Discharge (in cfs)
1.11	90.00%	0.230	400
1.19	**84.12%**	**0.399**	700
1.30	76.92%	0.557	980
1.50	66.67%	0.741	1,300
2.00	**50.00%**	**1.000**	1,760
2.33	42.92%	1.107	1,950
5.00	20.00%	1.506	2,650
6.30	**15.87%**	**1.601**	2,820
10.00	10.00%	1.770	3,120
25.00	4.00%	2.052	3,610
50.00	2.00%	2.235	3,930
100.00	**1.00%**	**2.398**	4,220

Lake Curry spillway has a total length of about 46 feet, so the value of L in equation (3) is 46 feet. The head was determined by subtracting 377.1 feet from all of the lake levels. Of course, if the lake level was less than 377.1 feet, there was no flow over the spillway.

The City releases about three cfs through an outlet structure. The actual release varies somewhat, but it is always less than seven cfs. The three cfs release is small enough that it is inconsequential when water is going over the spillway.

Table 10 shows the maximum lake level for the year, the number of days the lake spilled and the estimated maximum discharge over the spillway. The annual maximum discharge at the Napa River near St. Helena stream gage is shown for comparison. The discharge for the Napa River near St. Helena was estimated from the recorded gage height for the period 1997-2000. The details of estimating the missing discharges for the Napa River near St. Helena are shown in the appendix. The return period for the Napa River near St. Helena annual floods are also shown. During the 12 year period shown, the discharge over the spillway was always less than the estimated bankfull discharge (1.5-year frequency) of 1,300 cfs at the dam. In contrast, the Napa River near St. Helena equaled or exceeded its estimated bankfull discharge (4,760 cfs) in seven of the same 12 years.

Table 10 shows that the estimated zone of influence of Lake Curry on flood discharges was greater than 41 square miles in seven of the 12 years from 1991 through 2002. This indicates that the zone of influence of Lake Curry extended downstream of the Napa-Solano county line in those seven years. In other words, the flood discharges from Wooden Valley Creek, added to the decreased storm discharges in Suisun Creek, were probably insufficient to produce bankfull discharges between the confluence and the Napa-Solano county line in at least seven out of the 12 years studied.

The virtual elimination of bankfull discharges below Lake Curry affects the sediment transport processes below the dam and likely in Suisun Creek as far downstream of the Napa-Solano county line in many years. The lack of discharges in Suisun Creek greater than or equal to bankfull indicates that only the finer sediments tend to be moved in most years. Since the coarser bed material is not being moved, any deposition of fine material on the bed has the potential to increase the embeddedness of the larger material. An increase in embeddedness will tend to decrease the suitability of the bed for steelhead spawning. In addition, higher embeddedness tends to decrease the reproduction of aquatic insects that provide food for juvenile steelhead.

During the 12 year period of 1991 through 2002, Lake Curry spilled in eight years. However, all of the estimated spillway discharges during this period were less than the estimated unimpaired bankfull discharge of 1,300 cfs, for the 17 square mile watershed impounded by the reservoir.

Table 10. The table shows the maximum lake level for the year, the number of days the lake spilled and the estimated maximum discharge over the spillway. The annual maximum discharge at the Napa River near St. Helena stream gage is shown for comparison. The return period for the Napa River near St. Helena annual floods are also shown. During the 12 year period shown, the discharge over the spillway was always less than the estimated bankfull discharge (1.5-year frequency) of 1,300 cfs at the dam. In contrast, the Napa River near St. Helena equaled or exceeded its estimated bankfull discharge (4,760 cfs) in seven of the same 12 years. The discharge for the Napa River near St. Helena was estimated from the recorded gage height for the period 1997-2000. The estimated discharges for the Napa River near St Helena are shown in bold.

Water Year	Maximum Water Surface Level	Number of Days Lake Spilled	Estimated Maximum Spillway Discharge (in cfs)	Napa River near St. Helena (in cfs)	Napa River near St. Helena Recurrence Interval
1991	364.40	0	0.00	6940	2.24
1992	365.30	0	0.00	2890	1.22
1993	379.30	254	390	7,930	2.88
1994	375.90	0	0.00	900	1.08
1995	381.15	140	990	11,100	8.90
1996	379.60	127	480	5,800	1.77
1997	381.45	89	1,100	**10,190**	6.10
1998	380.73	134	840	**8,850**	3.79
1999	377.96	92	100	**5,870**	1.80
2000	377.85	22	80	**4,080**	1.37
2001	374.90	0	0.00	3,280	1.26
2002	377.80	N/A	70	3,970	1.36
Estimated Bankfull Discharge =			1,300	4,760	
Number of years ≥ Bankfull Discharge =			0	7	
Percentage of Years ≥ Bankfull Discharge =			0.00%	58.33%	

Assessment: Hydrology and Geomorphology

The Suisun Creek watershed consists of two major subbasins – Wooden Valley Creek and Suisun Creek. An evaluation of the slope class and natural confinement of these two creeks was completed to define several basic characteristics about each creek. Suisun Creek, from the Lake Curry outlet to Suisun Marsh is a low slope (<1%), unconfined, alluvial channel that under natural conditions would have a pool/riffle pattern and an adjacent floodplain where stormflows spread out and slow down. Under natural conditions, Suisun Creek would probably support significant riparian forest and may have spawning habitat for salmonids, and depending on the availability of cold water in summer, rearing habitat for salmonids.

Wooden Valley Creek varies from many steep headwater creeks to the unconfined alluvial creek in Wooden Valley to a low slope bedrock gorge to an unconfined channel. Because the channel does not become steep in its bedrock section, and flow is year round, it supports spawning and rearing habitat for salmonids, but has a limited area for riparian forest. The unconfined areas of Wooden Valley Creek under natural conditions would probably support significant riparian forest and salmonid rearing habitat and, if summer cold water is available, rearing habitat for salmonids. The stream network in both subbasins consists of steep tributary streams in the mountainous area that are prone to rapid movement of stormwater and sediment. The valley creeks are low in slope and store, as well as transport sediment and may require long periods to move out large sediment deposits.

Flood prone areas occur in the most downstream area of the watershed (stream miles 0-4). An increase in channel entrenchment in the floodplain areas of the upper watershed produces faster delivery of stormwater to the lower watershed. This condition combined with tidal inflows have likely increased flood problems in this area. Recent studies evaluated Lake Curry for control of large flood events, but it is too small and too distant to be effective.

Lake Curry's effect on small flood events (two-year flood) that shape and change the stream channel was evaluated. Records of the frequency and duration of flows over the spillway in a twelve-year period show a major effect on reducing bankfull flows and their effect on stream morphology for many miles downstream of the reservoir. During this same period the nearby Napa River experienced bankfull flows in seven of the twelve years and Suisun Creek experienced no bankfull flows below Lake Curry. Currently, Lake Curry releases 2.0 – 3.0 cfs into Suisun Creek in the summer.

Channel cross sections surveyed on Wooden Valley and Suisun Creek showed little change due to low rainfall and the likely effects of Lake Curry on Suisun Creek. Fine sediment levels measured at both study reaches were very high and indicate the need for erosion control and soil conservation projects in the watershed.

Vegetation

Uplands

The Suisun Creek watershed has a variety of native vegetation types. General vegetation types for the watershed were determined using the Information Center for the Environmental (ICE) Vegetation maps. The extent of the riparian forest was delineated in the GIS for Suisun and Wooden Valley Creeks. Transects of the riparian forest to document species diversity, vegetation density, understory vegetation, invasive plant species and wildlife habitat elements were completed in several locations along with numerous observations at various points along the creeks.

Suisun Creek watershed has a dry climate during the summer months and only drought-tolerant species are able to survive in most areas. Black oak woodland dominated by deciduous black oak (*Quercus kelloggii)* covers most of the hills in the upper areas of the watershed. Coast live oak (*Quercus agrifola*) woodland and blue oak woodland (*Quercus douglasii*) also occur on slopes of the watershed. Chaparral scrub occurs along the western edge of Wooden Valley and several areas of the north and eastern area of the Suisun Creek subbasin. For the most part the valley areas have been transformed to agricultural and urban uses.

Rare Plants

A search of the California Natural Diversity Database (CANDDB) administered by the California Department of Fish and Game was completed. The CANDDB contains records of occurrences of rare and endangered plant and animal species recorded on USGS topographic quadrangles. The CANDDB list does not represent a comprehensive search or evaluation of habitat or rare and endangered species occurrence. Instead the CANDDB is a database of known occurrences of rare and endangered species collected from EIRs, development project reports and research projects.

Table 11 shows the information from the CANDDB maps for the Suisun Creek watershed. In addition to these plants and animals, steelhead trout (*Oncorhynchus mykiss*) is a federally-listed threatened species that occurs in Suisun and Wooden Valley Creeks.

Riparian Forest

Riparian forest lines Suisun and Wooden Valley Creeks and many tributary streams. Figures 32-40 illustrate the location and extent of the riparian corridor as well as areas without riparian forest on Suisun and Wooden Valley Creeks. The average width of the riparian corridor along Wooden Valley Creek in Wooden Valley was measured at 172 feet and 120 feet along Suisun Creek from the confluence with Wooden Valley Creek to Suisun Marsh. Riparian forest is missing from portions of Wooden Valley and White Creeks.

Table 11. Natural Diversity Database Listings for the Suisun Creek Watershed					
USGS Topographic Quad Sheet Name	**Subbasin**		**Species Common Name**	**Species *Scientific Name***	**Listing Status**
Capell Valley	Wooden Valley Creek	Terrestrial Natural Community	Northern Vernal Pool		----
Mt. George	Wooden Valley Creek	Insect	Valley Elderberry Longhorn Beetle	*Desmocercus californicus dimorphus*	*Federally endangered*
Mt. George	Suisun Creek	Insect	Valley Elderberry Longhorn Beetle	*Desmocercus californicus dimorphus*	*Federally endangered*
Mt. George	Suisun Creek	Plant	Brewer's Western Flax	*Hesperilinon breweri*	*No listing*
Mt. George	Wooden Valley Creek	Plant	Marin Checkerbloom	*Sidalcea hickmanii ssp viridis*	*No listing*
Mt. George	Wooden Valley Creek	Plant	Dwarf Downingia	*Downingia pusilla*	*No listing*

Riparian forest grows on floodplains and channel banks of most year round and seasonal creeks (see Figure 41), and some ephemeral creeks. Most riparian tree species are deciduous, losing their leaves in the fall and shading the creek in the summer. Water temperatures in the stream are highly affected by the level of shading from riparian forest. Riparian trees also have dense root systems and can protect banks from erosion.

Based on field evaluations and transects, the riparian forest along the unconfined portions of Wooden Valley Creek and the entire length of Suisun Creek below Lake Curry includes a variety of tree species – willow (*Salix sp.*), white alder (*Alnus rhombifolia*), Oregon ash (*Fraxinus latifolia*), big leaf maple (*Acer macrophyllum*), box elder (*Acer negundo*), valley oak (*Quercus lobata*), California bay laurel (*Umbellularia californica*), California buckeye (*Aesculus californica*) and California black walnut (*Juglans californica*). Riparian forest develops along the bankfull channel with colonizer species such as willow and alder. Farther away from the channel, the more diverse forest occurs with maple, Oregon ash, California walnut, box elder, California buckeye and sometimes valley oak. In most locations on Suisun Creek, the riparian corridor is relatively narrow due to development of the floodplain.

In the confined channel of Wooden Valley Creek, large bay laurel and coast live oak, as well as willow and white alder, dominate the channel and steep rocky banks.

Figure 32. Index to Figures 33-40

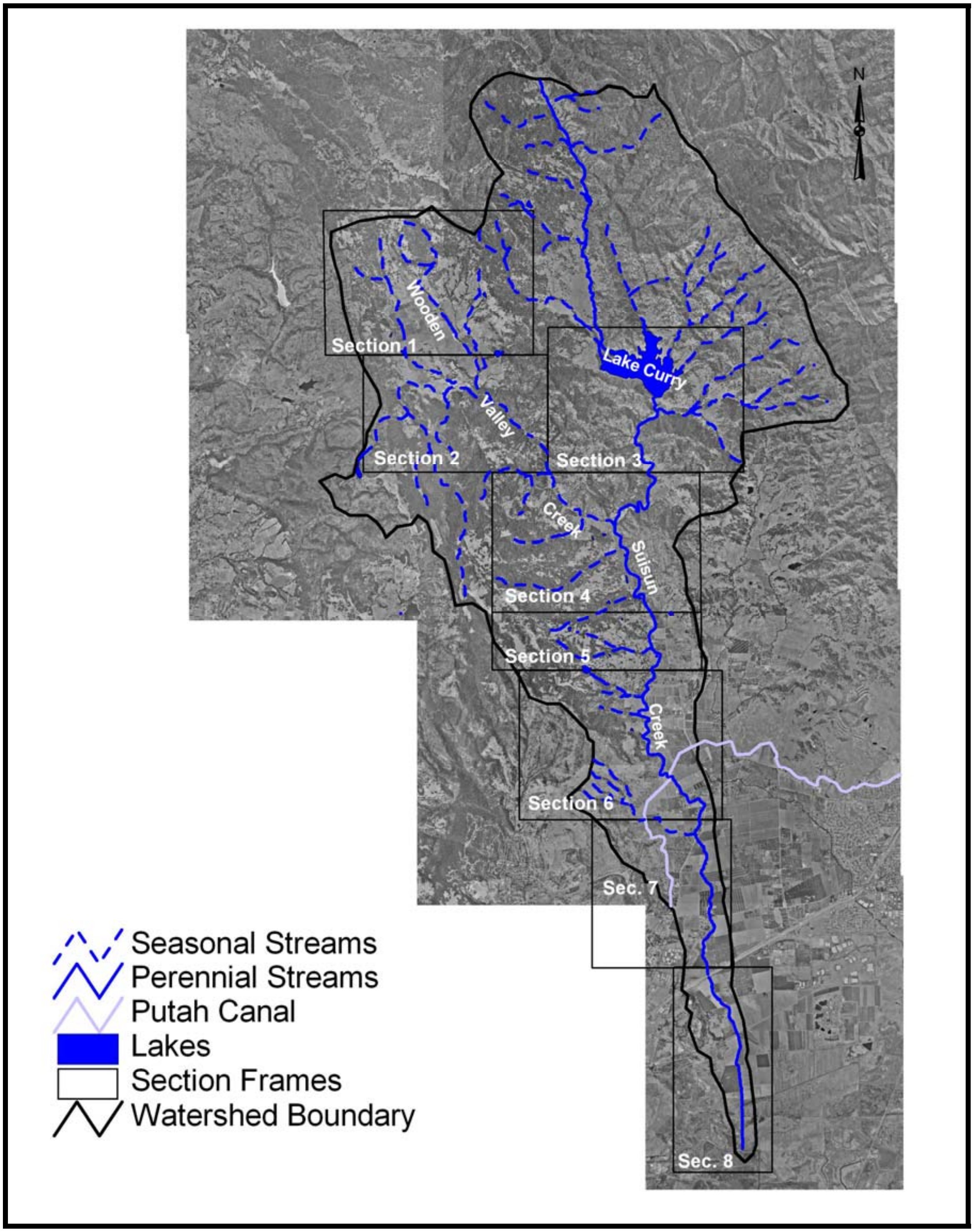


Figure 33. The Location and Extent of the Riparian Corridor along Suisun Creek in the Suisun Creek Watershed – Section 8

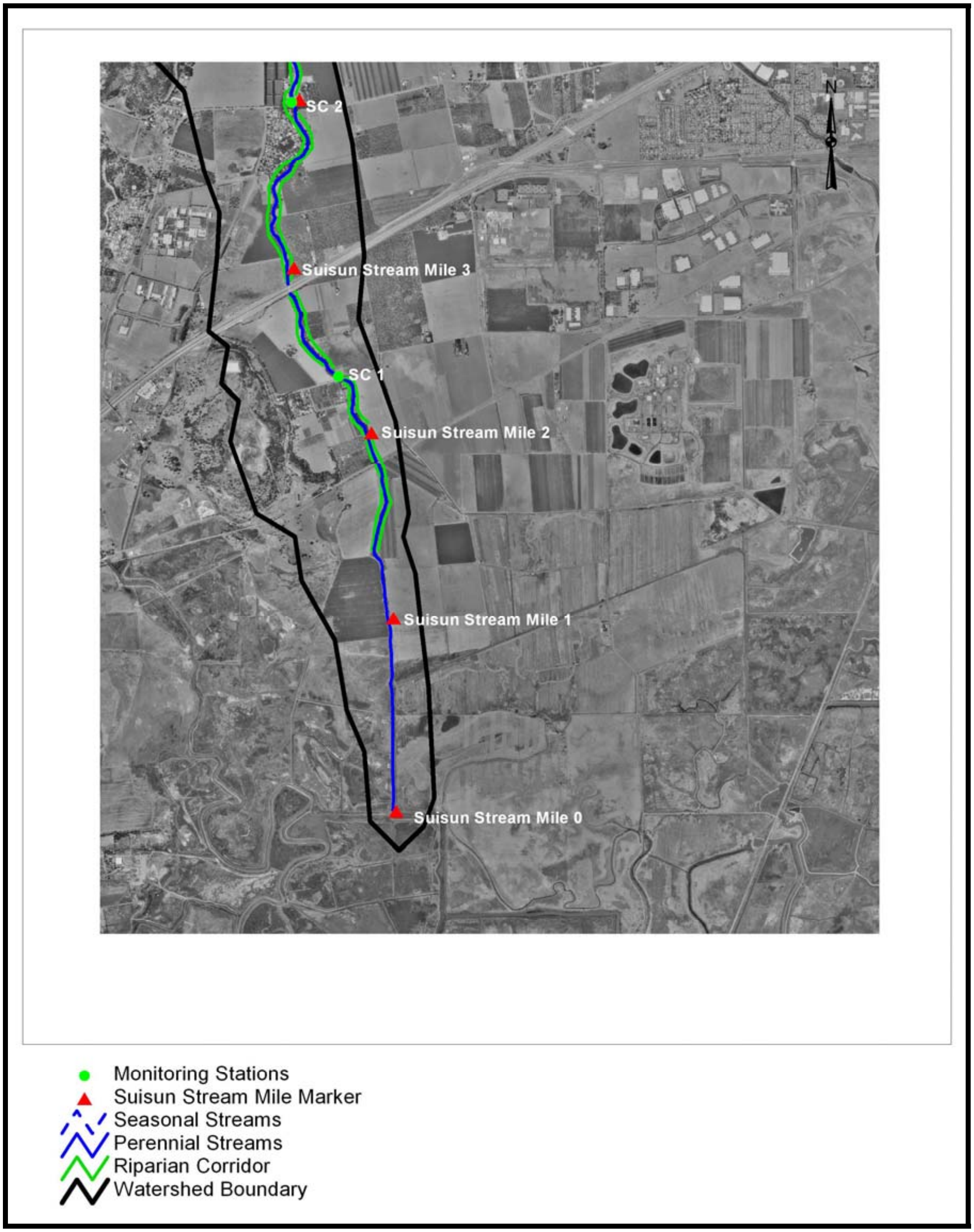


Figure 34. The Location and Extent of the Riparian Corridor along Suisun Creek in the Suisun Creek Watershed – Section 7

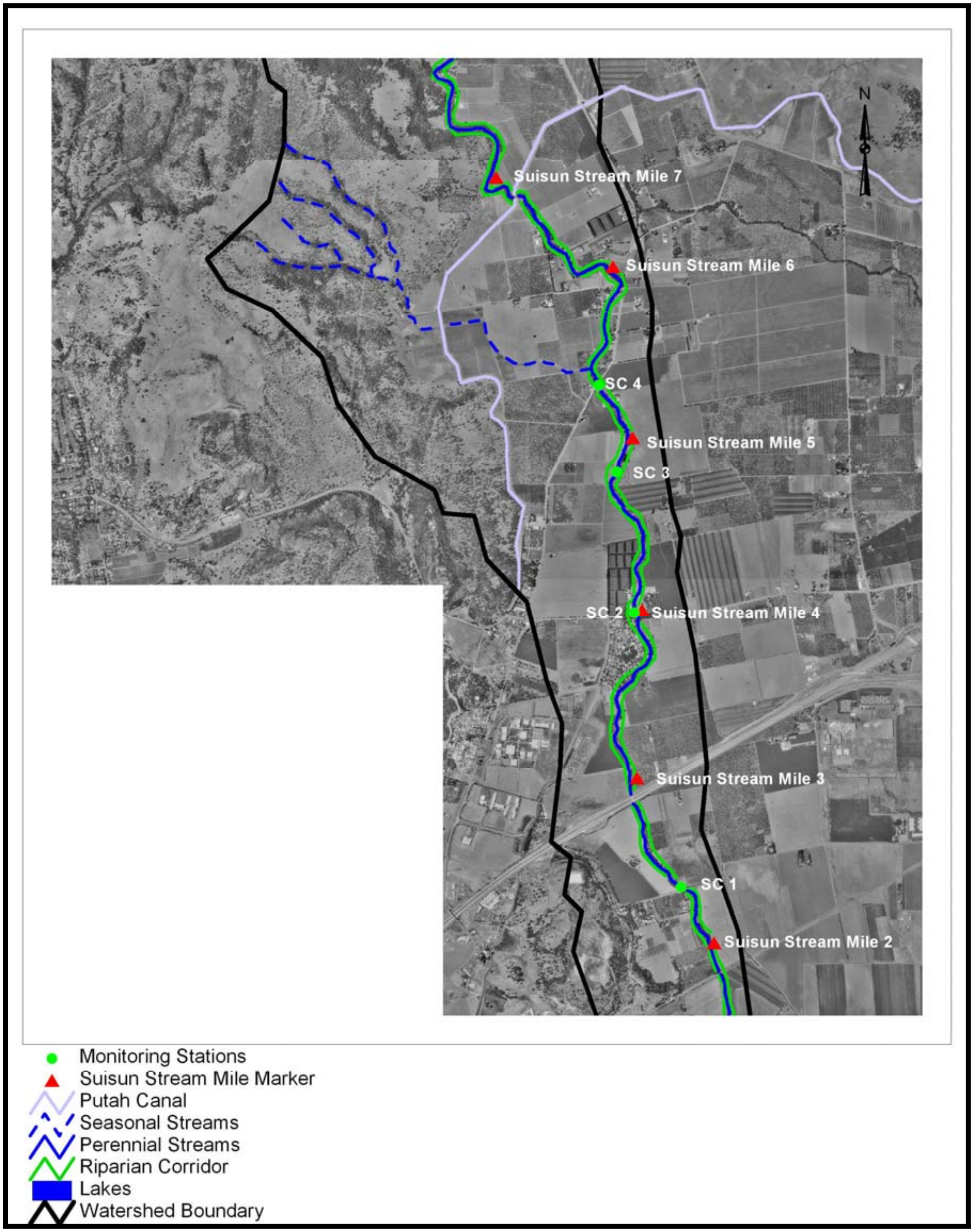


Figure 35. The Location and Extent of the Riparian Corridor along Suisun Creek in the Suisun Creek Watershed – Section 6

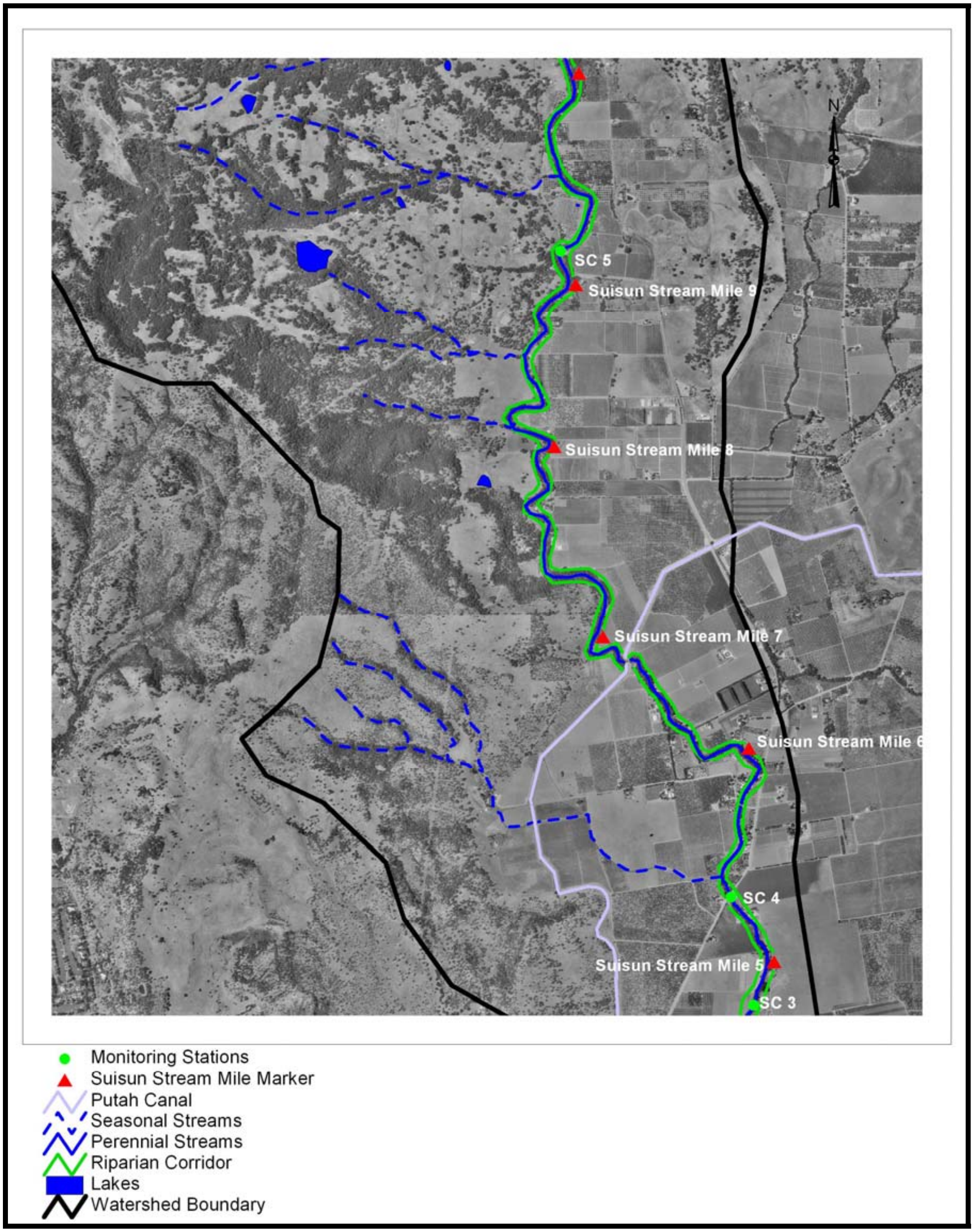


Figure 36. The Location and Extent of the Riparian Corridor along Suisun Creek in the Suisun Creek Watershed – Section 5

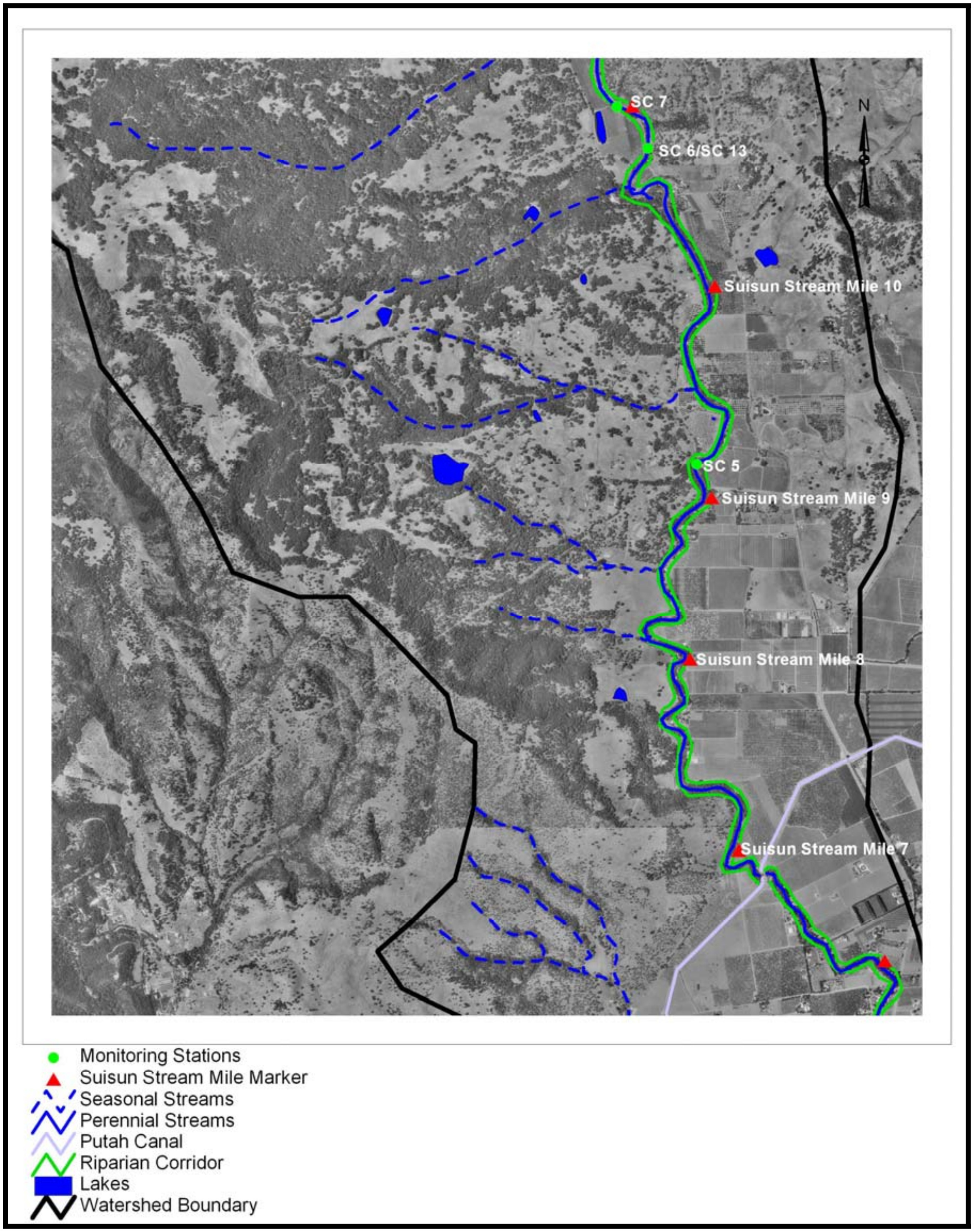


Figure 37. The Location and Extent of the Riparian Corridor along Suisun and Wooden Valley Creeks in the Suisun Creek Watershed – Section 4

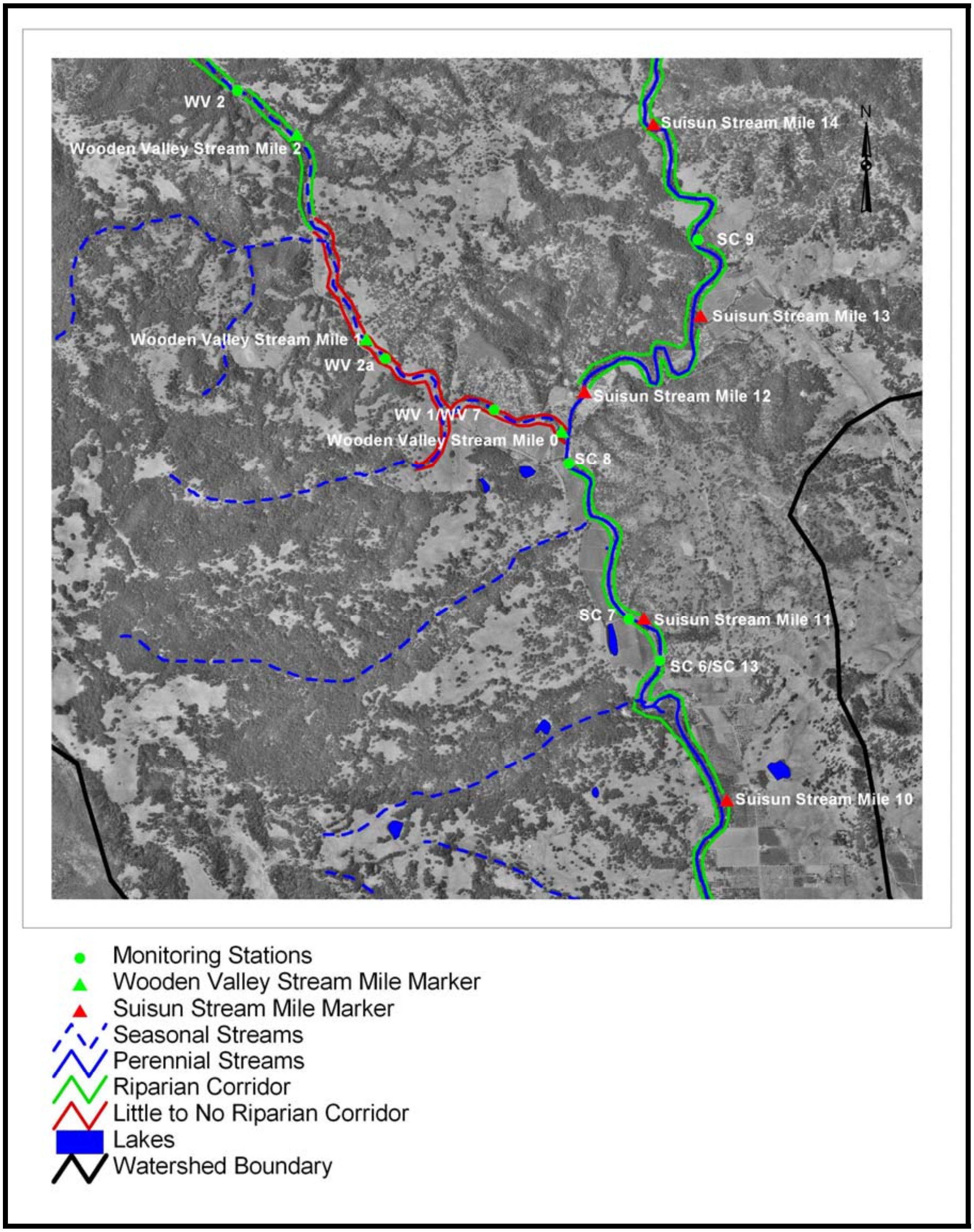


Figure 38. The Location and Extent of the Riparian Corridor along Suisun and Wooden Valley Creeks in the Suisun Creek Watershed – Section 3

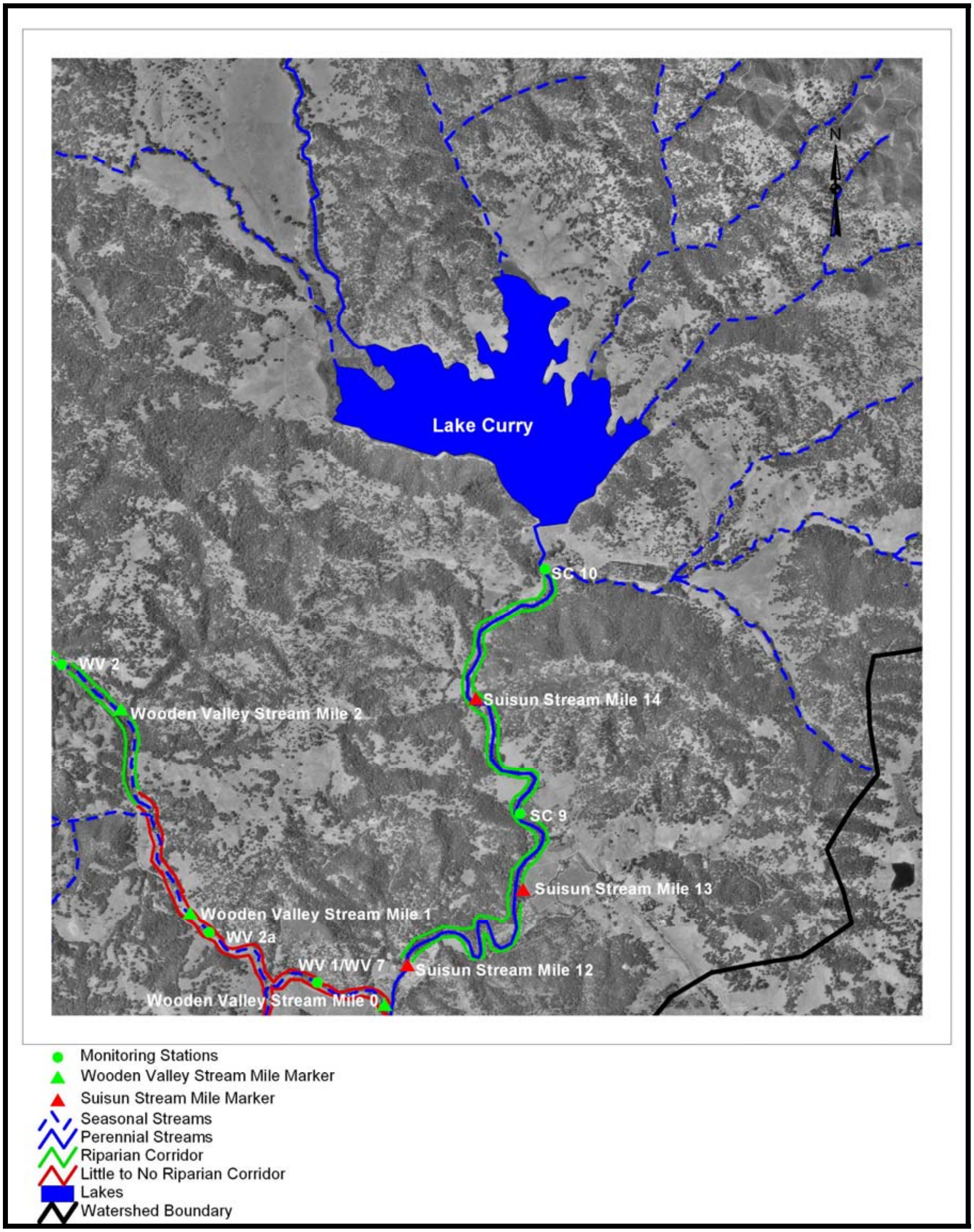


Figure 39. The Location and Extent of the Riparian Corridor along Wooden Valley and White Creeks in the Suisun Creek Watershed – Section 2

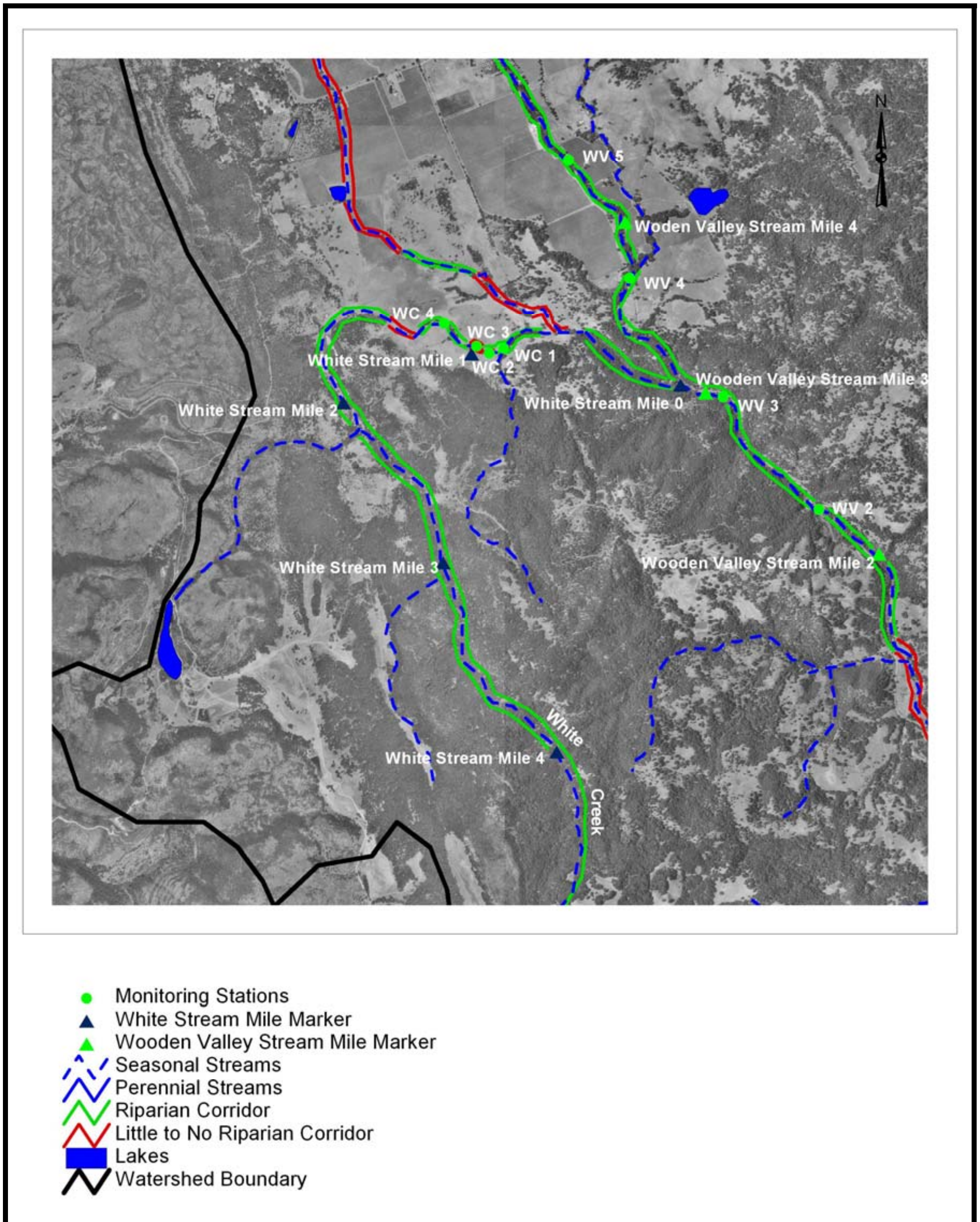
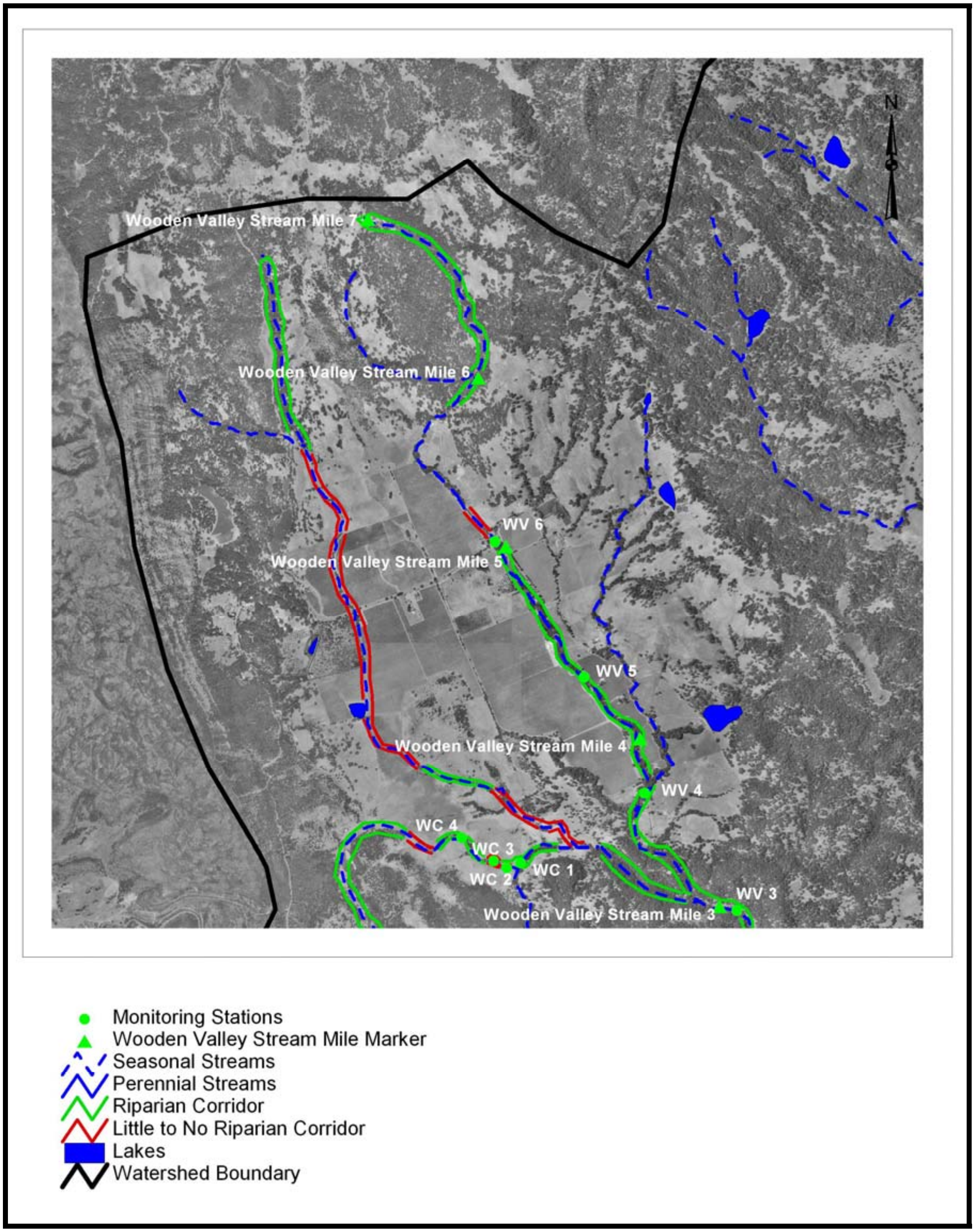


Figure 40. The Location and Extent of the Riparian Corridor along Wooden Valley and White Creeks in the Suisun Creek Watershed – Section 1



Wildlife values of riparian forest are greatest when the diversity of native plant species is high and creates numerous microhabitats for wildlife. A mixture of brushy, tall- and middle-sized trees, along with native understory plants and vines, provides for a variety of nesting and feeding areas for birds, mammals, amphibians and reptiles. A variety of native trees, along with downed logs and slash, standing dead trees, older trees with holes and loose bark, and plants with berries, seeds, acorns, cones and flowers give the riparian corridor food resources, nesting areas and the ability to support a large diversity of species in great numbers. The proximity of the riparian corridor to water increases its value. The linear extent and width of the riparian corridor and its proximity to upland habitats is another factor in determining habitat value. Table 12 is a list of animal species likely to be found in larger areas of riparian habitat in the Suisun Creek watershed as defined using the Wildlife Habitat Relationships (WHR) model of the California Department of Fish and Game (Zeiner et al 1988).

The riparian corridor in the Suisun Creek watershed has several invasive, non-native species including giant reed (*Arundo donax*), Himalayan blackberry (*Rubus discolor*), blue periwinkle (*Vinca major*) and Harding grass (*Phalaris aquatica*). These non-native species are introduced from other countries and become weeds in their new area, out-competing the native riparian plants. Because riparian corridors are adapted to floods and disturbance, and weedy invasive species are also adapted to invade disturbed areas, these species can take over riparian corridors. Invasive species have the effect of reducing the value of riparian areas as wildlife habitat by replacing native feeding and nesting habitat with non-native plants.

Giant reed (*Arundo donax*) is a prime example of the effect of invasive species on native plant communities (Brossard et al 2000). Giant reed is a grass that reaches 30 feet in height and grows in large clumps. It spreads as nodes of the grass break off, or as whole stalks knocked down in floods, lie down and root. Giant reed grows extraordinarily fast and out-competes native species. Giant reed also uses great volumes of water, more than most native riparian species. In stream channels where scour of vegetation is common, the reed is readily distributed. In many river systems (Santa Ana River, Russian River, Sonoma Creek) where giant reed has invaded, it has spread very quickly.

Currently, the extent of giant reed on Suisun Creek appears to be limited to isolated patches or clumps. No clumps were observed on Wooden Valley Creek. A special low elevation flight to produce new photographs with a more thorough inventory and mapping program is needed to characterize the problem and formulate an effective control and eradication strategy (see Section IV).

The other invasive species – Himalayan blackberry, blue periwinkle and Harding grass are found in the understory of the riparian corridor throughout both creek systems. Native understory plants such as snowberry (*Symphoricarpos rivularis),* spicebush (*Calycanthaceae occidentalis*), California blackberry (*Rubus ursinus*), sedges (*Carex sp.*) and rushes (*Juncus sp.*) have difficulty competing against the invasive species.

Figure 41. Transect Across Well-Developed Riparian Corridor on Unconfined Channel and Floodplain

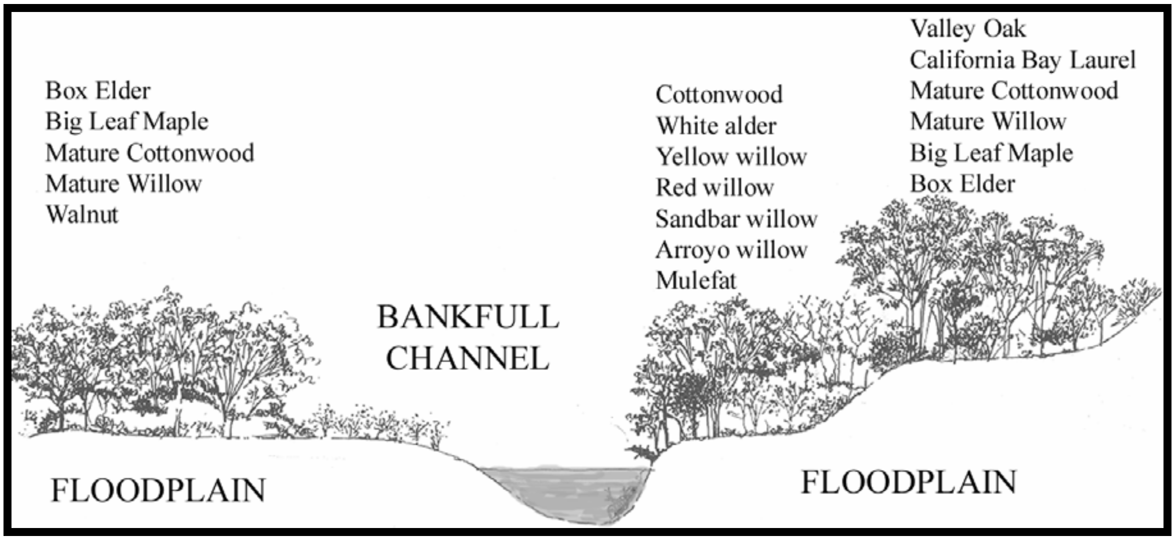


Table 12. Likely Wildlife Species in Larger Areas of Riparian Habitat in Suisun Creek Watershed, Defined by the Wildlife Habitat Relationships (WHR) Model of the California Department of Fish and Game

NAME	HABITAT SUITABILITY RATING		
	REPRODUCTION	COVER	FEEDING
California Giant Salamander	M	M	M
California Newt	M	M	M
Ensatina	M	M	M
Black Salamander	M	M	M
Western Toad	M	M	M
Western Pond Turtle	M	M	M
Western Fence Lizard	H	H	H
Western Skink	H	H	H
Ringneck Snake	M	M	M
Racer	M	M	M
Striped Racer	M	M	M
Gopher Snake	H	H	H
Common Kingsnake	H	H	H
Common Garter Snake	H	H	H
Western Terrestrial Garter Snake	H	H	H
Pacific Coast Aquatic Garter Snake	H	H	H
Night Snake	M	M	M

H = High M = Medium L = Low

Table 12. Likely Wildlife Species in Larger Areas of Riparian Habitat in Suisun Creek Watershed, Defined by the Wildlife Habitat Relationships (WHR) Model of the California Department of Fish and Game (cont.)

	HABITAT SUITABILITY RATING		
NAME	**REPRODUCTION**	**COVER**	**FEEDING**
Western Rattlesnake	H	H	H
Great Blue Heron	M	M	M
Great Egret	L	L	M
Green Heron	H	H	H
Mallard	M	M	M
Common Merganser	L	L	H
Osprey	H	H	H
White-Tailed Kite			M
Sharp-Shinned Hawk			H
Cooper's Hawk			H
Red-Shouldered Hawk			H
Red-Tailed Hawk			M
American Kestrel			M
Merlin			M
Ring-Necked Pheasant	L	M	L
Wild Turkey	M	M	H
California Quail	M	M	H
Killdeer	H	H	H
Spotted Sandpiper	H	H	H
Mourning Dove			H
Barn Owl	H	H	H
Western Screech Owl			H
Great Horned Owl			H
Northern Pygmy Owl			M
Long-Eared Owl			H
Common Nighthawk	L	L	H
Common Poorwill			M
Chimney Swift			M
Belted Kingfisher	H	H	H
Hairy Woodpecker	L	L	M
Pacific-Slope Flycatcher		M	M
Black Phoebe	H	H	H
Say's Phoebe	M	M	M
Ash-Throated Flycatcher			H
Western Kingbird			H
Loggerhead Shrike			M
Plumbeous Vireo		M	H
Cassin's Vireo	M	M	H
Warbling Vireo	H	H	H
American Crow			M
Common Raven	H	H	M

H = High M = Medium L = Low

Table 12. Likely Wildlife Species in Larger Areas of Riparian Habitat in Suisun Creek Watershed, Defined by the Wildlife Habitat Relationships (WHR) Model of the California Department of Fish and Game (cont.)			
	HABITAT SUITABILITY RATING		
NAME	REPRODUCTION	COVER	FEEDING
Tree Swallow			H
Violet-Green Swallow			H
Cliff Swallow	H	H	H
Bushtit			H
Canyon Wren	H	H	H
Bewick's Wren			M
House Wren			M
Western Bluebird			M
Swainson's Thrush	L	M	M
American Robin			H
California Thrasher			M
European Starling			M
Orange-Crowned Warbler	M	H	H
Nashville Warbler		M	M
Yellow Warbler	H	H	H
Yellow-Rumped Warbler			H
Black-Throated Gray Warbler		M	M
Townsend's Warbler		M	M
Macgillivray's Warbler			M
Common Yellowthroat	H	H	H
Wilson's Warbler	H	H	H
Yellow-Breasted Chat	L	L	M
Western Tanager		M	M
Spotted Towhee	L	L	M
California Towhee	L	L	M
Lark Sparrow	M	M	M
Fox Sparrow		M	M
Song Sparrow	H	H	H
Lincoln's Sparrow		M	M
White-Crowned Sparrow		H	H
Golden-Crowned Sparrow		H	H
Dark-Eyed Junco	H	H	H
Black-Headed Grosbeak			M
Lazuli Bunting	L	L	M
Brewer's Blackbird	L	M	M
Brown-Headed Cowbird	M		M
House Finch		L	H
Pine Siskin			H
Lesser Goldfinch			H
Lawrence's Goldfinch			H
American Goldfinch			H
H = High M = Medium L = Low			

Table 12. Likely Wildlife Species in Larger Areas of Riparian Habitat in Suisun Creek Watershed, Defined by the Wildlife Habitat Relationships (WHR) Model of the California Department of Fish and Game (cont.)			
	HABITAT SUITABILITY RATING		
NAME	REPRODUCTION	COVER	FEEDING
Virginia Opossum	H	H	H
Vagrant Shrew	H	H	H
Ornate Shrew	M	M	M
Broad-Footed Mole	M	M	M
Long-Eared Myotis	H	H	H
Fringed Myotis			H
Long-Legged Myotis	M	M	M
California Myotis	M	M	M
Western Pipistrelle			M
Big Brown Bat	H	H	H
Western Red Bat			M
Hoary Bat			M
Pallid Bat			M
Brush Rabbit	L	L	H
Desert Cottontail	M	M	H
Black-Tailed Jackrabbit	M	M	M
Sonoma Chipmunk	L	M	M
California Ground Squirrel	M	M	M
Western Harvest Mouse	M	M	M
Deer Mouse	M	M	M
Brush Mouse	H	H	H
Dusky-Footed Woodrat	M	M	M
Black Rat	H	H	H
Norway Rat	M	M	M
House Mouse	M	M	M
California Vole	M	M	M
Common Muskrat	H	H	H
Common Porcupine	L	L	M
Coyote	L	M	H
Gray Fox			H
Black Bear			M
Ringtail	L	L	M
Raccoon	L	L	M
Striped Skunk	M	M	H
Bobcat	L	L	M
Mule Deer	L	L	M
H = High M = Medium L = Low			

Total Number of Species: 136

For example, blue periwinkle produces allelopathic chemicals that suppress the growth of other plants. Once the understory of a native riparian forest is carpeted with blue periwinkle, the seeds of most native trees and understory plants will not germinate and the regeneration of the native forest is greatly reduced. Himalayan blackberry and Harding grass also replace native habitat and reduce the regeneration of native trees.

Locations along Suisun and Wooden Valley Creeks where the riparian corridor is largely missing, are indicated in Figures 37, 39 and 40. These locations can be planted with native riparian species after invasive species are controlled and site disturbance reduced. In addition to areas with no riparian cover, there is a need to increase the width of the riparian corridor in many locations. A single line of trees offers little to wildlife and will not provide structural protection against bank erosion.

Along Suisun Creek near stream mile 4.5, mature riparian forest of large oak and bay trees is being eroded out from stream banks as the channel undergoes the process of entrenchment and bank slumping. The channel is adjusting by deepening and incising into the alluvial floodplain. Once banks reach twenty feet or so in height, they become very unstable and begin to fail. The remaining habitat on the banktop and any trees along the bank are undercut as the bank slumps and the channel widens. Over time, a new floodplain at a lower elevation forms and revegetates, but as this change progresses, riparian trees now providing shade are lost and cold water habitat can also be lost. Property owners also must address bank erosion and its potential effects. As entrenchment of the Suisun Creek channel continues to progress, a pro-active program of revegetation and bank repair could provide shade to the stream much quicker while replacing native habitat and creating a more stable channel with potentially greater flood capacity than present.

Assessment: Riparian Vegetation

The extent and size of the riparian forest corridor along Suisun Creek and Wooden Valley Creek was mapped. Plant species diversity and abundance and the presence of wildlife habitat elements were measured with transects and assessments over both creeks. The riparian corridor has a diversity of large and small native trees and habitat elements such as snags, logs and wildlife food plants. However, in most areas the riparian corridor is relatively narrow.

There are several locations where there is little to no riparian corridor and water temperatures are high. At stream mile 4.5, the process of channel entrenchment is evident with bank erosion undercutting large oaks and much of the riparian corridor on the former, now abandoned, floodplain. This process will result in a wider, deep channel with a new floodplain and seedling riparian trees offering little shade for many years. Active revegetation projects could provide both native plants and stable banks.

Several invasive non-native species were found. Giant reed occurs in isolated clumps on Suisun Creek, but was not found on Wooden Valley Creek. Understory invaders – Himalayan blackberry, blue periwinkle and Harding grass are widespread along both creeks and their tributaries.

Water Temperature and Water Quality

Water temperatures and water quality were monitored at the stations shown in Figure 7.

Water Temperature

Background

Water temperature has a large effect on aquatic life and aquatic habitats. In a Mediterranean climate, water temperatures are cold during the late fall, winter and early spring rainy months. In the hot, dry summer months, water temperatures can increase greatly.

There are a number of factors that affect water temperature – the volume of water flow; the daily hours of sunlight; ambient air temperature; the amount of shade over the water surface, typically called canopy cover; the width and depth of the stream channel and water flow; and the source and temperature of summer water flow – groundwater or reservoir releases.

Most aquatic organisms live in either cold or warm water and are adapted to a particular range of temperatures. Steelhead trout are cold water fish, preferring water below 65ºF. At higher water temperatures of 70-75ºF, there is less dissolved oxygen in the water. While steelhead can withstand temperatures of 70ºF, if exposed to this warmer water for prolonged periods, juvenile fish become lethargic, swim slower and eat less. This behavior reduces the juvenile's ability to survive and makes them more prone to predation. When water temperatures are greater than 70ºF, steelhead need to have a cold water refuge area. This refuge area could be a cold groundwater inflow or spring along the bottom or banks of the creek, or a deep shady part of a pool where the fish can cool down in a current of 65-68ºF, or less, water. If a cold water refuge is not available, the warm water may prove lethal to the steelhead. If temperatures exceed 70-75ºF on a regular basis, or for many hours a day, steelhead juveniles will not survive (Barnhart 1986, California Department of Fish and Game 1998).

Another effect of warm water temperatures in a creek is the increase in predatory fish such as pike minnow (*Ptychocheilus grandis*) or introduced green sunfish (*Lepomis cyanellus*) and small-mouthed bass (*Micropterus. dolomieui*) and other reservoir species. As steelhead juveniles become lethargic at higher water temperatures and predatory fish become more numerous, predation can greatly diminish juvenile steelhead numbers.

Monitoring Results

Water temperatures were monitored at twenty-one stations on Suisun, Wooden Valley and White Creeks in 2002 and 2003. Air temperatures were monitored at two stations. Monitoring focused on the June to October period to assess water temperatures during the hottest time of the year. Canopy cover, width and depth of water, channel type and site conditions were also recorded (see Table 13).

Suisun Creek differs significantly from Wooden Valley and White Creek as it has a continuous summer release of water from Lake Curry. This release was 2.0 cfs in 2002 and 3.0 cfs in 2003 (D. Lynch, City of Vallejo). This reservoir release creates a constant flow in the creek and likely mixes any groundwater flows with reservoir water. Wooden Valley and White Creek have only natural flows from groundwater sources.

In 2001, the temperature of the water column in Lake Curry was monitored by Hanson Environmental, Inc. Lake Curry, like many reservoirs, is stratified in the spring and summer with a layer of warm water on the surface and a pool of colder water at the bottom of the reservoir. Although the lowest outlet on the reservoir outlet works is not functional, it is possible to release water through the outlet works from the cold water pool. The size of the cold water pool varies with the years' rainfall and the overall volume of stored water in the reservoir. In 2001, there was less than average rainfall and Lake Curry did not retain a large cold water pool all summer. Water releases were scaled back from 3.0 cfs to 2.0 cfs in mid-June to extend the release into October. An experimental release of 5-7.0 cfs was not completed due to concern that the cold water pool would be used up and warm water would be released from Lake Curry later in the season. In 2003, a relatively wet year, there was an adequate cold water pool to allow a 3.0 cfs release for the entire dry season.

The water temperature monitoring data was evaluated for several features: the average daily maximum, the average daily minimum and the average daily median temperatures and a seven-day moving average (MA) of both the average daily temperature and the average daily maximum temperature; the daily range in temperature and the number of continuous hours water temperatures exceeded 70ºF (Appendix 1). These analyses give an indication of whether the station location can support steelhead rearing over the summer. The moving averages, along with the three daily averages, give an indication of the overall temperature conditions at the station. If the moving average of the average maximum temperature is in the 68-75ºF or greater range, and the daily range is small, then the water is not cooling sufficiently over the 24-hour period. Finally, the graph of the number of continuous hours water temperatures exceed 70ºF gives an indication of the duration of unsuitable to lethal conditions for steelhead at the station.

It should be noted that water temperature monitoring data records are highly localized conditions. In the case of Suisun Creek, it may be possible for steelhead to find cold water up or downstream of a specific station. For White and Wooden Valley Creeks, where flow levels are low or pools are isolated without flow, there is little option for rearing steelhead to relocate from the monitoring station area. In 2002, dead juvenile steelhead were observed in White Creek where pools were warming and riparian canopy is inadequate. Live juveniles were also observed in White Creek where cold pools remained and were well-shaded.

Table 14 and Appendix 1 illustrate and summarize the temperature monitoring data.

Assessment: Water Temperature

The water temperature monitoring indicates that overall, Wooden Valley and White Creek have the coldest water temperatures and currently best steelhead rearing habitat. There are areas of each creek (Wooden Valley Creek Stations 1 and 2a; White Creek Stations 2 and 3), where riparian canopy is inadequate to maintain shade and retain summer pool habitat. Remaining areas of Wooden Valley Creek (Stations 2-6) have very good to excellent water temperatures and canopy cover for steelhead rearing. White Creek has several locations that have very good water temperatures and canopy cover for steelhead rearing. While all the Wooden Valley and White Creek stations with cold water temperatures have excellent canopy cover, the stations vary in being confined bedrock channels and unconfined alluvial channels. Summer water depths at all the stations with cold water temperatures are relatively shallow at around one foot.

Suisun Creek has good water temperatures for steelhead rearing at only two locations, Stations 9 and 10, immediately below the dam and approximately one-half mile downstream. Water temperatures at Stations 1-8 vary from marginal to too warm for steelhead rearing. Canopy cover at Stations 1-8 is largely inadequate to shade the creek and maintain cool water. The entrenchment of the Suisun Creek channel and associated bank erosion and loss of riparian cover combined with bank stabilization projects and beaver activity have reduced riparian shading at many stations. Additionally, reservoir releases likely mix and eliminate stratified water layers. Larger volume water releases may serve to create a larger water mass to attenuate solar inputs and produce cooler water temperatures.

Water temperatures were generally warmer in 2003 than 2002, which reflect the warmer summer air temperatures in 2003. The increase in the reservoir releases from 2.0 cfs in 2002 to 3.0 cfs in 2003 does not appear to be a large enough volume flow increase to maintain cold water conditions.

Projects to reduce water temperatures on both creeks are discussed in Section IV.

Table 13. Description of Water Temperature Monitoring Stations in Suisun Creek Watershed							
Station Number	**Location: Nearby Landmark**	**Type of Channel**	**Width/ Depth (in ft.)**	**Slope**	**Flow**	**Average % Canopy Cover**	**Comments**
Tributary: Suisun Creek							
SC 1 downstream	Near Cordelia Rd. bridge; stream mile 2.5	unconfined alluvial	21/3	<1%	Lake Curry reservoir release; top of tidal influence	89%	Channel is incised with levees on floodplain; well vegetated; same station for both 2002 & 2003; Hanson station #9 & 10 in 2000 & 2001
SC 2	Near Rockville Rd. bridge; stream mile 4	unconfined alluvial	23/1.5	<1%	Lake Curry reservoir release	47%	Same station for both 2002 & 2003; dense vegetation; incised channel; banks about 20 ft.; Hanson station #8 in 2000 & 2001
SC 3	Stream mile 4.5	unconfined alluvial	30/3	<1%	Lake Curry reservoir release	58%	Same station for both 2002 & 2003; incised channel banks about 20 ft.; significant bank failure, undercut vegetation; erosion downstream
SC 4	Suisun Valley Rd. bridge #1; stream mile 5.5	unconfined alluvial	16/3	<1%	Lake Curry reservoir release	68%	Drop structure on downstream side of bridge; deep pool and some bank erosion downstream; same station for both 2002 & 2003; Hanson station #6 & 7 in 2000 & 2001
SC 5	Suisun Valley Rd. bridge #2; stream mile 9	unconfined alluvial	33/4.5	<1%	Lake Curry reservoir release	88%	Same station in both 2002 & 2003; Hanson station #5 in 2000 & 2001
SC 6 SC 13 AIR	Suisun Creek study reach #1; stream mile 10	unconfined alluvial	35/1.5	<1%	Lake Curry reservoir release	40%	Lack of overstory vegetation; invasive Himalayan blackberry dominates bank; vandalism in 2003; some water temperature data lost; air temperature monitor at this station; same station in both 2002 & 2003; Hanson station #15 in 2001
SC 7	Stream mile 10.5	partially confined alluvial	35/4.5	<1%	Lake Curry reservoir release	32%	Limited overstory; previous bank erosion repaired with gabions; beaver activity; same station in both 2002 & 2003
SC 8	Wooden Valley Cross Rd. bridge; stream mile 12	unconfined alluvial	27/2.5	<1%	Lake Curry reservoir release	59%	Limited overstory; just downstream of confluence with Wooden Valley Creek; same station in both 2002 & 2003; Hanson station #4 in 2000 & 2001
SC 9	Stream mile 14	partially confined alluvial	19/2.5	<1%	Lake Curry reservoir release	54%	Limited overstory; beaver activity; same station in 2002 & 2003; Hanson station #16 in 2000 & 2001
SC 10 upstream	Pool at Lake Curry outlet; stream mile 14.5	partially confined alluvial	13/2.0	<1%	Lake Curry reservoir release	72%	Station only in 2003; Hanson stations #1 & 2 in 2000 & 2001

Table 13. Description of Water Temperature Monitoring Stations in Suisun Creek Watershed (cont.)

Station Number	Location; Nearby Landmark	Type of Channel	Width/ Depth (in ft.)	Slope	Flow	Average % Canopy Cover	Comments
Tributary: Wooden Valley Creek							
WV 1 WV 7 AIR downstream	WV study reach #1; stream mile 0.5	unconfined alluvial	45/1	<1%	Natural runoff; regularly dries up by August	25%	Previous major bank erosion has been repaired with rock riprap; willows have re-grown on banks and in channel; no major overstory; same station in both 2002 & 2003; Hanson station #18 April-August 2001
WV 2a	Stream mile 1	unconfined alluvial	40/2.3	<1%	Natural runoff; isolated pools by July/August	48%	Pool created by drop structure; rest of channel dry; station only in 2003
WV 2	Near Wooden Valley Rd. bridge #1; stream mile 2	confined	N/A	<2-4%	Natural runoff	N/A	Good vegetative cover with perennial flow; same station in both 2002 & 2003; vandalism in 2003 with some loss of data
WV 3	Near Wooden Valley Rd. bridge #2; stream mile 3	confined	13/1.5	<2-4%	Natural runoff perennial flow; downstream of confluence with White Creek; consistently greater flow than WV 4	92%	Station experienced vandalism in 2002 with some loss of data; new site ~ 500 ft. upstream used in 2003; rocky, well-shaded creek
WV 4	Near Wooden Valley Rd. bridge #3; stream mile 4	confined	8/1.5	<2-4%	Natural runoff; perennial flow; observed consistently less flow than WV 3	91%	New culvert installed at Wooden Valley Bridge in 2002; same station in both 2002 & 2003; rocky, well-shaded creek
WV 5	Near Wooden Valley Rd. bridge #4; stream mile 4.5	partially confined	11/0.9	<1-2%	Natural runoff; perennial flow with low summer levels	93%	Some erosion in channel with mature trees undercutting; same station in both 2002 & 2003
WV 6 upstream	Near Wooden Valley Rd. bridge #5; stream mile 5	unconfined	8/0.8	<1-2%	Natural runoff; perennial flow with low summer levels	82%	Road culvert cleared of sediment in 2003 with riprap on upstream banks; instrument destroyed as part of riprap project; data lost for portion of 2003; station only in 2003
Tributary: White Creek							
WC 1 downstream	Stream mile 0.75	unconfined	12/1	<1%	Natural runoff; groundwater fed pool; continuous flow downstream of this point in both 2002 & 2003	82%	Dense riparian cover and groundwater fed pool; live steelhead juveniles up to 4" observed both years, but 3 dead steelhead juveniles found in late summer 2002
WC 2	Stream mile 0.76	unconfined	N/A	<1%	Natural runoff; site dried up by August both 2002 & 2003	92%	Inadequate riparian cover upstream of small pool
WC 3	Stream mile 0.77	unconfined	N/A	<1%	Natural runoff; site dried up by July or August both 2002 & 2003	33%	Inadequate riparian cover to maintain pool; dead juvenile steelhead found in 2002
WC 4 upstream	Stream mile 1.25	unconfined	6/2	<1%	Natural runoff; groundwater in isolated pools in summer	93%	Isolated groundwater fed pools in largely summer dry channel; dense alder grove; same station in both 2002 & 2003

Table 14. Suisun Creek Water Temperature Monitoring Summary						
Station	**Year**	**7-Day Moving Average of Average Daily Temperature**	**7-Day Moving Average of Average Daily Maximum Temperature**	**Daily Range**	**Number of Hours >70ºF (in hours)**	**Comments**
TRIBUTARY: SUISUN CREEK						
SC 1 downstream	2002 (Figures 43-46)	Jun-Jul: 64-68ºF Aug-Sep: 62-67ºF	Jun-Jul: 68-72ºF Aug-Sep: 62-68ºF	0.5-3ºF	Jun- Jul: 15-20 hrs Aug-Sep: 8 hrs	Very small daily temperature range; temperature above 70ºF for significant time
	2003 (Figures 119-122)	Jun- Jul: 64-70ºF Aug-Sep: 64-66ºF	Jun- Jul: 66-72ºF Aug-Sep: 65-68ºF	0.5-3ºF	Jun- Jul: 12-18 hrs Aug-Sep: 9 hrs	Very small daily temperature range; temperature above 70ºF for long periods
	Summary: ***Marginal for steelhead rearing***					
SC 2	2002 (Figures 47-50)	Jun- Jul: 65-69ºF Aug-Sep: 63-67ºF	Jun- Jul: 68-72ºF Aug-Sep: 66-72ºF	1-5ºF	Jun- Jul: 14-17 hrs Aug-Sep: 6-9 hrs	Small daily temperature range; temperatures above 70ºF for long periods
	2003 (Figures 123-126)	Jun- Jul: 66-72ºF Aug-Sep: 65-70ºF	Jun- Jul: 70-78ºF Aug-Sep: 68-78ºF	1-6ºF	Jun- Jul: 10-19 hrs Aug-Sep: 7-15 hrs	High average daily maximum temperatures; small daily temperature range; long periods of temperatures above 70°F
	Summary: ***Marginal to too warm for steelhead rearing***					
SC 3	2002 (Figures 51-54)	Jun- Jul: 66-70ºF Aug-Sep: 62-68ºF	Jun- Jul: 68-73ºF Aug-Sep: 66-72ºF	1-3ºF	Jun- Jul: 12-18 hrs Aug-Sep: 9-11 hrs	Small daily temperature range; somewhat high average daily maximum temperature
	2003 (Figures 127-130)	Jun- Jul: 66-72ºF Aug-Sep: 65-70ºF	Jun- Jul: 70-75ºF Aug-Sep: 68-72ºF	<1-4ºF	Jun- Jul: 10-24 hrs Aug-Sep: 7-17 hrs	High to somewhat high average daily maximum temperatures; small daily temperature range; long periods of temperatures above 70ºF
	Summary: ***Marginal to too warm for steelhead rearing***					
SC 4	2002 (Figures 55-58)	Jun- Jul: 65-69ºF Aug-Sep: 62-68ºF	Jun- Jul: 69-72ºF Aug-Sep: 66-70ºF	1-5ºF	Jun- Jul: 5-15 hrs Aug-Sep: 7-11 hrs	Somewhat high average daily maximum temperature; small daily temperature range
	2003 (Figures 131-134)	Jun- Jul: 65-72ºF Aug-Sep: 65-70ºF	Jun- Jul: 72-77ºF Aug-Sep: 70-72ºF	1-8ºF	Jun- Jul: 10-24 hrs Aug-Sep: 8-15 hrs	High average daily maximum temperatures; long periods of temperatures above 70ºF
	Summary: ***Marginal to too warm for steelhead rearing***					
SC 5	2002 (Figures 59-62)	Jun- Jul: 67-72ºF Aug-Sep: 63-69ºF	Jun- Jul: 72-77ºF Aug-Sep: 68-72ºF	1-4ºF	Jun- Jul: 7-20 hrs Aug-Sep: 2-12 hrs	High to somewhat high average maximum temperature; temperatures above 70ºF for significant period
	2003 (Figures 135-138)	Jun- Jul: 66-74ºF Aug-Sep: 65-74ºF	Jun- Jul: 68-77ºF Aug-Sep: 65-72ºF	1-3ºF	Jun- Jul: 12-24 hrs Aug-Sep: 6-24 hrs	High average maximum temperature; long time period of above 70ºF temperatures; small daily temperature range
	Summary: ***Marginal to too warm for steelhead rearing***					

Table 14. Suisun Creek Water Temperature Monitoring Summary (cont.)						
Station	**Year**	**7-Day Moving Average of Average Daily Temperature**	**7-Day Moving Average of Average Daily Maximum Temperature**	**Daily Range**	**Number of Hours >70ºF (in hours)**	**Comments**
TRIBUTARY: SUISUN CREEK						
SC 6	2002 (Figures 63-66)	Jun- Jul: 67-73ºF Aug-Sep: 61-71ºF	Jun- Jul: 73-97ºF Aug-Sep: 70-76ºF	1-4ºF	Jun- Jul: 5-17 hrs Aug-Sep: 4-14 hrs	Very high average maximum temperature; small daily temperature range; temperatures well above 70ºF for significant time periods
	2003 (Figures 139-142)	Jun- Jul: 64-70ºF Aug-Sep: 65-70ºF	Jun- Jul: 72-77ºF Aug-Sep: 68-78ºF	1-4ºF	Jun: 5-17 hrs Aug-Sep: 4-14 hrs	No data for most of July as instrument was removed from creek; high average maximum daily temperature; small daily temperature range; temperatures above 70º F for significant time periods
	Summary: Too warm for steelhead rearing					
SC 7	2002 (Figures 67-70)	Jun- Jul: 65-71ºF Aug-Sep: 62-68ºF	Jun- Jul: 69-73ºF Aug-Sep: 64-70ºF	1-3.5ºF	Jun- Jul: 5-24 hrs Aug-Sep: 1-4 hrs	Somewhat high average maximum temperatures; small daily temperature range; significant time period above 70ºF
	2003 (Figures 143-146)	Jun- Jul: 65-71ºF Aug-Sep: 64-71ºF	Jun- Jul: 70-77ºF Aug-Sep: 66-74ºF	<1-4ºF	Jun- Jul: 6-24 hrs Aug-Sep: 6-17 hrs	High average maximum temperature; small daily temperature range; significant time period above 70ºF
	Summary: *Marginal to too warm for steelhead rearing*					
SC 8	2002 (Figures 71-74)	Jun- Jul: 66-70ºF Aug-Sep: 61-69ºF	Jun- Jul: 70-75ºF Aug-Sep: 62-74ºF	<1-3ºF	Jun- Jul: 4-18 hrs Aug-Sep: 1-12 hrs	High average maximum temperature; small daily temperature range; significant time period above 70ºF
	2003 (Figures 147-150)	Jun- Jul: 64-71ºF Aug-Sep: 65-70ºF	Jun- Jul: 68-72ºF Aug-Sep: 65-70ºF	<1-5ºF	Jun- Jul: 2-18 hrs Aug-Sep: 7-13 hrs	Somewhat high average maximum temperature; small daily range; long periods of greater than 70ºF temperatures
	Summary: *Marginal to too warm for steelhead rearing*					
SC 9	2002 (Figures 75-78)	Jun- Jul: 63-66ºF Aug-Sep: 61-66ºF	Jun- Jul: 68-70ºF Aug-Sep: 62-68ºF	1-6ºF	Jun- Jul: >1-7 hrs Aug-Sep: >1 hr	Small range of relatively low average maximum temperatures; short time periods of greater than 70ºF temperatures
	2003 (Figures 151-154)	Jun- Jul: 62-67ºF Aug-Sep: 61-66ºF	Jun- Jul: 66-72ºF Aug-Sep: 68-68ºF	1-6ºF	Jun- Jul: >1-9.5 hrs Aug-Sep: 2-6 hrs	Average maximum temperatures relatively cool; short time periods of greater than 70ºF temperatures
	Summary: *Good for steelhead rearing*					
SC 10 upstream	2003 (Figures 155-158)	Jun- Jul: 68-62ºF Aug-Sep: 62-64ºF	Jun-Sep: 60-66ºF	<1-1ºF	Jun-Sep: 0 hrs	Temperatures reflect reservoir water releases
	Summary: *Good for steelhead rearing*					

Table 14. Suisun Creek Water Temperature Monitoring Summary (cont.)						
Station	**Year**	**7-Day Moving Average of Average Daily Temperature**	**7-Day Moving Average of Average Daily Maximum Temperature**	**Daily Range**	**Number of Hours >70ºF (in hours)**	**Comments**
TRIBUTARY: WOODEN VALLEY CREEK						
WV 1 downstream	2002 (Figures 79-82)	Jun-Jul: 69-75ºF Aug-Sep: dried up	Jun-Jul: 60-90ºF Aug-Sep: dried up	4-10ºF	Jun-Jul: 10-20 hrs Aug-Sep: dried up	Station completely dried up by August
	2003 (Figures 159-162)	Jun- Jul: 68-72ºF Aug-Sep: dried up	Jun- Jul: 65-85ºF Aug-Sep: dried up	3-7ºF	Jun-Jul: 5-16 hrs Aug-Sep: dried up	Station completely dried up in August
	Summary: *Poor steelhead rearing – dries up*					
WV 2a	2003 (Figures 163-166)	Jun-Aug: 61-71ºF Aug-Sep: 67-69ºF	Jun-Aug: 65-78ºF Aug-Sep: 69-72ºF	1-14ºF	Jun-Aug: 4-15 hrs Aug-Sep: 1-10 hrs	Relatively high water temperatures with somewhat long periods of water temperatures over 70ºF
	Summary: *Marginal to too warm for steelhead rearing*					
WV 2	2002 (Figures 83-86)	Jun-Aug: 63-67ºF Aug-Sep: 58-65ºF	Jun-Aug: 65-71ºF Aug-Sep: 60-66ºF	1-4ºF	Jun-Aug: 2-10 hrs Aug-Sep: 0 hrs	Cool average maximum water temperatures; low range and low number of hours of temperatures greater than 70ºF
	2003 (Figures 167-170)	Jun-Aug: 61-67ºF Aug: 63-67ºF	Jun-Aug: 63-68ºF Aug: 65-68ºF	<1-1ºF	Jun-Aug: <1-2.5 hrs Aug: 0 hrs	Cool average maximum water temperatures; low range and low number of hours of temperatures greater than 70ºF
	Summary: *Very good for steelhead rearing*					
WV 3	2002 (Figures 87-90)	Jun-Aug: 61-65ºF Aug: 60-63ºF	Jun-Aug: 65-68ºF Aug: 62-66ºF	1-4ºF	Jun-Aug: 1-6 hrs Aug: 0 hrs	Cold maximum temperatures; low number of hours of temperatures in excess of 70ºF
	2003 (Figures 171-174)	Jun-Aug: 59-67ºF Aug-Sep: 61-66ºF	Jun-Aug: 63-71ºF Aug-Sep: 65-70ºF	1-5ºF	Jun-Aug: 4-9 hrs Aug-Sep: 2-5 hrs	Cold maximum temperatures; low number of hours of temperatures in excess of 70ºF
	Summary: *Very good for steelhead rearing*					
WV 4	2002 (Figures 91-94)	Jun- Jul: 60-65ºF Aug-Sep: 58-64ºF	Jun- Jul: 64-69ºF Aug-Sep: 60-66ºF	0.5-5ºF	Jun- Jul: 2.5-5 hrs Aug-Sep: 0 hrs	Cold average maximum temperatures; very low number of hours of temperatures in excess of 70ºF
	2003 (Figures 175-178)	Jun- Jul: 59-66ºF Aug-Sep: 60-65ºF	Jun- Jul: 62-70ºF Aug-Sep: 60-66ºF	<1-5ºF	Jun- Jul: 2-5 hrs Aug-Sep: 0 hrs	Cold average maximum temperatures; very low number of hours of temperatures in excess of 70ºF
	Summary: *Very good for steelhead rearing*					
WV 5	2002 (Figures 95-98)	Jun- Jul: 60-64ºF Aug-Sep: 59-63ºF	Jun- Jul: 64-66ºF Aug-Sep: 60-65ºF	<1-6ºF	Jun- Jul: 0 hrs Aug-Sep: 0 hrs	Cold average maximum temperatures; no hours of temperatures in excess of 70ºF
	2003 (Figures 179-182)	Jun- Jul: 61-66ºF Aug-Sep: 60-65ºF	Jun- Jul: 61-67ºF Aug-Sep: 60-65ºF	<1-3.5ºF	Jun- Jul: 0 hrs Aug-Sep: 0 hrs	Cold average maximum temperatures; no hours of temperatures in excess of 70ºF
	Summary: *Excellent for steelhead rearing*					
WV 6 upstream	2003 (Figures 183-186)	Jun- Jul: 60-64ºF Aug: 63-64ºF	Jun- Jul: 61-66ºF Aug: 63-64ºF	1-9ºF	Jun- Jul: 2.5 hrs Aug: 0 hrs	Cold average maximum temperature; few hours of temperatures in excess of 70ºF
	Summary: *Excellent for steelhead rearing*					

Table 14. Suisun Creek Water Temperature Monitoring Summary (cont.)						
Station	**Year**	**7-day Moving Average of Average Daily Temperature**	**7-Day Moving Average of Average Daily Maximum Temperature**	**Daily Range**	**Number of Hours >70ºF (in hours)**	**Comments**
TRIBUTARY: WHITE CREEK						
WC 1 downstream	2002 (Figures 99-102)	Jun 25- Jul: 60-63ºF Aug-Sep: 57-62ºF	Jun 25- Jul: 62-65ºF Aug-Sep: 58-62ºF	<1-5ºF	Jun 25- Jul: 0 hrs Aug-Sep: 0 hrs	Cold average maximum temperature; no hours of temperatures in excess of 70ºF
	2003 (Figures 187-190)	Jun 1- Jul: 59-66ºF Aug-Sep: 58-65ºF	Jun 1- Jul: 61-70ºF Aug-Sep: 60-70ºF	1-10ºF	Jun 1- Jul: 3-8 hrs Aug-Sep: 4-7 hrs	Relatively cold average maximum temperatures; relatively low number of hours over 70ºF
	Summary: *Very good for steelhead rearing*					
WC 2	2002 (Figures 103-106)	Jun- Jul: 66-68ºF Aug-Sep: dried up	Jun- Jul: 69-70ºF Aug-Sep: dried up	<1-1ºF	Jun- Jul: 0 hrs Aug-Sep: dried up	Station completely dried up in July
	2003 (Figures 191-194)	Jun- Jul: 64-69ºF Aug-Sep: dried up	Jun- Jul: 68-80ºF Aug-Sep: dried up	1-6ºF	Jun- Jul: 2-9 hrs Aug-Sep: dried up	Station completely dried up in July
	Summary: *Poor steelhead rearing – dries up*					
WC 3	2002 (Figures 107-110)	Jun- Jul: 65-70ºF Aug-Sep: dried up	Jun- Jul: 72-78ºF Aug-Sep: dried up	1-10ºF	Jun- Jul: >20 hrs Aug-Sep: dried up	Station completely dried up
	2003 (Figures 195-198)	Jun- Jul: 60-71ºF Aug-Sep: dried up	Jun- Jul: 63-74ºF Aug-Sep: dried up	1-7ºF	Jun- Jul: 3-21 hrs Aug-Sep: dried up	Station completely dried up
	Summary: *Poor steelhead rearing – dries up*					
WC 4 upstream	2002 (Figures 111-114)	Jun- Jul: 61-65ºF Aug-Sep: 57-62ºF	Jun- Jul: 61-69ºF Aug-Sep: 58-63ºF	1-12ºF	Jun- Jul: 1-7 hrs Aug-Sep: 0 hrs	Cold average maximum temperatures; few hours of temperatures over 70ºF
	2003 (Figures 199-202)	Jun- Jul: 58-68ºF Aug-Sep: 59-65ºF	Jun- Jul: 65-70ºF Aug-Sep: 60-65ºF	<1-7ºF	Jun- Jul: 25 hrs Aug-Sep: 0 hrs	Relatively cold average maximum temperatures; few hours of temperatures over 70ºF
	Summary: *Very good for steelhead rearing*					

Water Quality

Background

The quality of the water in a stream is affected by activities in the watershed as well as the natural features of the watershed. There are three broad types of materials found in water. The first one is suspended material such as clay particles, which affects the clarity of the water. Chemicals make up another type of material found in water. The third material is biological organisms such as phytoplankton, single-celled floating algae. In most cases, it is the concentration of chemicals in the water that is of concern.

Water vapor in the sky and rain falling to the ground, picks up chemicals from the air. Rain hitting the earth can dissolve chemicals from the land surface and move them into a creek. Rainfall and stormwater will dissolve chemicals from soil and rock as it percolates into and through soil layers. Even in a forest the rainfall will pick up low levels of organic acids from decaying plants on the forest floor. In urban areas, rainfall will pick up oil and grease, heavy metals, pesticides, nutrients and other materials and move them into a creek.

The amount of chemicals in a stream will vary over the time of the year. During winter when rainfall and streamflow levels are high, the large amount of water serves to dilute the concentrations of chemicals in streamflow. However, during the dry months of the year when streamflow is low, the inflow of chemicals is not diluted and can have significant effects on water quality and aquatic life. For example, summertime irrigation of lawns, gardens and agricultural areas can produce chemicals in runoff such as nitrogen and phosphate from fertilizers. These substances serve as nutrients in the aquatic system and are available in very low amounts under natural conditions. These nutrients stimulate algal growth. Algae grow rapidly and form thick mats on the water surface or carpets on the stream bottom. Eventually, as the nutrients are used up, the algae growth diminishes and dies back and bacteria break down the algae. As this process occurs, the bacteria use up much of the oxygen in the water through respiration. This process of algal growth and die-off can result in a reduction of the dissolved oxygen in the stream and have negative effects on steelhead and aquatic life (Davis et al 1963, Meehan 1991, Schmitz 1996).

The temperature and pH of the water also changes the effect of some chemicals on the water. For example, ammonia, a form of nitrogen, becomes far more toxic to fish and aquatic organisms under higher temperatures or higher pH. This difference is due to a change in the chemical form of the ammonia from an ionized form (NH_4^+) to the un-ionized form (NH_3) that is far more toxic. Because of these interactions, water quality monitoring includes tests for a group of chemicals along with temperature and pH.

Certain water quality parameters are monitored to indicate the ambient water quality in a creek (Stednick 1991, San Francisco Regional Water Quality Control Board 1994).

These include:
Water temperature – unlike the continuous monitoring of water temperature using the data loggers, this measurement is of the water temperature when the other parameters are measured. A non-mercury thermometer is placed in the stream for at least three minutes at the same location where the other parameters will be sampled and read immediately after removal from the water.

pH – is the measurement of hydrogen ions and hydroxyl ions defining the acid or base level of the water. The pH scale runs from 0 (highly acidic) to 14 (highly basic) with 7.0 as neutral. The scale is logarithmic, meaning that a small change in numbers, from 7.0 to 5.0 represents an increase in hydrogen ion of one-hundred times. pH is largely influenced by soil and hydrology, but is also affected by land uses.

Most aquatic organisms are adapted to a small range of pH and cannot tolerate changes. pH levels influence the availability of nutrients and their effects on aquatic life. For example, at acidic pH levels, heavy metals that are typically bound to clay particles, become released into the water, become available to aquatic organisms and can concentrate through the food chain.

Dissolved oxygen (DO) - is the oxygen content of water. Steelhead trout require relatively high levels of DO as do many aquatic insect larvae. Carp, catfish and snails are examples of aquatic organisms adapted to low levels of DO. DO enters the water from the atmosphere through turbulence as water flows over riffles and cascades in the stream. DO levels vary with water temperature; higher temperatures reduce dissolved oxygen levels. As described previously, unnaturally high nutrient levels that induce algal blooms can decrease DO through the respiration of bacteria breaking down the algae.

Similarly, septic leakage can result in bacterial action and reduce DO levels. High inputs of sewage or fertilizer can reduce DO levels to the point of killing fish in a section of stream. Aquatic plant growth can also create daily fluctuations in DO levels. During daylight hours, when plants and algae are photosynthesizing, oxygen is created, but during the night, the plants respire and may use up much of the DO in the stream. Excessive aquatic plant or algal growth can result in very low DO levels in the early morning hours.

Ammonia – contains nitrogen, a plant nutrient, which if available at a high level, will induce algal blooms and eventually lower DO levels. Ammonia typically comes from livestock waste, sewage and septic leakage and fertilizer runoff. High levels of ammonia in the water keep fish from excreting ammonia wastes from their bodies and can result in a toxic condition. At higher pH or water temperatures, ammonia changes from the ionized form (NH_4^+) to the un-ionized form (NH_3) and becomes far more toxic to aquatic life.

Nitrate – is another form of nitrogen that is found in creeks at low levels under natural conditions. Bacteria in the water extract nitrogen from the air and convert it into nitrate. Soil bacteria convert plant material into nitrate. Excessive nitrate will induce algal blooms and ultimately reduce DO levels in the stream. Sources of nitrate include livestock waste, eroded agricultural and residential soil, fertilizers, septic leakage and sewage.

Phosphate – is another nutrient that, when available in excessive amounts, can induce algal blooms and ultimately lower DO levels. Under natural conditions phosphate, a form of phosphorous, binds to soil particles and, if released through erosion into streams, is quickly taken up by plants or algae. Sources of excessive phosphate include soap and detergent such as from car washing, sewage and septic leakage, fertilizer runoff and livestock waste.

Conductivity – is the flow of electricity through a water sample and measures the amount of dissolved solids or salts in the water. Specific conductance is the conductivity at the specific water temperature of 25ºC. Common salts found in a creek are chloride, nitrate, sulfate and phosphorous anions (negatively charged particles) and sodium, calcium, magnesium, iron and aluminum cations (positively charged particles). A high conductivity reading indicates a high level of dissolved solids. During the summer when groundwater makes up most of the streamflow, conductivity levels are higher as groundwater moves through soil and rock leaching salts. Rainfall contains almost no salts and therefore in winter, streams have a lower conductivity reading. Leaking septic systems, fertilizer, and urban runoff will increase conductivity readings.

Monitoring Results

Ambient water quality was monitored at twelve stations on White, Wooden Valley and Suisun Creeks in 2002 on a monthly basis from June through October. The parameters monitored include dissolved oxygen, pH, ammonia-nitrogen, nitrate-nitrogen and phosphorous. In 2003, a dissolved oxygen meter was used. Table 15 shows the results of this monitoring.

Data from 2002 collected by the Regional Water Quality Control Board SWAMP program for eight stations (Figure 42) are summarized in Table 16. A YSI monitoring instrument was placed for two weeks in the creek at each station in various seasons. The Regional Board is preparing an interpretive report on these results and other data.

As part of the studies done by Hanson Environmental, Inc., dissolved oxygen, pH, conductivity, and temperature were measured at three stations from December 2000 to August 2001 at one to two month intervals and at various time periods in a daily cycle to compare daytime and nighttime DO levels. Table 17 shows the temperature, DO, pH and conductivity monitoring completed by Hanson Environmental, Inc. for three stations on Suisun Creek. This set of measurements was done in the early morning (5 a.m.) and evening (4-5 p.m.) to evaluate diel changes in DO levels.

Table 15. Water Quality Monitoring 2002 and 2003											
Station*	**Tributary System**	**Date**	**Water Temperature (ºF)**	**Dissolved Oxygen (mg/l)**	**pH**	**Ammonia -Nitrogen (mg/l)**	**Converted Ammonia (mg/l)**	**Nitrate Nitrogen (mg/l)**	**Converted Nitrate (mg/l)**	**Phosphate (mg/l)**	**Dissolved Oxygen (% saturation)**
SC 2	Suisun	6/27/02	69	9.4	8	0.1	0.13	0	0	0	
		8/2/02	70	9.8	8	.075	0.975	0.5	2.2	0	
		9/27/02	63	8.8	8	0.1	0.13	0.25	1.1	0	
		10/29/02	55	6.5	7.6	0.2	0.26	0.25	1.1	0	
		8/20/03									99.2
SC 3	Suisun	6/26/02	72	10	8.2	0.1	0.13	0.25	1.1	0	
		8/2/02	73	10	8	0.25	0.325	0.5	2.2	0	
		9/27/02	65	8.1	8	0.2	0.26	0.3	1.32	1	
		10/29/02	57	7.4	7.9	0.25	0.325	0.5	2.2	0	
		8/20/03									79.0
SC 4	Suisun	6/26/02	72	10	7.8	0.25	0.325	0.5	2.2	0	
		8/2/02	70	8.8	7.8	0.375	0.4875	0.5	2.2	0	
		9/27/02	66	8	N/A	0.1	0.13	0.25	1.1	1	
		10/29/02	55	7.7	7.4	0.2	0.26	3	13.2	0	
		8/20/03									113.0
SC 5	Suisun	6/26/02	74	9.2	7.8	0.1	0.13	0.5	2.2	0	
		8/2/02	72	6.4	7.8	0.5	0.65	0.25	1.1	0	
		9/27/02	63	9	7.6	0.1	0.13	0.25	1.1	0.1	
		10/29/02	55	7.9	7.7	0.2	0.26	0.25	1.1	0	
		8/20/03									115.0
SC 6	Suisun	6/26/02	71	8.5	8.1	0.25	0.325	0.25	1.1	0	
		8/2/02	N/A	7.8	8	0.25	0.325	0	0	0	
		9/27/02	62	9.5	8.1	0.1	0.13	0.25	1.1	1	
		10/29/02	55	9.6	8	0.5	0.65	0.25	1.1	0	
		8/20/03									116.0
SC 9	Suisun	8/1/02	76	9.2	8.3	0.25	0.325	0.25	1.1	0	
		9/26/02	66	9	8.1	0.3	0.39	0.25	1.1	1	
		10/29/02	57	9.3	8.2	0.35	0.455	0.25	1.1	0	
		8/21/03									94.3
WV 2a	Wooden Valley	6/26/02	76	9	8.2	0.25	0.325	0	0	0	
		8/1/02	88	N/A	8.2	0.1	0.13	0.25	1.1	0	
		9/26/02	75	5	7.6	0.35	0.4555	0.25	1.1	0	
		10/29/02	63	3.1	7.6	0.7	0.91	0.25	1.1	0	
		8/22/03									69.5

Table 15. Water Quality Monitoring 2002 and 2003 (cont.)											
Station*	**Tributary System**	**Date**	**Water Temperature (ºF)**	**Dissolved Oxygen (mg/l)**	**pH**	**Ammonia -Nitrogen (mg/l)**	**Converted Ammonia (mg/l)**	**Nitrate Nitrogen (mg/l)**	**Converted Nitrate (mg/l)**	**Phosphate (mg/l)**	**Dissolved Oxygen (% saturation)**
WV 3	Wooden Valley	6/26/02	64	9.5	8.1	0.1	0.13	1	4.4	0	
		8/1/02	70	8.4	8	0.1	0.13	0.75	3.3	0	
		9/26/02	63	8.4	8	0.25	0.325	0.25	1.1	1	
		10/31/02	48	7.9	8	0.2	0.26	0.25	1.1	0	
		8/20/03									95.5
WV 5	Wooden Valley	6/26/02	63	9	7.4	0.25	0.325	3	13.2	0	
		8/1/02	66	7.4	7.4	0.25	0.325	4	17.6	0	
		9/26/02	64	6.4	6.9	0.1	0.13	2	8.8	1	
		10/31/02	55	6.1	7.1	2	2.6	0.25	1.1	0	
		8/21/03									68.5
WV 6	Wooden Valley	6/26/02	64	7.5	7.4	0.25	0.325	0.5	2.2	0	
		8/1/02	68	7.6	7.4	0.25	0.325	0.175	0.77	0	
		9/26/02	62	3.8	7.5	0.2	0.26	0.25	1.1	0	
		10/31/02	62	2.9	7.7	0.2	0.26	0.25	1.1	0	
		8/21/03									28.5
WC 1	White	9/26/02	58	5.1	7.7	0.2	0.2	0.26	N/A	N/A	
		10/31/02	51	1.1	7.5	0.2	0.26	0.25	1.1	0	
		8/21/03									49.8
WC 4	White	6/26/02	62	N/A	7.6	0.1	0.13	0.25	1.1	0	
		8/1/02	60	1.6	7.4	0.1	0.13	0.25	1.1	0	
		9/26/02	61	1.8	7.5	0.2	0.26	0.25	1.1	0	
		10/31/02	54	2.9	7.5	0.5	0.65	0.25	1.1	0	
		8/21/03									25.0

* See Figure 7 for station locations

Table 16. Surface Water Ambient Monitoring Program (SWAMP) of the San Francisco Bay Regional Water Quality Control Board Suisun Creek Watershed Monitoring											
Suisun Watershed		**Winter Wet Season**			**Spring Runoff**						
Monitoring Location*		**207SUI020**	**207SUI110**	**207SUI125**	**207SUI020**	**207SUI050**	**207SUI090**	**207SUI110**	**207SUI125**	**207SUI180**	**207SUI185**
Start Date		**1/21/2002**	**1/4/2002**	**2/15/2002**	**4/25/2002**	**4/25/2002**	**4/25/2002**	**3/26/2002**	**3/26/2002**	**3/26/2002**	**3/26/2002**
End Date		**2/5/2002**	**1/21/2002**	**3/1/2002**	**5/7/2002**	**5/7/2002**	**5/7/2002**	**4/9/2002**	**4/9/2002**	**4/9/2002**	**3/29/2002**
Number of data points		**1425**	**1631**	**1335**	**1141**	**1135**	**1141**	**1325**	**1325**	**1325**	**314**
Temperature (°C)	Min.	6.8	5.7	8.2	12.5	11.9	11.7	9.7	11.4	8.4	9.3
	0.25	8.3	7.9	10.5	14.2	13.7	13.9	12.9	13.6	12.6	11.5
	Median	8.8	10.2	11.1	15.1	14.9	15.1	14.7	14.6	13.9	13.2
	0.75	9.4	11.3	12.1	16.2	16.0	16.5	17.7	16.4	15.8	14.6
	Max.	10.8	13.3	14.7	18.8	19.9	20.1	22.5	18.7	18.3	17.4
	QA Qualifier	Estimated, 5	Estimated, 5	Estimated, 5	Estimated, 5	Estimated, 5	Estimated, 5	Estimated, 5	Estimated, 5	Estimated, 5	Estimated, 5
pH	Min.	7.62	7.80	7.84	7.40	7.85	7.58	8.00	7.70	7.72	8.15
	0.25	7.66	7.98	7.93	7.44	7.95	7.70	8.04	7.78	7.98	8.21
	Median	7.68	8.05	8.00	7.47	8.07	7.79	8.11	7.90	8.03	8.23
	0.75	7.72	8.10	8.19	7.51	8.34	8.03	8.29	8.16	8.26	8.35
	Max.	7.92	8.63	8.51	7.59	8.64	8.28	8.49	8.62	8.49	8.46
	Data Quality Objective: +/- .5 pH units	0.03	0.14	0.08	0.08	0.01	0.03	0.04	0.03	0.05	0.04
	QA Qualifier	Estimated, 3	Estimated, 3, 4	Estimated, 3	Valid	Estimated, 3	Estimated, 3	Estimated, 3	Estimated, 3	Estimated, 3	Estimated, 3
Dissolved Oxygen (%)	Min.	93.70	Reject	90.90	78.90	79.70	79.90	92.10	83.70	93.30	94.20
	0.25	95.30	Reject	94.00	83.40	86.20	85.10	95.30	88.40	98.20	95.30
	Median	96.40	Reject	96.50	86.70	92.50	90.00	97.60	91.50	101.30	96.30
	0.75	100.80	Reject	104.90	97.30	114.65	109.20	106.60	107.20	107.20	101.78
	Max.	124.50	Reject	122.90	107.30	135.30	128.80	119.20	124.30	114.50	110.10
	Data Quality Objective: +/- 5.0%	1.0	Reject	1.5	1.1	1.4	2.5	3.2	1.3	5.0	2.2
	QA Qualifier	Valid	**Reject**	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid
*See Figure 42											

Table 16. Surface Water Ambient Monitoring Program (SWAMP) of the San Francisco Bay Regional Water Quality Control Board Suisun Creek Watershed Monitoring (cont.)											
Suisun Watershed		**Winter Wet Season**			**Spring Runoff**						
Monitoring Location*		**207SUI020**	**207SUI110**	**207SUI125**	**207SUI020**	**207SUI050**	**207SUI090**	**207SUI110**	**207SUI125**	**207SUI180**	**207SUI185**
Start Date		**1/21/2002**	**1/4/2002**	**2/15/2002**	**4/25/2002**	**4/25/2002**	**4/25/2002**	**3/26/2002**	**3/26/2002**	**3/26/2002**	**3/26/2002**
End Date		**2/5/2002**	**1/21/2002**	**3/1/2002**	**5/7/2002**	**5/7/2002**	**5/7/2002**	**4/9/2002**	**4/9/2002**	**4/9/2002**	**3/29/2002**
Number of data points		**1425**	**1631**	**1335**	**1141**	**1135**	**1141**	**1325**	**1325**	**1325**	**314**
Dissolved Oxygen (mg/L)	Min.	10.58	Reject	9.54	7.70	7.76	7.58	8.50	8.17	8.86	9.33
	0.25	11.07	Reject	10.39	8.40	8.81	8.60	9.58	8.96	9.93	9.92
	Median	11.29	Reject	10.62	8.83	9.44	9.26	10.08	9.45	10.58	10.35
	0.75	11.71	Reject	11.44	9.64	11.45	10.86	10.58	10.81	11.19	10.78
	Max.	14.08	Reject	13.22	10.86	12.95	12.45	11.67	12.22	12.34	11.69
	Data Quality Objective: +/- 0.5 mg/l	NA	Reject	NA	NA	NA	NA	NA	NA	NA	NA
	QA Qualifier	Valid, 1	**Reject**	Valid, 1	Valid, 1	Valid, 1	Valid, 1	Valid, 1	Valid, 1	Valid, 1	Valid, 1
Specific Conductivity (mS/cm)	Min.	0.39	0.16	0.39	0.46	0.48	0.46	0.40	0.42	0.21	0.57
	0.25	0.41	0.29	0.40	0.48	0.48	0.48	0.43	0.44	0.22	0.57
	Median	0.42	0.34	0.41	0.48	0.49	0.48	0.44	0.45	0.23	0.58
	0.75	0.42	0.37	0.42	0.49	0.49	0.48	0.45	0.45	0.23	0.58
	Max.	0.44	0.39	0.43	0.49	0.49	0.49	0.46	0.46	0.25	0.58
	Data Quality Objective: +/- 0.05 mS/cm	0.02	0.01	0.02	0.00	0.01	0.01	0.00	0.00	0.00	0.00
	QA Qualifier	Valid	Estimated, 4	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid
*See Figure 42											

Table 16. Surface Water Ambient Monitoring Program (SWAMP) of the San Francisco Bay Regional Water Quality Control Board Suisun Creek Watershed Monitoring (cont.)												
Suisun Watershed		**Summer Dry Season**						**Late Summer**				
Monitoring Location*		**207SUI020**	**207SUI050**	**207SUI090**	**207SUI110**	**207SUI125**	**207SUI185**	**207SUI020**	**207SUI050**	**207SUI090**	**207SUI125**	**207SUI185**
Start Date		**7/3/2002**	**7/3/2002**	**7/3/2002**	**6/20/2002**	**6/20/2002**	**6/20/2002**	**10/24/2002**	**10/24/2002**	**10/23/2002**	**10/24/2002**	**10/24/2002**
End Date		**7/16/2002**	**7/16/2002**	**7/16/2002**	**7/1/2002**	**7/1/2002**	**7/1/2002**	**10/30/2002**	**10/30/2002**	**10/29/2002**	**10/30/2002**	**10/30/2002**
Number of data points		**1248**	**1246**	**1245**	**1050**	**1048**	**1050**	**567**	**570**	**564**	**562**	**561**
Temperature (°C)	Min.	17.4	17.7	17.8	17.0	15.3	15.3	12.7	11.1	11.8	12.3	9.6
	0.25	18.9	20.1	20.2	19.8	17.7	17.4	13.5	12.2	13.0	13.5	10.6
	Median	20.1	21.7	21.2	22.0	19.1	19.1	13.9	12.8	13.5	14.2	11.4
	0.75	21.0	23.1	22.0	24.8	20.2	20.5	14.2	13.4	13.9	14.8	12.0
	Max.	24.2	26.5	23.9	29.3	22.4	24.0	14.7	14.4	14.7	15.6	12.8
	QA Qualifier	Estimated, 5	Estimated, 5	Estimated, 5	Estimated, 5	Estimated, 5	Estimated, 5	Estimated, 5	Estimated, 5	Estimated, 5	Estimated, 5	Estimated, 5
pH	Min.	7.06	7.59	6.68	7.45	7.75	7.99	6.80	7.43	7.35	7.64	7.99
	0.25	7.48	7.76	7.46	7.54	7.79	8.07	7.00	7.85	7.46	7.71	8.02
	Median	7.61	7.85	7.54	7.67	7.86	8.16	7.37	7.88	7.48	7.74	8.03
	0.75	7.68	7.98	7.59	7.95	8.08	8.40	7.43	7.92	7.53	7.80	8.06
	Max.	7.93	8.15	7.72	8.41	8.23	8.62	7.50	8.06	7.62	7.93	8.10
	Data Quality Objective: +/- .5 pH units	0.03	0.03	0.07	0.00	0.06	0.07	0.05	0.06	0.10	0.06	0.04
	QA Qualifier	Valid	Valid	Valid	Valid	Valid	Valid	Estimated, 2	Estimated, 2	Estimated, 2	Valid	Valid
Dissolved Oxygen (%)	Min.	65.20	55.80	50.30	43.80	82.00	73.00	47.80	85.10	85.20	78.30	86.00
	0.25	78.50	68.30	76.80	58.93	85.20	82.70	70.20	88.40	86.90	86.70	88.00
	Median	83.65	79.55	80.30	83.45	90.75	87.85	78.60	92.00	89.15	88.20	89.20
	0.75	101.80	96.15	91.70	148.78	109.00	100.60	86.40	96.40	94.33	94.93	92.40
	Max.	117.40	112.10	100.70	205.10	121.40	112.60	104.40	106.10	101.40	103.30	96.00
	Data Quality Objective: +/- 5.0%	1.0	2.3	1.0	1.3	1.8	3.3	4.3	4.5	2.1	0.3	0.2
	QA Qualifier	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid

*See Figure 42

Table 16. Surface Water Ambient Monitoring Program (SWAMP) of the San Francisco Bay Regional Water Quality Control Board Suisun Creek Watershed Monitoring (cont.)

Suisun Watershed		Summer Dry Season						Late Summer				
Monitoring Location*		207SUI020	207SUI050	207SUI090	207SUI110	207SUI125	207SUI185	207SUI020	207SUI050	207SUI090	207SUI125	207SUI185
Start Date		7/3/2002	7/3/2002	7/3/2002	6/20/2002	6/20/2002	6/20/2002	10/24/2002	10/24/2002	10/23/2002	10/24/2002	10/24/2002
End Date		7/16/2002	7/16/2002	7/16/2002	7/1/2002	7/1/2002	7/1/2002	10/30/2002	10/30/2002	10/29/2002	10/30/2002	10/30/2002
Number of data points		1248	1246	1245	1050	1048	1050	567	570	564	562	561
Dissolved Oxygen (mg/L)	Min.	6.06	4.95	4.42	3.90	7.36	6.62	5.06	9.13	8.83	8.25	9.37
	0.25	7.17	6.15	6.86	5.39	7.93	7.77	7.26	9.49	9.12	8.87	9.67
	Median	7.76	7.06	7.22	7.27	8.60	8.29	8.11	9.75	9.35	9.15	9.83
	0.75	9.03	8.18	8.12	12.47	10.14	9.17	8.87	10.06	9.78	9.79	10.05
	Max.	10.30	9.43	8.88	16.26	11.14	10.43	10.61	10.93	10.43	10.35	10.41
	Data Quality Objective: +/- 0.5 mg/l	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	QA Qualifier	Valid, 1	Valid, 1	Valid, 1	Valid, 1	Valid, 1	Valid, 1	Valid, 1	Valid, 1	Valid, 1	Valid, 1	Valid, 1
Specific Conductivity (mS/cm)	Min.	0.363	0.48	0.44	0.56	0.42	0.49	0.36	0.47	0.43	0.41	0.52
	0.25	0.379	0.49	0.45	0.58	0.42	0.49	0.38	0.47	0.43	0.42	0.53
	Median	0.393	0.49	0.45	0.59	0.42	0.50	0.39	0.47	0.43	0.42	0.53
	0.75	0.412	0.49	0.45	0.59	0.43	0.50	0.39	0.48	0.43	0.42	0.53
	Max.	0.449	0.49	0.71	0.61	0.43	0.51	0.42	0.48	0.44	0.43	0.53
	Data Quality Objective: +/- 0.05 mS/cm	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	QA Qualifier	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid

*See Figure 42

Figure 42. Surface Water Ambient Monitoring Program (SWAMP) Monitoring Stations

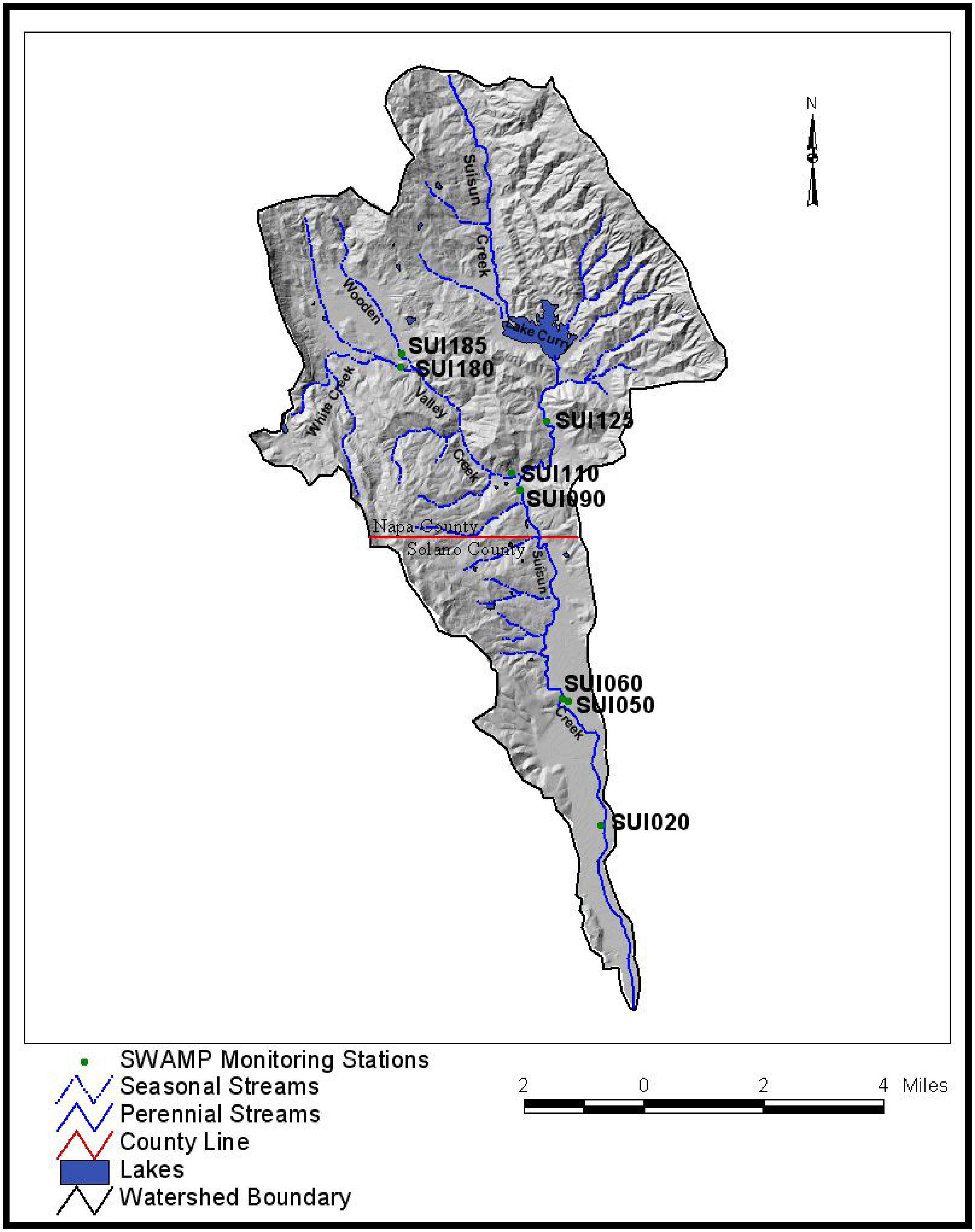


Table 17. Water Quality Measurements for Suisun Creek completed by Hanson Environmental, Inc. 2000-2001

Stations	**SC 1 (Hanson Station #9)**		**SC 4 (Hanson Station #6)**		**SC 6 (Hanson Station #15)**	
12/23/00	**AM**	**PM**	**AM**	**PM**	**AM**	**PM**
Water Temperature ºC (ºF)	8.9 (48.0)	9.1 (48.4)	8.3 (46.9)	9.3 (48.7)	8.6 (47.5)	9.4 (48.9)
Dissolved Oxygen (mg/l)	9.2	10.1	8.7	11.4	9.6	10.2
pH	7.9	7.8	7.6	7.7	7.8	8.0
Conductivity (mS/cm)	505	504	479	477	463	462
2/24/01						
Water Temperature ºC (ºF)	9.5 (49.1)	8.8 (47.8)	9.4 (48.9)	8.8 (47.8)	8.7 (47.6)	9.0 (48.2)
Dissolved Oxygen (mg/l)	8.9	10.6	10.5	10.0	11.0	10.0
pH	--	7.7	--	7.7	--	8.0
Conductivity (mS/cm)	261	171	258	167	264	165
4/12/01						
Water Temperature ºC (ºF)	12.7 (54.9)	14.3 (57.7)	12.6 (54.7)	14.4 (57.9)	12.2 (53.9)	14.7 (58.5)
Dissolved Oxygen (mg/l)	8.7	9.4	8.9	9.7	8.7	10.3
pH	8.0	8.2	7.8	7.9	8.0	8.1
Conductivity (mS/cm)	460	466	438	438	451	447
5/10/01						
Water Temperature ºC (ºF)	18.4 (65.12)	20.8 (69.4)	18.8 (65.8)	21.5 (70.7)	18.3 (64.9)	22.1 (71.8)
Dissolved Oxygen (mg/l)	6.1	7.0	6.1	7.6	6.5	6.4
pH	7.9	7.9	7.0	7.9	7.8	8.1
Conductivity (mS/cm)	439	431	442	424	448	446
6/7/01						
Water Temperature ºC (ºF)	18.8 (65.8)	21.1 (71.8)	18.7 (65.7)	21.2 (70.2)	19.9 (67.8)	23.3 (73.9)
Dissolved Oxygen (mg/l)	6.0	7.7	6.1	7.0	6.6	6.4
pH	8.1	8.0	7.9	7.7	7.9	8.0
Conductivity (mS/cm)	393	402	395	412	443	441
8/2/01						
Water Temperature ºC (ºF)	17.4 (63.3)	19.0 (66.2)	17.8 (64.0)	21.7 (71.0)	19.0 (66.3)	23.7 (74.7)
Dissolved Oxygen (mg/l)	6.5	7.9	6.9	7.9	6.4	7.8
pH	8.1	8.0	7.6	7.7	7.9	8.3
Conductivity (mS/cm)	384	392	388	367	454	443

Assessment: Water Quality

The 2002 water quality monitoring shows very low levels of dissolved oxygen of less than 5 parts per million (ppm) in several locations. A minimum level of 7 mg/l is needed to support steelhead rearing. At station WV2a, the low DO is associated with high water temperatures and a need for increased riparian cover in this area of Wooden Valley Creek. At stations WC 1, 4 and WV 6, water temperatures are cold, but DO levels are low. These stations are isolated groundwater-fed pools with dense riparian cover, which lack of any surface flow creating turbulence and increasing DO levels.

There are a number of stations where converted ammonia levels and converted nitrate levels are somewhat high. However, algal blooms were only recorded in a few locations (SC7, SC3, WV2a).

The Hanson Environmental, Inc. diel measurements show DO levels in the 6.0—6.5 mg/l range for stations on Suisun Creek in May, June and August. These levels of 6.0—6.5 are somewhat below the recommended 7 mg/l level needed to support rearing steelhead and most aquatic insects. These stations also showed water temperatures in the 65—75° range during the May-August period. The SWAMP data set has similar variations and levels of dissolved oxygen as the Hanson Environmental, Inc. data along with a number of other stations showing greater variation in DO levels. Summer water temperatures recorded by SWAMP are similar to the data loggers, but because the measurements only reflect two weeks, the full summer/fall temperature range is not captured.

Water quality data show low levels of nutrients and adequate levels of dissolved oxygen to support steelhead trout rearing at many stations. Since DO levels increase with water temperature, the stations without adequate canopy cover have lower DO levels. Improvements to canopy cover to reduce water temperatures and changes to flow rates should increase DO levels at many locations.

Aquatic Habitat

There are a number of features that need to be present in a creek to provide high quality aquatic habitat for steelhead trout (California Department of Fish and Game 1998). The features include – adequate cold water flow with oxygen, large wood or stumps, boulders, tree roots and undercut banks, riparian vegetation, food resources such as aquatic insect larvae, a variety of in-stream channel forms – pools, riffles, bars, glides consistent with a natural meandering channel and floodplain/channel relationship, limited fine sediment levels and bank erosion, and barrier free access along the channel. Many of these features are discussed in previous sections and depicted in Figures 8 and 9.

As part of this watershed assessment, a stream survey of Wooden Valley and White Creeks was completed following the California Department of Fish and Game protocol. Hanson Environmental, Inc. completed a stream survey in 2001 of Suisun Creek using a modified version of this same protocol.

The monitoring information generated by SWAMP of the San Francisco Bay Area Regional Water Quality Control Board for aquatic insects (Benthic Macro-invertebrates or BMI) at stations in the Suisun Creek watershed is also included.

The Historic Fishery

Steelhead trout likely have inhabited the Suisun Creek watershed prior to California statehood and historic times. Records dating from the 1990s all indicate steelhead trout adults running in Suisun and Wooden Valley Creeks.

Report on Four Reservoirs in Napa and Solano Counties by Leo Shapovalov, California Division of Fish and Game, July 1940, reviews conditions at four reservoirs including Lake Curry. The report describes the fish run and the depth of Lake Curry.

> "The resident caretaker reports that sea-run steelhead run up Gordon Valley Creek (Suisun Creek) to the spillway and also ascend Wooden Valley Creek…
>
> "Four small tributary streams enter the reservoir. The resident caretaker states that this year they will probably run all summer.
>
> "The resident caretaker reported that at 8 a.m. on June 25, the surface temperature in open water was 75ºF and the temperature at a 50-foot depth of 65ºF. The maximum depth on June 25 was about 70 feet.
>
> "Last summer the reservoir is reported to have dropped to the lowest level in its history, 25 or 30 feet below the spillway level. At this time the water was still 30 to 40 feet deep at its deepest point."

An Historical Review of the Fish and Wildlife Resources of the San Francisco Bay Area by John Skinner, Department of Fish and Game, 1962, lists Suisun Creek as the only trout stream in Solano County and describes Suisun as supporting an annual run of steelhead and resident rainbow trout.

A recent compilation of records on steelhead trout presence in San Francisco Bay Area streams *Historic Distribution and Current Status of Steelhead (Oncorhynchus mykiss), Coho salmon (O. kisutch) and Chinook salmon (O. tshawytscha) in Streams of the San Francisco Estuary, California* by Robert Leidy, Gordon Becker and Brett Harvey, October, 2003, includes the following information for the Suisun Creek watershed:

Suisun Creek

"Lake Curry was formed by the construction of Gordon Valley Dam on Suisun Creek in 1926. No fishway was built as part of this project (Shapovalov 1940). In a 1940 report, California Department of Fish and Game (CDFG) cited the reservoir caretaker as seeing "sea-run" steelhead running up Suisun Creek to the dam spillway.

A May 1956 CDFG survey found steelhead fingerlings "abundant" in the upper portions of Suisun Creek and its tributaries, particularly in and just below the confluence of Wooden Valley Creek (Westgate 1956). Steelhead also were present, although in smaller numbers, downstream to mouth. The survey report stated the CDFG's opinion that the Suisun Creek system could not support a substantial trout fishery due to over-appropriation of water (Westgate 1956).

In a 1962 report, Skinner indicated that Suisun Creek was an historical migration route and habitat for steelhead and/or Coho salmon (Skinner 1962). At that time, the creek was said to be "lightly used" as steelhead and/or Coho salmon habitat (Skinner 1962). In this reference, no distinction is made between use by steelhead and by Coho salmon.

In April 1964, CDFG sampled Suisun Creek at the upper end of Suisun Valley near Mankas Corner. Several steelhead (~150mm) were observed, and the survey report noted some spawning gravels present in the vicinity of the site (Gerstung 1964).

A 1969 CDFG memorandum noted an estimated run of less than 50 steelhead in the Suisun Creek watershed (Greenwald 1969). CDFG stated that juvenile steelhead were observed throughout the watershed and further noted a lack of nursery habitat as the population's limiting factor (Greenwald 1969).

In February 1975, CDFG electro-fished 30 meter reaches near the Rockville Road bridge construction site. Thirty-nine steelhead were found in the reach immediately upstream and 96 in the reach immediately downstream of the site (Rugg 1975). Rockville Road crosses Suisun Creek immediately upstream of Interstate 80.

In July 1980, CDFG visually surveyed and electro-fished Suisun Creek between the Southern Pacific Railroad Bridge, downstream of Interstate 80, and the Wooden Valley Creek confluence. No steelhead were found, but the survey report stated that the creek sustained a winter steelhead run (Cox 1980). The report noted anglers taking steelhead in the summer of 1979, as well as local residents' claims that runs had decreased in recent years (Cox 1980). CDFG recommended management for steelhead by removing barriers, improving agricultural practices and preventing dumping.

Three Suisun Creek sites downstream of Lake Curry were sampled in October 1981 as part of a fish distribution study. No steelhead were found (Leidy 1984). In a 1984 report, CDFG noted that Suisun Creek had a self-sustaining, natural steelhead population (Meyer 1984).

Between March and July 2001, steelhead were observed in Suisun Creek by people performing habitat mapping and monitoring activities. In March, an adult female steelhead (673 mm fork-length) was found approximately 0.25 miles downstream of the Wooden Valley Creek confluence (Hanson Environmental, Inc.). In June and early July, three additional adult steelhead (530 to approximately 640 mm) were observed in the creek between approximately six and 11 miles downstream of Lake Curry. Juvenile steelhead also were observed downstream of the dam. These fish typically ranged from 160-170 mm in length (Hanson Environmental, Inc.)."

Wooden Valley Creek

"CDFG reported in 1940 that the caretaker of Lake Curry (on Suisun Creek) observed steelhead runs in Wooden Valley Creek (Shapovalov 1940). IN May 1956, CDFG sampled throughout the Suisun Creek drainage, and started in a report that steelhead in the Suisun Creek system were most abundant in Wooden Valley Creek downstream from Wooden Valley (Westgate 1956).

A 1959 CDFG correspondence cited Mr. Bolten Hall, the local game warden, a saying that Wooden Valley Creek supported a small run of steelhead trout every year (Jones 1959). The letter stated CDFG's position that Wooden Valley Creek provided a steelhead trout fishery that was worth preserving through insurance of adequate flows (Jones (1959).

In April 1964, CDFG surveyed Wooden Valley Creek in the canyon downstream of Wooden Valley. Two to eight steelhead juveniles were noted in deeper pools in the reach (Gerstrung 1964). Numerous steelhead juveniles to 150 mm in length were observed in the canyon below Wooden Valley. The survey report noted patches of "excellent" spawning gravels (Gerstrung 1964).

A 1965 CDFG letter regarding a box culvert on Wooden Valley Creek noted that the stream was important to salmonid populations. The letter contained recommendations for providing fish passage at the project (Jones 1965). A 1969 CDFG memorandum identified the greatest concentrations of steelhead juveniles in the Suisun Creek system to be in Wooden Valley Creek (Greenwald 1969). A 1980 CDFG stream survey report for Suisun Creek noted that juvenile steelhead were seen in surveys of Wooden Valley Creek that year (Cox 1980).

Wooden Valley Creek was sampled October 1981 as part of a fish distribution study. No steelhead were collected in a 15 meter reach along Wooden Valley

Road (Leidy 1984). An undated draft letter from CDFG to the City of Vallejo Water Superintendent identified the lack of surface flows below Lake Curry as the principal element limiting the productivity of steelhead in Suisun Creek (Hunter *n.d.*).

In December 2001, a pair of spawning "salmon" were observed constructing a redd in the lower reach of Wooden Valley Creek near Wooden Valley Road (Blizard 2001). A pair of spawned out carcasses (one male, one female) and possibly another male salmon also were observed (Blizard 2001).

White Creek

"White Creek is a tributary of Wooden Valley Creek and flows through the property of Wild Horse Valley Ranch. In 1980, Professor John Hopkirk of Sonoma State University identified White Creek as one of the last remaining spawning streams for steelhead trout within the Suisun Creek system."

Historic Record of Salmon and Steelhead in Solano County Streams by JRP Historical Consulting Service for the Solano County Water Agency in 2001 reviews a broad range of documents for references to steelhead presence in Solano County streams. In addition to the references quoted in the previous section, the following are cited:

"Lander, Paul. Telephone Interview. March 15, 2001. Mr. Landier, a resident and fisherman of Solano County since the 1940s, asserted that he had seen king, Chinook salmon and steelhead trout in Suisun Creek when he first moved to the area around 1943.

"U.S. Army Corps of Engineers, Sacramento District Transcript of Public Hearing for Flood Control on Streams in vicinity of Fairfield, California held June 29, 1964 included a letter dated February 26, 1963 from the CDFG stating:

"Suisun Creek contains a run of steelhead that ascend the stream during high water periods en route to spawning areas in the headwaters."

Wooden Valley and White Creeks Stream Habitat Survey

Figure 43 illustrates the portions of Wooden Valley Creek included in the habitat survey. Areas that were not surveyed were either dry or landowner access was not received. The survey was completed in June 2002.
Steelhead trout (may also be rainbow trout, the non-anadromous form) were observed during the stream survey in all areas of the survey in pool habitats. Multiple age classes were seen: young of the year (1-3 inches), one-year + (3-6 inches) and two-year + (great than 6 inches). In addition, several larger trout (~12 inches) were observed in deeper pools. Other fish species observed include:

- California roach (*Lavina symmetricus*)
- Other Cyprinids (*unidentified species*)
- Sculpin (*Cottus sp.*)
- Bluegill (*lepomis macrochiris*)
- Green sunfish (*Lepomis cyanellus*)
- Threespine stickleback (*Gasterosteus aculeatus aculeatus*)
- Mosquitofish (*Gambusia affinis*)

The stream survey found a need for large wood and shelter elements to enhance in-stream habitat for steelhead rearing. The survey also found excessive fine sediment in the streambed and bank erosion in a number of areas where riparian revegetation is also needed. In the year of the survey (2002), water levels were low and the frequency of pools limited. A lack of adequate riparian vegetation on White Creek created high water temperatures.

The stream survey also identified a number of potential fish passage barriers. These barriers consist of culverts and a concrete dam and are indicated on Figure 44.

Hanson Environmental, Inc. completed a stream habitat survey of much of Suisun Creek in June and July, 2001 when reservoir releases from Lake Curry were 2 cfs (see Figure 43). The surveys found that pools were the dominant habitat type and that the availability of spawning gravel was very limited. Similar to Wooden Valley Creek, Suisun Creek had a lack of large wood, undercut banks, root wads and boulders to serve as shelter for rearing steelhead. Suisun Creek also had a lack of adequate riparian canopy. Stream velocity was also identified as a major limiting factor to rearing steelhead. The survey identified a large number of potential fish passage barriers (Figure 44) consisting primarily of beaver dams. The beaver dams also create many of the pools that dominate creek habitat. The drop structure under Suisun Valley Road bridge (SC 4) was also identified as a potential fish passage barrier.

The stream survey also recorded bank heights and several geomorphic features and found the lack of a floodplain along nearly 70% of the stream. Bank heights were recorded in excess of ten feet on 60% of the stream, indicating an entrenched or incised condition over much of unconfined, alluvial sections of Suisun Creek similar to observations made at many other points by other scientists.

The stream survey included observations of adult steelhead in Suisun Creek and juvenile rainbow or steelhead trout. Both adult and juvenile fish were observed at various points over much of the stream. One adult female fish carcass was found and it did not have a clipped adipose fin indicating it was not a hatchery fish, but possibly a wild fish. Evaluation of the genetic features of the fish would be needed for confirmation. Hanson Environmental, Inc. collected tissue from the carcass to allow for later genetic evaluation.

Figure 43. Wooden Valley Creek Habitat Survey

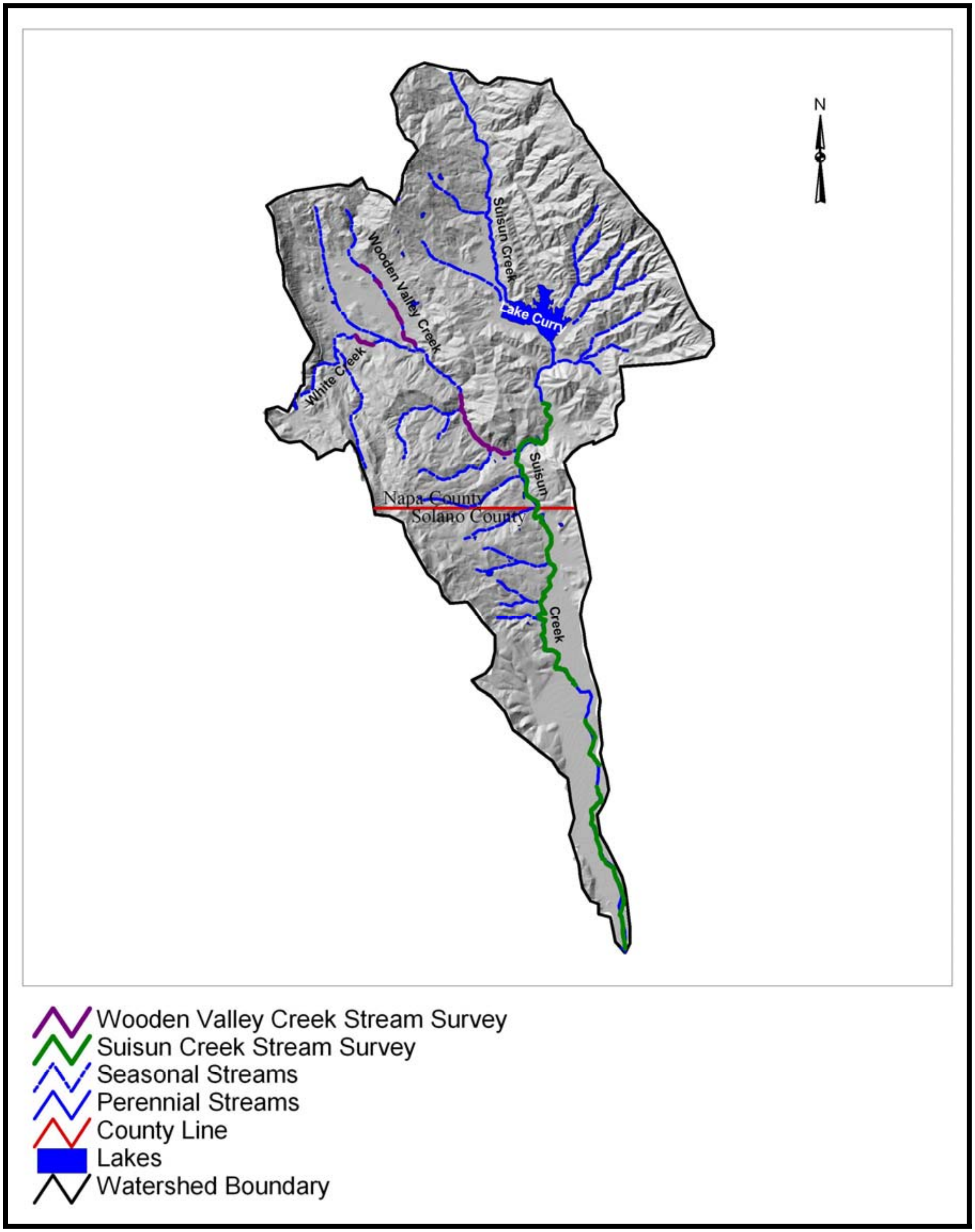
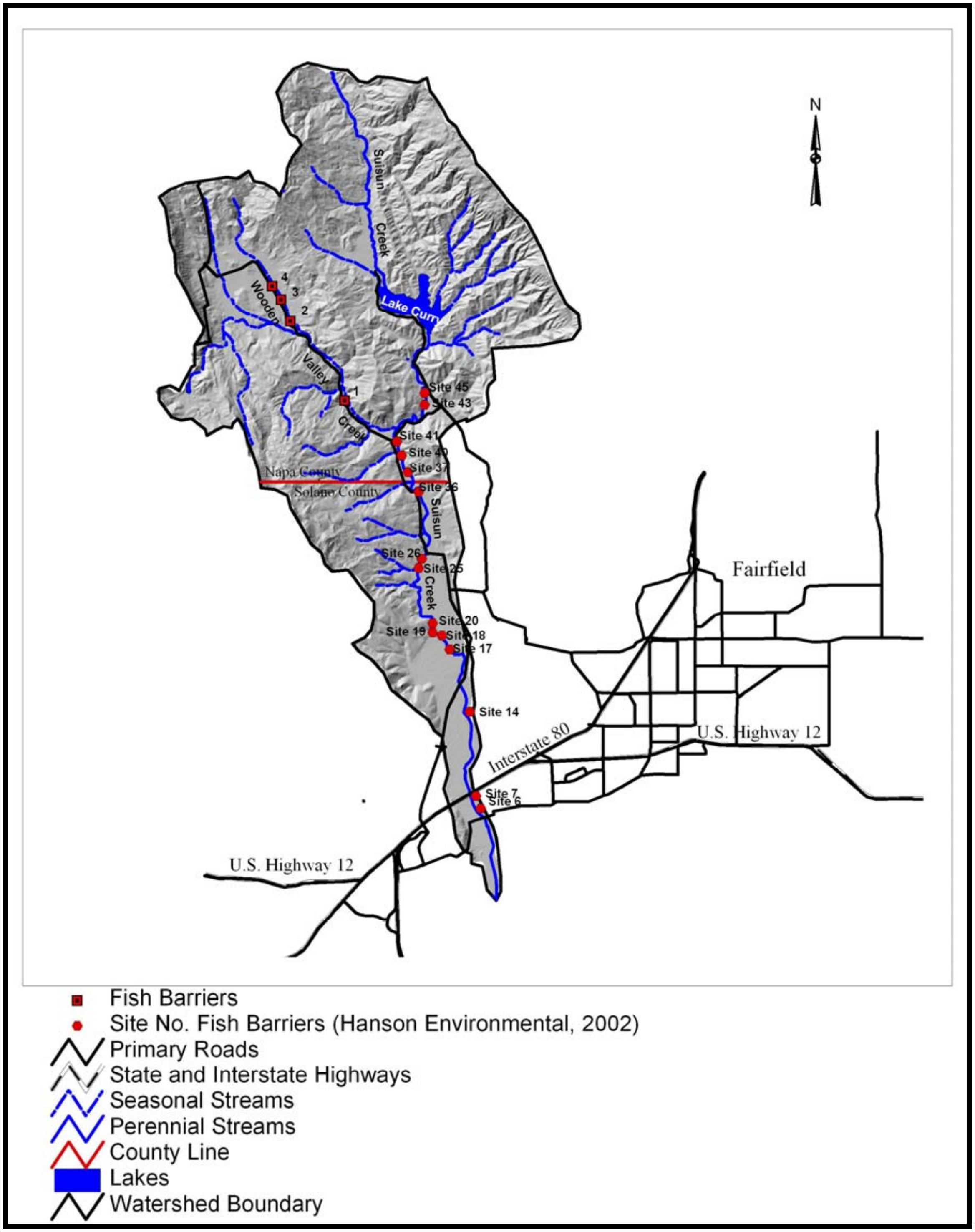


Figure 44. Fish Passage Barriers in the Suisun Creek Watershed



Aquatic Insects or Benthic Macro-invertebrates (BMIs)

Background

Benthic macro-invertebrates, or aquatic insects, live amongst the rocks, logs, wood, plant roots, and boulders in creeks (see Figure 45). The diversity and abundance of benthic macro-invertebrates are an indication of the health of a creek.

Macro-invertebrates are an essential part of the creek ecosystem. Each group occupies a different microhabitat. The more complex the stream, the greater the diversity of microhabitats and the greater the diversity and abundance of aquatic insects.

Macro-invertebrates are separated into different groups:

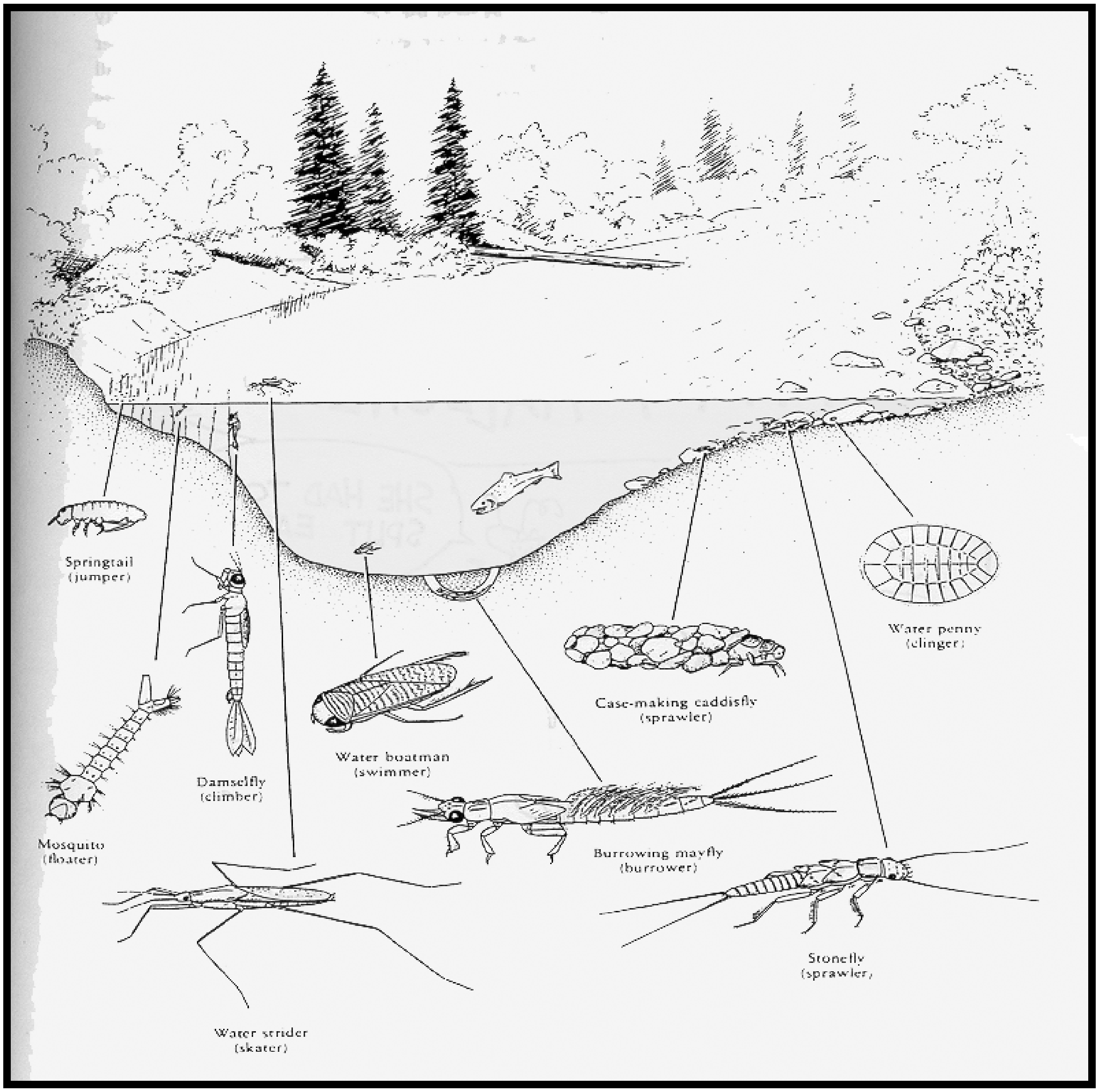
- Aquatic insects such as stoneflies, mayflies, dragonflies, caddisflies and damselflies
- Clams and mussels
- Snails and limpets
- Segmented worms
- Crustaceans

Each group undergoes a different life cycle from egg to adult and occupies various microhabitats. For macro-invertebrates, the currents of water in a stream provide sources of food as well as a risk of being carried away. Macro-invertebrates have adaptations to living in moving water. These adaptations include: small size bodies, flattened body forms, streamlined body forms to reduce resistance to water currents, hooks such as claws on legs to attach to rocks, and sticky secretions to attach to rocks and substrates (California Department of Fish and Game 1998 and 2000, Environmental Protection Agency 1989).

Microhabitats in a stream channel include riffles, pools, runs, large wood and tree roots. A riffle, a sill of rocks that stretches across the stream channel, has fast moving water and have numerous sites for macro-invertebrates. Runs and pools have deep, slower moving currents and support macro-invertebrates, but do not have the variety of microhabitats that riffles contain. Large wood and tree roots create many diverse places for macro-invertebrates. Of all these areas in the stream channel, the riffle can have the highest diversity and abundance of macro-invertebrates and can be sampled in a manner that can be replicated over time. For these reasons, riffles are the focus of macro-invertebrate monitoring.

Macro-invertebrates are sensitive to water quality, siltation, water temperatures and changes in the form of the creek channel such as vegetation clearing, channel straightening, or gravel removal. Monitoring macro-invertebrates gives an index of the health of the creek and can be used to evaluate the occurrence of various types of pollution and other changes in watershed conditions, such as urban development

Figure 45. Benthic Macro-invertebrates



as well as improvements in creek conditions from restoration and erosion control activities.

Different macro-invertebrate groups are more sensitive or more tolerant to pollutants in the stream. The sensitive groups include Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies) also termed EPT. BMI monitoring results usually report the percentage of EPT found in the monitoring sample. Table 18 lists the results of BMI sampling performed in 2001 by the Regional Water Quality Control Board. Currently, the Regional Board and Matt Cover, the researcher who collected the BMI data, are preparing an interpretive report. In general, the BMI data show a high percentage of the pollution-sensitive EPT group indicating generally good water quality.

Assessment: Aquatic Habitat

There are accounts dating to the 1940s indicating steelhead trout have inhabited the Suisun Creek watershed. Stream surveys of Wooden Valley and White Creeks found juvenile steelhead or rainbow trout throughout the system. The Suisun Creek stream survey found both juveniles and adult steelhead. Both stream surveys found a need for large wood in the streams to increase shelter for juveniles. Fine sediment is excessive in both creeks and pools are the dominant habitat type with limited spawning gravel. A number of fish passage barriers were identified, including a large number of beaver dams as well as old concrete structures obstructing the channel.

Benthic macro-invertebrates (BMIs) were monitored by the Regional Board SWAMP program. The data indicated good water quality conditions.

Land Use and Land Planning

Land use plays a major role in the condition of the watershed, the generation of fine sediment, the volume and timing of stormwater flows, the type and concentration of water pollutants, the extent of riparian forest and the condition of creek channels (Meehan 1991, Mount 1995, Reid et al 1984).

The Suisun Creek watershed is primarily private agricultural land and rangeland. Winegrapes, pears, row crops and livestock are the primary agricultural products. There are a limited number of rural residential uses spread out in the watershed and urban/industrial land uses in the southern portion of the Suisun Valley adjacent to Interstate 80. Suisun Creek watershed is over 95% rural and natural lands giving this watershed the hydrologic features needed to support steelhead trout and a healthy aquatic ecosystem. However, the watershed also has intensive agricultural uses, livestock grazing near creeks, dirt roads throughout much of the watershed and a large municipal water supply reservoir. All these land uses have altered the hydrology and sediment generation in the system.

Table 18. Benthic Macro-invertebrate Monitoring – Suisun Creek Watershed – Regional Water Quality Control Board SWAMP 2001-2002

Site Code*	**SUI-010**	**SUI-020**	**SUI-050**	**SUI-060**	**SUI-110**	**SUI-130**	**SUI180**	**SUI-210**	**SUI-260**
Cumulative Taxa	30	35	29	27	35	36	31	24	35
Percent Dominant Taxon	43	29	32	31	43	37	26	42	35
EPT Index (%)	25	36	35	42	57	52	61	25	11
Sensitive EPT Index (%)	3	9	5	8	11	11	36	4	8
Cumulative EPT Taxa	15	15	17	14	15	18	13	8	11
Shannon Diversity	1.8	2.1	2.1	2.0	1.8	2.0	2.3	1.7	2.1
Tolerance Value	5.6	5.6	5.2	5.2	4.9	5.0	3.9	5.1	5.9
Percent Intolerant Taxa (0-2)	1	7	5	7	11	11	36	3	8
Percent Tolerant Taxa (8-10)	13	13	2	0	2	3	3	0	17
Percent Collectors	74	72	60	62	67	64	72	49	49
Percent Filterers	20	19	33	27	26	30	9	43	32
Percent Grazers	1	4	3	5	6	1	14	2	1
Percent Predators	5	5	4	5	2	5	5	4	17
Percent Shredders	0	0	0	0	0	0	0	2	1

*See Figure 42 for site locations.

Intensive agriculture consisting of vineyard, orchards and row crops are concentrated in the floodplains of Suisun Valley and Wooden Valley. Hillside vineyards are limited. Intensive agricultural areas, particularly where annual crops are grown and fields are regularly tilled, can generate fine sediment in winter storms and through wind generated erosion. In vineyards and orchards, if the ground between rows is regularly tilled and cover crops and winterization practices are not carried out, many tons of fine sediment can be produced. Livestock areas may have gullies or sheet erosion from soil compaction by cattle or overgrazing. In all instances, dirt roads can be the largest source of fine sediment. The condition of agricultural lands in Suisun Valley and Wooden Valley was evaluated in January 2002. Use of cover crops and winterization practices was found to be largely missing.

Drainage ditches in many areas of Suisun Valley had no vegetation to reduce fine sediment transport into creeks. Basic soil conservation practices – cover crops in vineyards, filter strips around row crop areas, winterization of farm roads, were not evident in most areas of Suisun and Wooden Valleys.

Roads were delineated as part of the GIS in Figures 46-54. Roads in most watersheds represent the biggest source of fine sediment, regardless of the land use they serve. It is likely that many of the dirt roads need erosion control measures. Many of the roads closest to the creeks are public roads. Ditch and culvert outlet erosion on Suisun Valley Road and Wooden Valley Road are common, producing fine sediment into the creek system. Highly eroded soil areas are also delineated in Figures 48-51. These areas are highly susceptible to erosion from roads, vegetation clearing, tillage, construction and other actions. In addition, roads on steep hillsides in excess of 10% slope, are also more susceptible to erosion.

Urban and industrial land uses have the ability to generate runoff in much greater quantities than agricultural lands and create urban effects of incision and increased bank erosion in creeks.

Additionally, urban and paved road runoff tends to carry the by-products of cars – oil and grease residues, heavy metals and anti-freeze. CalTrans, which along with Napa and Solano Counties maintains Wooden Valley and Suisun Valley Roads, does not have plans to widen either road.

Figure 46. Index to Figures 47-54

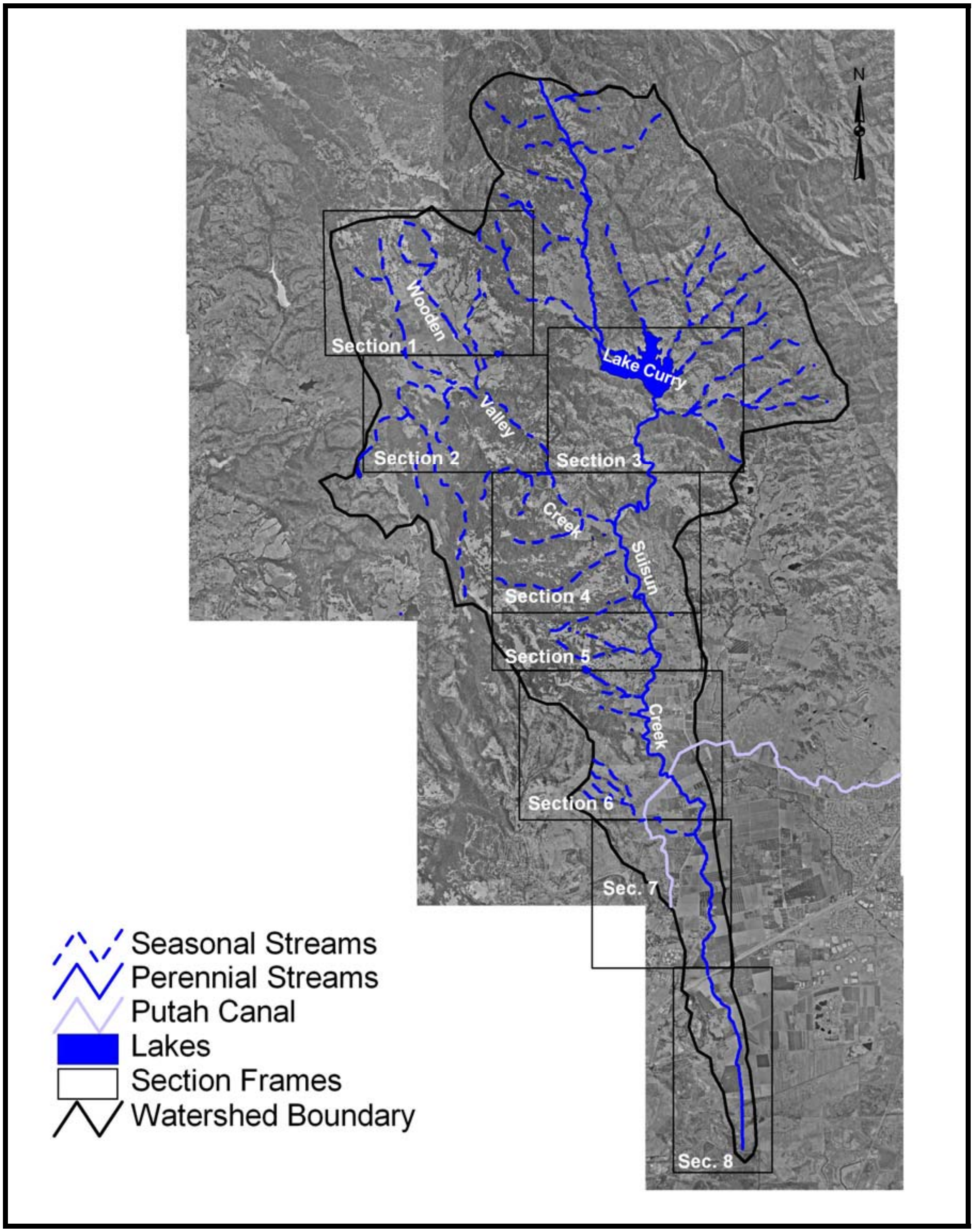


Figure 47. Roads in the Suisun Creek Watershed – Section 8

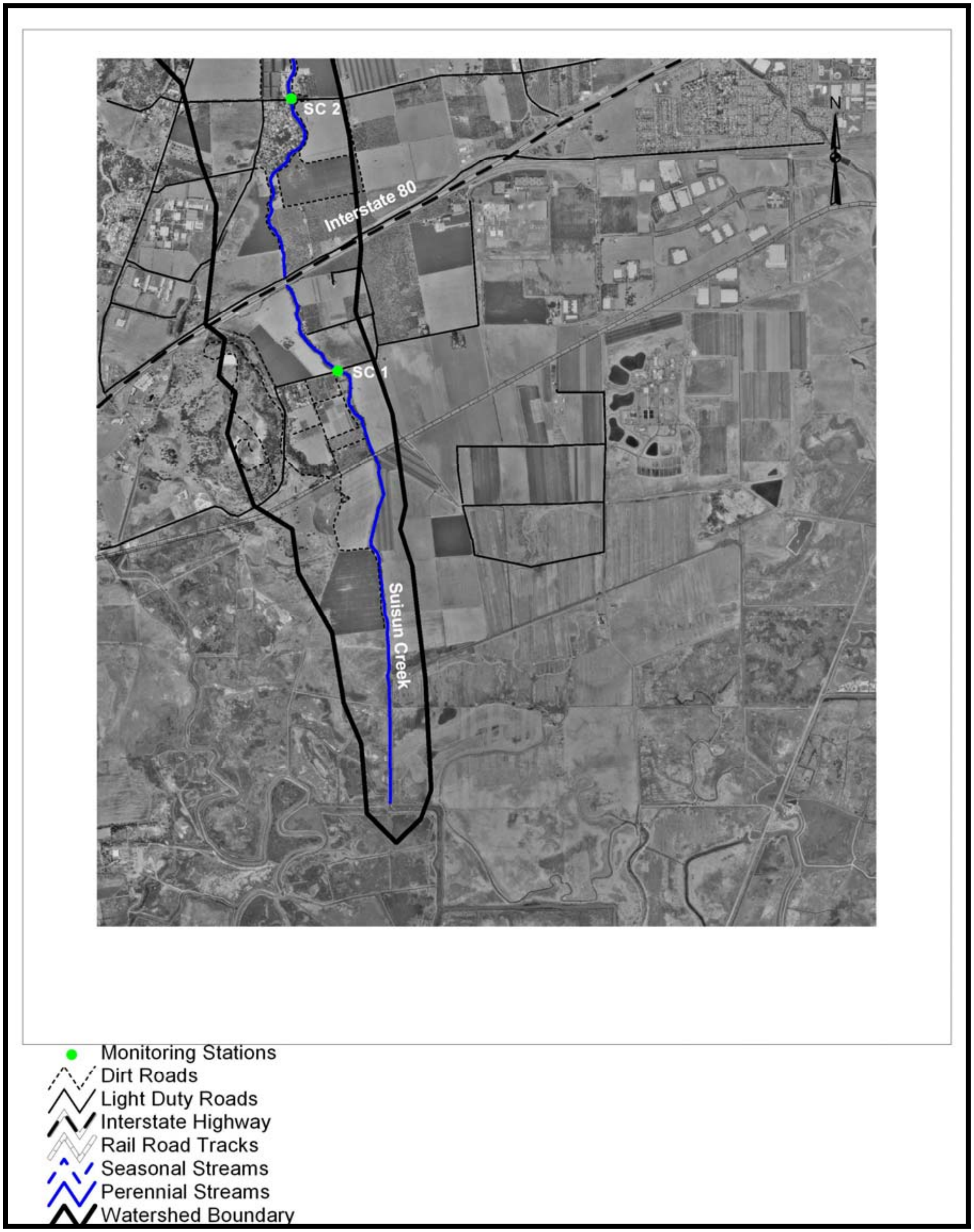


Figure 48. Roads in the Suisun Creek Watershed – Section 7

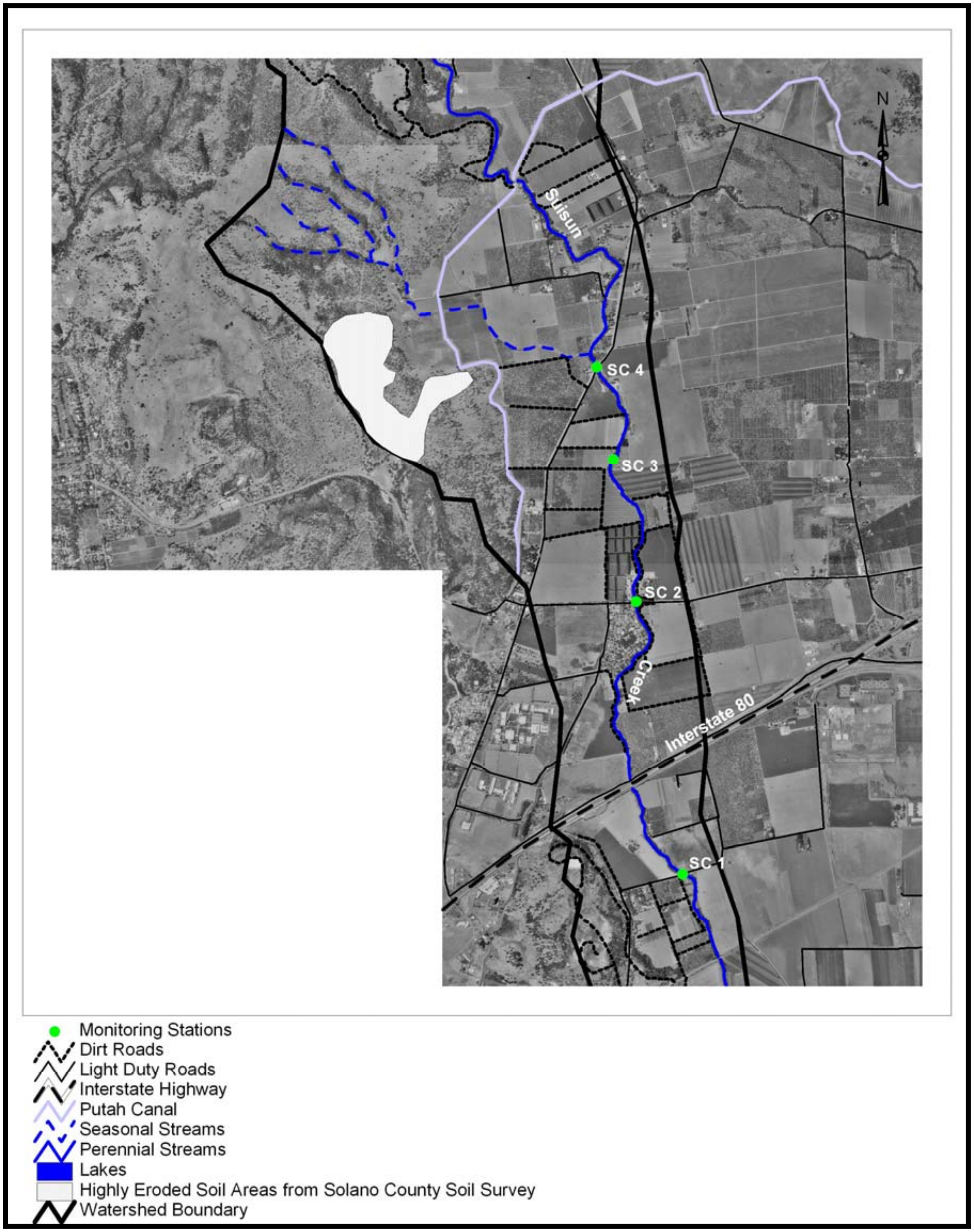


Figure 49. Roads in the Suisun Creek Watershed – Section 6

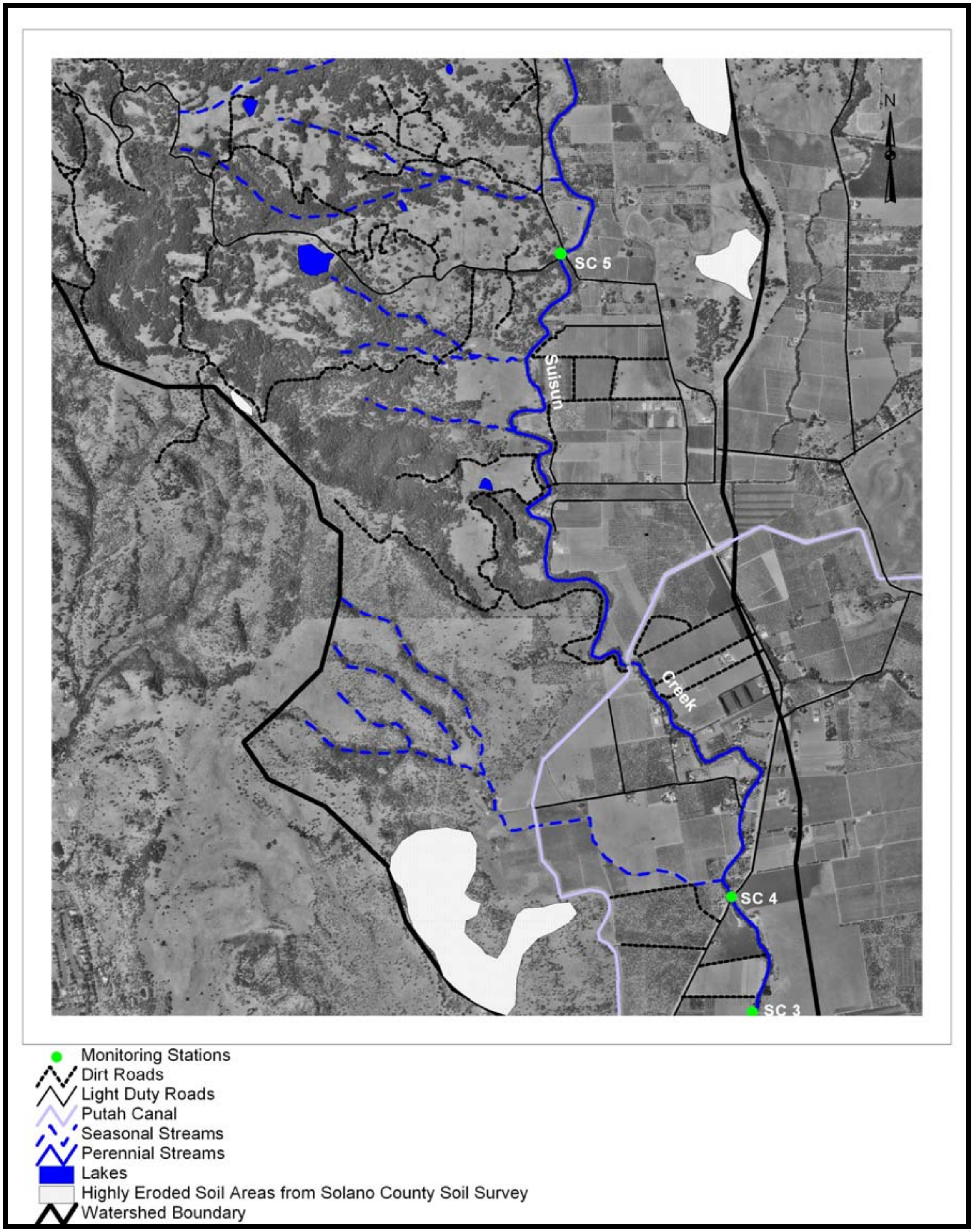


Figure 50. Roads in the Suisun Creek Watershed – Section 5

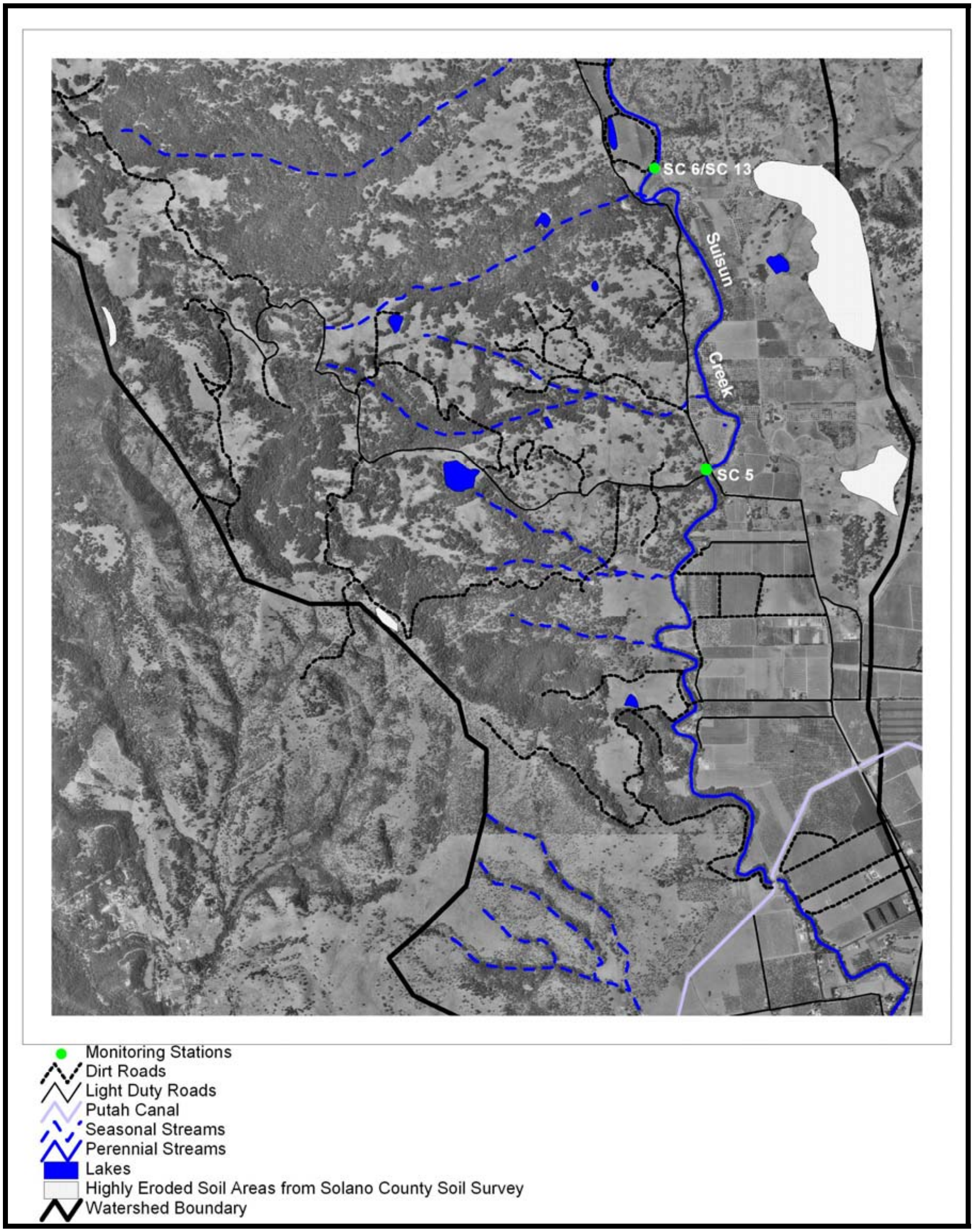


Figure 51. Roads in the Suisun Creek Watershed – Section 4

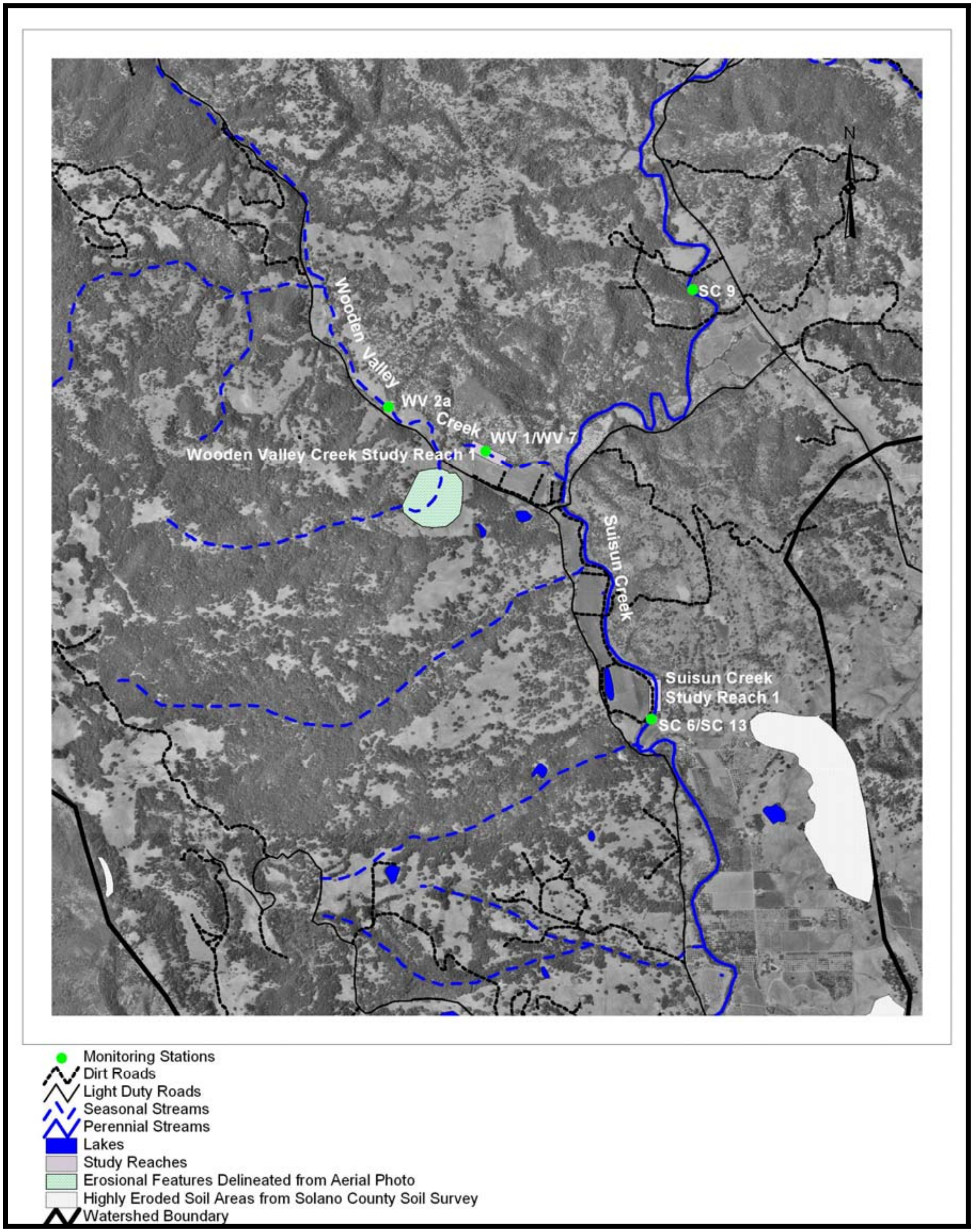


Figure 52. Roads in the Suisun Creek Watershed – Section 3

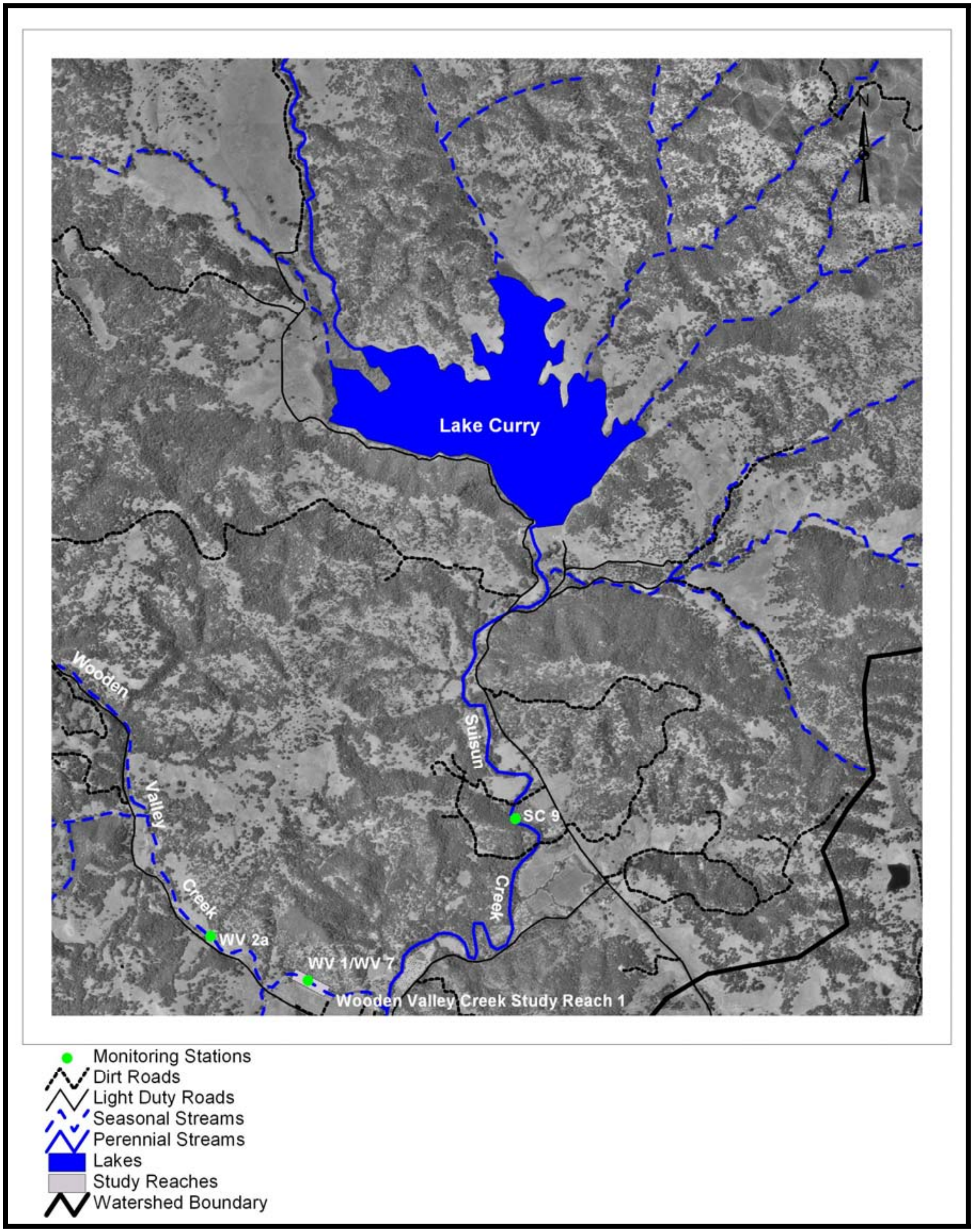


Figure 53. Roads in the Suisun Creek Watershed – Section 2

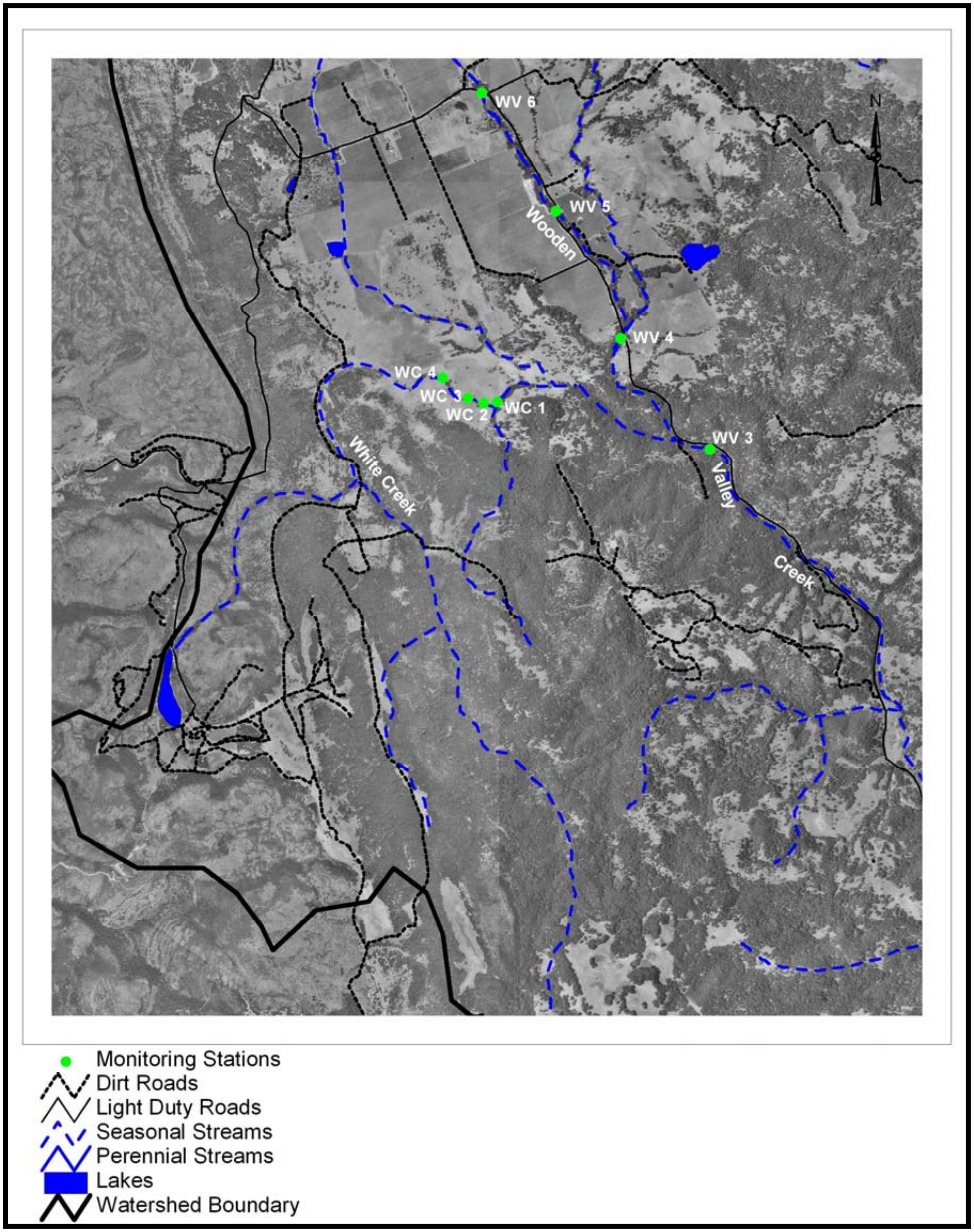
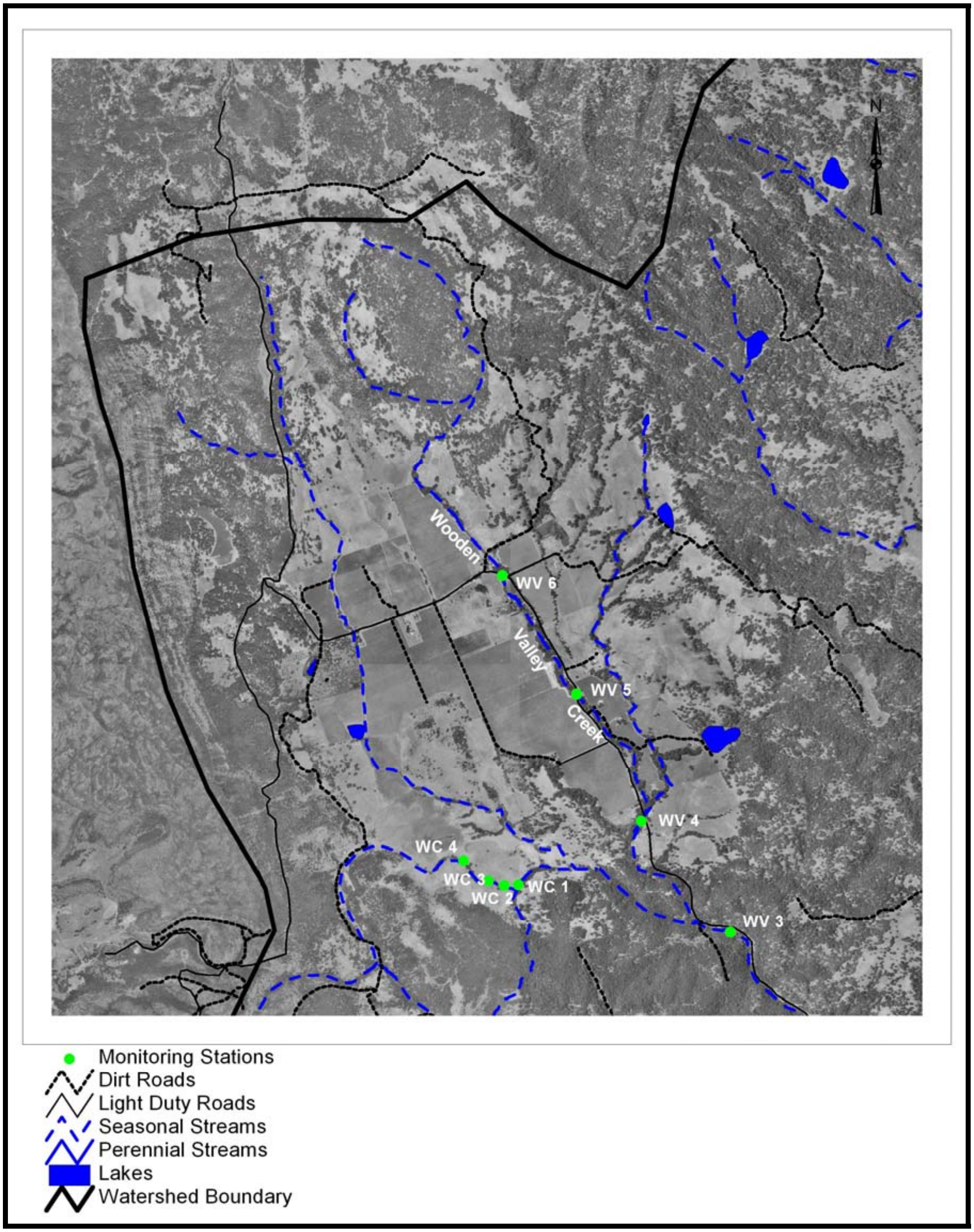


Figure 54. Roads in the Suisun Creek Watershed – Section 1



Land Use Planning

The Suisun Creek watershed lies in Napa and Solano Counties and does not include any cities. Each county has a General Plan that lays out the planned future uses of lands.

Solano County's General Plan concentrates on city centered urban growth. Suisun Valley is primarily designated for intensive and extensive agriculture with hillside areas designated as Open Space/Watershed. In the southern portion of the watershed near Interstate 80, there are small areas designated for Residential, Public (Solano Community College), Highway Commercial and Commercial Service. South of Rockville, the hills to the west are designated for residential development at two to seven units per acre and park and recreation use.

In the Napa County General Plan, Suisun Valley and Wooden Valley are designated for Open Space-Agricultural Resource and the mountainous areas are designated for Agriculture, Watershed and Open Space.

Both General Plans indicate that no major land use change, such as large-scale urban development is being considered. Prior to any major developments, an amendment to the General Plan, as well as numerous other permits would be required for approval.

Assessment: Land Use and Planning

The majority of the Suisun Creek watershed is private agricultural land used for livestock, vineyard, orchards and row crops. Agricultural land management practices need improvement through voluntary efforts with landowners to reduce soil erosion.

Roads in the watershed, both public and private, are also likely sources of erosion and fine sediment into creeks. General Plans for Napa and Solano Counties indicate open space and agricultural land uses for most of the watershed.

Summary of Watershed Assessment and Monitoring

The 53 square-mile Suisun Creek watershed is largely rural, dominated by wild land and agricultural land. Unlike most urban Bay area creeks and watersheds, the rural nature of the watershed creates many of the conditions required to create and sustain aquatic and steelhead trout habitats. However the assessment and monitoring for Suisun Creek watershed identified a number of conditions that need to be improved to enhance aquatic and riparian habitats and steelhead trout survival. These conditions include:

- Summer water temperatures are marginal to too warm for steelhead rearing in many areas of Suisun Creek below Lake Curry and in several isolated locations in

Wooden Valley and White Creeks; however, cold water conditions dominate much of Wooden Valley and White Creeks.

- Riparian canopy cover is inadequate on much of Suisun Creek, lower Wooden Valley Creek and parts of White Creek contributing to the high summer water temperatures. The riparian corridor is narrow in most locations.

- Several invasive non-native plant species – giant reed, blue periwinkle, Himalayan blackberry and Harding grass have spread into many areas of the riparian corridor. Invasive plants are a major problem for riparian habitats.

- There was a high level of fine sediment in the channel in the areas monitored. Soil erosion from a wide variety of sources such as public and private roads, bank erosion, agricultural and urban lands needs to be reduced.

- There are a number of fish passage barriers in Suisun and Wooden Valley Creeks that need to be altered or removed. In addition, many areas of the creek need additional large wood to create productive complex habitat for steelhead trout.

- Lake Curry affects the magnitude and frequency of stormflows on Suisun Creek, especially the smaller two-year floods. As the number of small flood events is diminished, fine sediment can build up on the channel bed in spawning and rearing habitats. The large number of beaver dams on Suisun Creek that block fish passage may also be supported by the lack of regular scouring stormflows on Suisun Creek.

- Lake Curry releases water in summer from the lower outlets in the reservoir. Water temperature measurements for the 2.0 and 3.0 cfs releases into Suisun Creek in 2002 and 2003 indicate a need to increase the volume of flow and canopy cover. A larger volume or mass of water in Suisun Creek can likely attenuate solar inputs and maintain a lower water temperature than the current low level release.

- Additional monitoring of water temperatures, water quality and fine sediment levels along with surveying of channel study reaches is needed to implement an adaptive management approach in the watershed.

- Monitoring information collected should inform the next set of enhancement actions. A more thorough survey of the Suisun Creek channel is need to evaluate the locations and extent of channel entrenchment and its potential effects on both downstream flood problems and riparian and aquatic habitats. This type of survey should be completed in cooperation with landowners and the Solano County Water Agency Flood Control Committee.

- All projects need to be developed with landowner involvement and cooperation to implement and sustain long term improvements in the watershed and aquatic and riparian habitats.

- Cooperation between the City of Vallejo, environmental and fishery groups, agricultural groups, state and federal agencies and elected officials is needed to evaluate alternatives for re-operation of Lake Curry. The preferred alternative needs to provide for: use of the municipal water supply in Lake Curry, continued local water service, and protection and enhancement of riparian and aquatic habitats and endangered steelhead trout habitats.

IV. ENHANCEMENT ACTIONS

The monitoring and watershed assessment found a number of conditions in the creeks and watershed that, if enhanced, could improve aquatic, riparian and steelhead habitats. Aquatic and riparian habitats are affected by many processes and conditions in the watershed and creek (Environmental Protection Agency 2000, US Department of Agriculture 1998, Roni et al 2002). For this reason, no single project can serve to provide all the actions needed to restore and sustain aquatic and riparian habitats and support steelhead trout. Instead a number of actions and projects are needed.

The current monitoring and assessment information was used to identify the following enhancement actions. As these actions are implemented, monitoring should continue and identify different or additional enhancement actions. This process is termed adaptive management and requires both an array of scientific monitoring at long-term stations and community and landowner involvement to implement the program. The approach to implementation of all improvements must be through cooperative relationships with landowners in the watershed. Since the majority of land management decisions are made by local landowners then cooperation with the land manager is the most effective way to improve the conditions in the watershed and creeks.

1. Restoring Riparian Forest on Denuded Channel Areas to Reduce Water Temperatures

Several areas on Wooden Valley and White Creeks have little to no riparian cover (Figures 33-40) and therefore have very high water temperatures or dry conditions. The landowners of these areas will need to support revegetation and the projects would need to be designed to take into account the landowner's needs as well as the practical aspects of native plant revegetation.

The following steps are needed:

- Discuss project with landowner and complete revegetation design to incorporate landowner needs.

- Riparian trees such as willow, white alder, box elder, Oregon ash, California bay laurel and oak should be included in the revegetation design. Planting locations should reflect each species' relationship to the bankfull channel in a natural system (see Figure 41). A riparian ecologist should complete the revegetation design.

- Native plant materials from the Suisun Creek watershed should be grown for use in the project.

- Any invasive plants should be treated and eradicated prior to revegetation.

- Permits for the project would be needed from the California Department of Fish and Game.

- Plants need to be installed in winter and irrigated for 24 hours every three weeks with a drip system for the first three dry seasons (April-first rains).

- Exclusionary fencing for livestock or a riparian pasture project may be needed. Protective tubing to reduce deer and rodent browse may also be needed along with periodic weeding.

2. Controlling Invasive Species in the Riparian Corridor to Enhance the Corridor, Reduce Water Temperatures and Reduce Pierce's Disease Problems for Grapegrowers

2A. Giant Reed (Arundo donax) Mapping, Eradication Strategy and Implementation of Removal Projects

In the watershed assessment, small clumps of giant reed (*Arundo donax)* were noted. This indicates the beginning of a larger infestation. *Arundo* grows in dense clumps up to 25 feet in height and spreads rapidly through clonal reproduction. *Arundo* out-competes many native plant species and provides little to no wildlife habitat. Because *Arundo* is a 25 foot tall grass, it does not provide shade to the creek or large wood and insects for fish habitat in the way native riparian forest does.

The following steps are needed:

- Map the full extent of the Arundo infestation using low elevation infrared photographs taken in winter when many native riparian species are leafless. This method has been applied in both the Russian and Napa River systems with good results. The maps should be entered into the watershed GIS.

- Though the extent of Arundo growth and general locations are the main focus of this mapping project, the determination of stand growth-patterns in relation to surrounding vegetation is considered important due to the implications for eradication efforts and long term monitoring. Classify Arundo stands into the following categories:

- Overstory: discreet stands of Arundo growing as a monoculture, visible on both the low level aerial photos and the low-level oblique photographs taken in winter.

- Overstory/Intermixed: stands of Arundo growing as overstory, but intermixed with other same-sized shrubs and trees.

- Understory: stands of Arundo growing as the understory layer, with an overstory canopy consisting of larger-sized trees.

- From the GIS layers, the location, extent and acreage of the infestation would be evaluated and an eradication strategy formulated using mechanical and chemical eradication methods. The strategy should extend from upstream to downstream to reduce the potential for re-infestation.

- Once several eradication concepts have been developed, the landowners on the creek need to be involved and have input. It will be critical to work closely with landowners to eradicate this plant and continue follow-up activities. We have proposed completing two community workshops and mailing a summary of the *Arundo* problem and removal strategy to all creekside landowners.

- Working with cooperative landowners, removal projects with native plant revegetation would be completed as model or demonstration projects. Sites will be prioritized from upstream to downstream and allow for further landowner involvement and a demonstration removal workshop. It will take time to remove all of the *Arundo*. Creation of the eradication strategy and the start of the removal process would encourage landowners and identify future projects and possibly other sponsors. Removal will use either cut and paint with glyphosate or cut and tarp methods. Both of these methods, as well as prioritizing by location on the creek, have proven to be cost effective eradication measures.

- Pre- and post- project monitoring of the riparian corridor at each demonstration project site should be completed. Transects across the riparian corridor would record the density, number and species of plants, tree height and dbh (diameter at breast height) at each four-foot interval. Transects should be located at 500-1000 foot distances in the project sites. In addition, features such as wildlife habitat elements (snags, food sources etc.) should be recorded. Four canopy cover measurements will be recorded at each four- foot interval in the stream channel using a spherical densiometer. These transects should be done prior to any project work and every year for three years following project implementation. Data from these transects would indicate changes in plant density, abundance and wildlife value as well as shade cover. The monitoring should also evaluate the effectiveness of the eradication projects and identify needed follow-up.

- Once the demonstration projects are completed field days with landowners should be held to develop the next round of eradication projects

2B. Native Riparian Revegetation and Demonstration Invasive Plant Removal Projects

Besides *Arundo donax*, several other invasive non-native species were found to be widespread in the riparian corridor – blue periwinkle (*Vinca major*), Harding grass (*Phalaris aquatica)* and Himalayan blackberry (*Rubus discolor*). These invasive plants cover over native understory and stream bank areas impairing regeneration of native plants. Native tree seeds cannot germinate through the thick mat of invasive plants. As the riparian forest grows old and dies with little to no regeneration, the invasive species are all that remain. Over time, this type of succession in the vegetation reduces shade canopy over the creek and would result in increased water temperatures. In addition, blue periwinkle and Himalayan blackberry are of specific concern to grapegrowers as they harbor Pierce's disease, a bacterial disease fatal to grapevines, the primary agricultural crop on the creek floodplain.

The following steps are needed:

- ❑ Many landowners are interested in having demonstration projects completed on their riparian corridor to remove invasive plants and replant with natives. In some locations, these projects would increase native riparian tree cover and thus reduce water temperatures. We have selected several sites encompassing up to 12 acres on both Suisun and Wooden Valley Creeks for demonstration projects.

- ❑ Eradication designs should be reviewed with the property owner and revised as needed.

- ❑ Permits from the California Department of Fish and Game should be sought.

- ❑ In the fall, invasive Himalayan blackberry would be cut and stems painted with full strength glyphosate. If needed, plant biomass would be hauled out of the flood prone area and disposed of. Blue periwinkle is eradicated with a foliar application of glyphosate when the plant is green and growing typically in the spring prior to summer heat. The periwinkle would be sprayed and biomass removed.

- ❑ As part of the project design, a revegetation project would be included and should be implemented after one or two seasons of control, depending on the severity of the invasives.

    - Riparian trees such as willow, white alder, box elder, Oregon ash, California bay laurel and oak should be included in the revegetation design. Planting locations should reflect the relationship to the bankfull channel of each species as found in natural systems. A riparian ecologist should complete the revegetation design.

    - Native plant materials from the Suisun Creek watershed should be grown for use in the project.

- Plants need to be installed in winter and irrigated for 24 hours every three weeks with a drip system for the first three dry seasons (April-first rains).

- Exclusionary fencing for livestock or a riparian pasture project may be needed. Protective tubing to reduce deer and rodent browse may also be needed along with periodic weeding

- ❑ The project implementation phase would include workshops and tours for landowners. Eradication of these species requires long-term maintenance and follow-through by the owner. All treatments would be completed with workshops of local landowners to demonstrate the appropriate use of herbicide and how to avoid overspray and loss of native plants. Since two of these invasive species can affect the viability of grapevines, the agricultural community has a vested interest in learning about control and removal of the invasive plants and how to revegetate, care for native plants, as well as how to obtain permits and financial and technical assistance. A summary of the projects with this information would be mailed to all creekside landowners.

- ❑ The demonstration projects will build the knowledge base in the local community to address this problem effectively and develop additional projects for the watershed program with other landowners.

- ❑ Pre- and post- project monitoring of the riparian corridor at each site should be completed. Transects across the riparian corridor should record the density, number and species of under and overstory plants, at each four-foot interval. Transects should be located at 500-1000 foot distances in the project site. In addition, features such as wildlife habitat elements (snags, food sources etc.) should be recorded. These transects should be done prior to any project work and each year for three years following project implementation. Data from these transects would indicate changes in plant density, species diversity, abundance and wildlife value.

3. Reducing Fine Sediment in Creeks by Improving Land Management Measures

Excess sediment was identified as a problem for aquatic habitats in the watershed assessment. A number of sources of the excess sediment were identified and include roads, gullies and agricultural lands distributed throughout the watershed. For the most part, the watershed is private land, but public roads are also a factor. The watershed assessment did not include a quantitative evaluation of sediment sources and reductions. The most effective way to reduce the fine sediment and sustain the reduction is to work closely with landowners/managers to improve management practices and to assess and repair sediment sources such as roads and major erosion sites.

The following steps are needed:

3A. Farm Conservation Planning Program

- Several landowners in the watershed have requested the Fish Friendly Farming (FFF) Program from the Russian, Navarro and Napa River watersheds be implemented in the Suisun Creek watershed. The FFF Program or a similar effort should employ a comprehensive approach to improving the conditions and management practices on agricultural lands through the collaboration of the land manager or farmer with a technical expert to produce a farm conservation plan.

- Under the FFF Program, landowners/managers attend workshops and use the FFF Program materials developed for the Russian, Navarro and Napa River watersheds. These materials include a workbook of inventory methods and Beneficial Management Practices (BMPs) for all aspects of agricultural property including dirt roads, sediment sources, reservoirs, fencing, creeks, agricultural lands and a farm conservation plan template. If another program is developed, it would need to be comprehensive and science-based to be effective in identifying and reducing fine sediment.

- Following the farmer workshops, technical experts would complete a one-on-one site visit with the farmer. This step is important in building local capacity and ability to manage watershed lands by working with the land manager/farmer directly on the farm site and determining what changes and projects are needed.

- From the site visit, the technical experts would complete the technically difficult portions of the farm conservation plan, such as the road assessment, road repair/management plan, and erosion site repair. The farmer would complete the portion of the farm conservation plan addressing agricultural land management such as vineyards and orchards. The final product would be a technically sound and complete farm conservation plan, prepared in conjunction with the farmer that identifies needed repair and restoration projects and changes in management practices or maintenance activities. The implementation timeline in each farm conservation plan defines the actions to occur over the next ten-year period.

- Sediment source reduction would be implemented from agricultural lands, erosion sites and roads both through specific projects identified in the farm conservation plan and through changes in management practices carried out by the farmer. Projects would be eligible for public fund cost share.

3B. Community Workshops for Rural Residential Landowners

- In addition to agricultural landowners, rural residential landowners would be invited to a series of workshops focusing on roads, erosion control, pesticide use, invasive plants, creek care and other subjects. The workshop would instruct rural residential owners in methods to conserve resources and increase water quality and increase the local knowledge base to manage watershed lands. Rural roads are often a major source of sediment and would be one focus of the workshop. The workshops would provide the tools for rural residential owners to reduce sediment, pesticide runoff, invasive plants, improve creek habitats and remove fish passage barriers.

3C. Coordination with County Road Departments and CalTrans

The pubic roads in the watershed in several locations are causing increased erosion at culvert outlets and, due to their locations next to creeks, directly transmit sediment and pollutants into Suisun and Wooden Valley Creeks.

- ❑ Meetings with county road maintenance personnel and CalTrans planners and maintenance personnel should be set up to discuss changes in road practices to reduce sediment sources and pollutant loading and removal of fish passage barriers.

4. <u>Improving Riparian Corridors; Removing Fish Passage Barriers; Increasing Large Wood in Creeks for Fish Habitat and Improving Land Management Measures</u>

4A. Farm Conservation Planning Program

The watershed assessment identified a need for greater canopy cover and a wider riparian corridor to provide shade to the creeks. In addition, a number of fish passage barriers were identified along with and a need in nearly all the creeks to increase large wood in pool areas as fish habitat improvements. Since the watershed is primarily private land increasing and improving riparian corridors and removing fish barriers should be carried out with the landowner/manager.

These revisions to private land can also be addressed through a farm conservation plan program similar to the Fish Friendly Farming (FFF) Program.

The following steps are needed:

- ❑ Use the FFF Program or develop a comprehensive science-based program that includes Best Management Practices and a farm conservation plan evaluation to address:
    - Revegetation of riparian corridors with appropriate native species
    - Revisions to channel form, if required, and adequate width and diversity to provide ecological functions and bank stabilization functions
    - Removal of invasive species
    - Removal of fish barriers
    - Placement of large wood both as part of streambank stabilization and habitat improvement

- Monitoring and maintenance of plantings and mature trees

- ❑ Under the program, the landowner/manager would attend workshops and develop a farm conservation plan. Farm conservation plans would make use of this watershed assessment and address limiting factors identified, such as fish barrier removal or modification and riparian corridor enhancement.

- ❑ Following the farmer workshops, technical experts would complete one-on-one site visits with the farmer. The creek channel riparian corridor and adjacent floodplain would be inventoried and assessed.

- ❑ From the site visit, the technical expert would complete the creek section of the farm conservation plan, including a stream inventory and riparian corridor evaluation, fish passage barrier evaluation, creek restoration/revegetation plan and potentially a plan for addition of large wood to in-stream habitat areas.

- ❑ Riparian corridor and aquatic habitat restoration should be implemented through specific projects identified in the farm conservation plan and through management and maintenance practices to continue control of invasive plants, irrigate new plantings, weeding and other actions. Projects would be eligible for cost chare funding. The farm conservation plan outlines actions of revegetation of riparian corridors, water conservation and other measures needed to produce high water quality and improve the aquatic and riparian ecosystem for fish and wildlife.

4B. Additional Riparian Revegetation and Aquatic Habitat Enhancement Projects

While the farm conservation plan program offers the most effective method to address a number of land management improvements, revegetation and enhancement projects outside of this program offer additional opportunities.

The following steps are needed:

- ❑ As part of the landowner workshops in action #2, information would be provided so that interested landowners can meet with the project manager and a riparian revegetation, barrier removal or wood placement project can be developed.

5. Development and Evaluation of Re-Operation Alternatives for Lake Curry

The watershed assessment identified the operation of Lake Curry as causing a number of problems for Suisun Creek as well as offering an opportunity to supply cold summer water flows for steelhead trout.

Lake Curry, the reservoir created by Gordon Valley Dam in 1926, has a surface area of 377 acres, and an original design volume of 10,700 acre feet. Given the area and volume, the mean depth is approximately 28 feet, with the original maximum depth likely to be around 100 feet. It is not known if sedimentation from the upper watershed has led to a decrease in the lake volume or depth.

In summer, surface water in the reservoir experiences elevated temperatures that are typically higher than in the streams that drain to the reservoir. If this heated surface water is subsequently discharged into Suisun Creek, it can raise stream temperatures, lower dissolved oxygen levels, and create water quality problems. Water temperatures measured in Lake Curry and Suisun Creek have indicated that the shallow depths of the upstream end of Lake Curry limit the size of the pool of cold water for releases into the creek. The outlet works for Lake Curry, which date from 1926, limit the ability to release cold water from the deeper area of the reservoir for fish and use warmer surface layers for water supply. Suisun Creek water temperature monitoring indicates that with the low release level of 2.0-3.0 cfs, temperatures are marginal to too warm. A larger release may be required to reduce water temperatures by increasing the mass of water flowing in the creek. A greater volume of flow is able to absorb the heat from solar radiation and attenuate it thereby maintaining lower water temperatures given current canopy cover and channel conditions. The low volume flow on Suisun Creek presently demonstrates little heat attenuation with water temperatures dropping little over a 24-hour period maintaining warm conditions.

Additionally, increasing the depth and capacity of Lake Curry needs to be evaluated to increase the available pool of cold water. A greater volume release is worth evaluating especially if the outlet works can be retrofitted to allow releases from the deepest area of the reservoir and increased storage capacity can create an adequate cold water pool.

Several features of the reservoir – its bathymetry, major upstream sediment sources, operational constraints and seasonal temperature variations in low, medium and high rainfall years need to be established. Data from the watershed assessment can then be used with a model to simulate a set of operational alternatives calibrated with the quantified data. The model HSPF is recommended for simulating reservoir operations and alternatives. This model has been used in thousands of evaluations and has proven accuracy.

The following steps are needed:

- ❑ In order to determine the active volume of water that may be available for water supply and in-stream release, a reliable map of the existing reservoir bathymetry (depths) would be developed. It has been 75 years since the dam was constructed and there could be an appreciable sediment buildup. A detailed bathymetric survey was completed 11 years ago. A new bathymetric survey will provide one-foot contours of the lake bottom and is required to accurately determine the available dead and active storage and evaluate sediment accumulations in the last survey. Additionally, a survey of city, county, and state records would be conducted to acquire the original design drawings or survey of the dam site and any previous dredging to determine total sediment accumulation in the reservoir.

- An estimate of the annual sediment-loading rate would be developed for the reservoir. The loading should be based on a comparison of the original lake bathymetry and the new bathymetry. To augment this bathymetry, a field reconnaissance survey would be conducted of the upper watershed to identify any significant areas of erosion. This field reconnaissance would be augmented with a review of existing aerial photographs, and an estimate of sediment loading based on land use and condition.

- Prior to analyzing reservoir operations, a feasibility analysis of various project alternatives should be developed. The analysis would focus on the feasibility of implementing various physical and operational changes to Lake Curry. The feasibility analysis would identify opportunities and constraints for each element. The elements will include, but are not limited to, modifying the outlet works to provide for withdrawal of water from different depths in the reservoir, raising the dam to increase storage, modifying or replacing the spillway or outlet works to change the magnitude and frequency of flood flows, and dredging the reservoir to restore water storage capacity.

- To determine the optimum operation of the reservoir for water supply requirements and in-stream flows, a reservoir operations analysis model should be developed for Lake Curry. The base of the system would be the continuous watershed simulation model HSPF. This model was developed by the USGS and Stanford University and has been used on hundreds of watersheds across the country. The system will model long-term continuous inflow, outflow, precipitation, and evaporation from the reservoir. Water supply requirements, fisheries needs, and stream habitat needs will be entered as programmed demands on the reservoir. From this operations model, delivery rates and probabilities would be developed for each demand type. Changes to the reservoir operation would be developed and analyzed over a 40-year simulation period. Typical “wet”, “dry”, and “normal” delivery rates would be developed for each scenario.

- This analysis would produce a thorough evaluation of the potential for improving Lake Curry to assure a reliable water supply that minimizes environmental effects and actually benefits Suisun Creek. The use of a simulation model would quantify the improvement created by each alternative or combinations of alternatives, allow for a sound decision-making process by the City of Vallejo and the SCRT and result in a long-term sustainable outcome.

5. Monitoring and Adaptive Management

This task will provide quantitative measurements of sediment, channel form, water quality and water temperature at the stations and study reaches used in the watershed assessment as well as complete a more extensive morphological survey of Suisun Creek. This information should be used to revise projects in the watershed program and direct actions to address limiting factors based on the results of the monitoring program.

The following steps are needed:

- Yearly surveys of the two study reaches should be continued to create a long record of channel change to determine the overall trends in the system. The study reach approach allows for sample locations to be located where sediment supply and streambed changes from watershed activities are most likely to occur. Therefore, monitoring can act as an early warning system, measuring conditions that directly affect steelhead habitat.

- In addition to the study reaches, water temperature data loggers should be set to record water temperatures at 30-minute intervals and placed at the 21 established stations on the two creeks from May to October.

- Monthly water quality sampling should be done at up to 12 stations to test for pH, nitrate, ammonia, phosphate and dissolved oxygen using YSI meters and La Motte test kits to provide ambient water quality data.

- BMI sampling will follow the Fish and Game Aquatic Bioassessment Laboratory procedures and should be completed at four sites every three years.

- Experienced, qualified professional scientists providing Quality Assurance/Quality Control would oversee all field monitoring. All instruments would be calibrated prior to use and properly maintained and inventoried.

- A yearly summary report of monitoring results should be released comparing each year to prior year results to demonstrate changes and their significance.

- In addition to the yearly monitoring, a larger survey of the length of Suisun Creek is needed to fully describe the channel entrenchment and define the relationship of this change in channel form to flood problems in the lower watershed.

- Landowner access will be requested for the entire length of the creek.

- A qualified surveyor and fluvial geomorphologist should complete the survey to assure that the level of detail is adequate. A series of channel cross sections and a longitudinal profile should be done. This set of surveys could be used in conjunction with the Solano County Water Agency's effort to address flood problems to design an environmentally-friendly and permitable project to repair the creek and reduce flood levels.

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